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INSTALLATION RESTORATION PROGRAM
FIRST DRAFT
TECHNICAL EVALUATION REPORT FOR THE DEMONSTRATION OF RADIO FREQUENCY SOIL DECONTAMINATION AT SITE S-1

KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

APRIL 1995

HALLIBURTON NUS ENVIRONMENTAL CORPORATION
800 OAK RIDGE TURNPIKE A-600
OAK RIDGE, TENNESSEE 37830

PREPARED FOR

AIR FORCE MATERIEL COMMAND
SA-ALC/EMR
KELLY AIR FORCE BASE

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
ENVIRONMENTAL SERVICES OFFICE
ENVIRONMENTAL RESTORATION DIVISION (AFCEE/ESR)
BROOKS AIR FORCE BASE, TEXAS 78235-5000

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13. ABSTRACT *(Maximum 200 words)*

The Air Force's Armstrong Laboratory at Tyndall Air Force Base, Florida, has supported the research and development of Radio Frequency Soil Decontamination. Radio frequency soil decontamination is essentially a heat-assisted soil vapor extraction process. Site S-1 at Kelly Air Force Base, San Antonio, Texas, was selected for the demonstration of two patented techniques. The site is a former sump that collected spills and surface run-off from a waste petroleum, oils, and lubricants and solvent storage and transfer area. In 1993, a technique developed by the IIT Research Institute using an array of electrodes placed in the soil was demonstrated. In 1994, a technique developed by KAI Technologies, Inc. using a single applicator placed in a vertical borehole was demonstrated. Approximately 120 tons of soil were heated during each demonstration to a temperature of about 150 degrees Celsius.

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Soil Vapor Extraction

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FOR

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APRIL 1995

PREPARED BY

HALLIBURTON NUS ENVIRONMENTAL CORPORATION
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NOTICE

This report has been prepared for the United States Air Force by Halliburton NUS Environmental Corporation for the purpose of aiding in the implementation of a final action plan under the Air Force Installation Restoration Program (IRP). As the report relates to actual or possible releases of potentially hazardous substances, its release prior to an Air Force final decision on remedial action may be in the public's interest. The limited objectives of this report and the ongoing nature of the IRP, along with the evolving knowledge of site conditions and chemical effects on the environment and health, must be considered when evaluating this report, since subsequent facts may become known which may make this report premature or inaccurate. Acceptance of this report in performance of the contract under which it is prepared does not mean that the U.S. Air Force adopts the conclusions, recommendations or other views expressed herein, which are those of the contractor only and do not necessarily reflect the official position of the United States Air Force.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS

Section Page

APPENDICES

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence (Brooks AFB)
AFOSH	Air Force Occupational Safety and Health
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
BTU	British Thermal Unit
CAMU	Corrective Action Management Unit
CAT/OX	Catalytic Oxidation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CI	Confidence Interval
DC	Direct Current
DCE	Dichloroethene
DNAPL	Dense Non-Aqueous Phase Liquid
DOD	Department of Defense
DOE	Department of Energy
DRO	Diesel Range Organics
EPA	Environmental Protection Agency
EPCF	Environmental Process Control Facility
ERMO	Environmental Restoration Management Operations
FCC	Federal Communications Commission
FFS	Focused Feasibility Study
FID	Flame Ionization Detector
FM	Frequency Modulation
FS	Feasibility Study
GC	Gas Chromatograph
HNUS	Halliburton NUS Corporation
Hz	Hertz (cycles per second)
IIT	Illinois Institute of Technology
IITRI	Illinois Institute of Technology Research Institute
IRP	Installation Restoration Program
IRPIMS	Installation Restoration Program Information Management System
ISM	Industrial, Scientific, and Medical (radio frequencies)
IWTP	Industrial Waste Treatment Plant
KAI	KAI Technologies, Incorporated
kW	Kilowatt
kW/hr	Kilowatt-hour
LEL	Lower Explosive Limit

ACRONYMS AND ABBREVIATIONS (CONTINUED)

NAPL	Nonaqueous Phase Liquids
NCP	National Contingency Plan, or National Oil and Hazardous Substances Pollution Contingency Plan
NGVD	National Geodetic Vertical Datum
NIOSH	National Institute for Occupational Safety and Health
NUS	Halliburton NUS Environmental Corporation
O&M	Operation and Maintenance
ODC	Other Direct Costs
OSHA	Occupational Safety and Health Administration
OVA	Organic Vapor Analyzer
PCE	Tetrachloroethene or Perchlororethene
PFD	Process Flow Diagram
POL	Petroleum, Oil, and Lubricants
PPE	Personal Protective Equipment
PQL	Practical Quantitation Limit
PVC	Polyvinyl Chloride
R&D	Research and Development
RF	Radio Frequency
RFH	Radio Frequency Heating
RI	Remedial Investigation
SA-ALC	San Antonio Air Logistics Center
SAIC	Science Applications International Corporation
SCFM	Standard Cubic Feet per Minute
SITE	Superfund Innovative Technology Evaluation
SM	Site Manager
SSO	Site Safety Officer
SVE	Soil Vapor Extraction
SVOC	Semivolatile Organic Compound
TACB	Texas Air Control Board
TCLP	Toxic Characteristic Leaching Procedure
TNRCC	Texas Natural Resources Conservation Commission
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TRPH	Total Recoverable Petroleum Hydrocarbons
USAF	United States Air Force
VOC	Volatile Organic Compound
VT	Vapor Treatment
W	Watt (s)

EXECUTIVE SUMMARY

The United States Air Force developed the Installation Restoration Program to assess past hazardous waste disposal and spill sites and prepare remedial actions consistent with the National Contingency Plan for those sites that pose a threat to human health or the environment. Within that program the Site Remediation Division of the Environics Directorate of the Air Force's Armstrong Laboratory at Tyndall AFB, Florida, has supported the research and development of Radio Frequency Soil Decontamination.

Armstrong Laboratory was sufficiently encouraged by the early test results in sandy soils at Tyndall AFB, Florida, and Volk Field, Wisconsin, to pursue larger-scale demonstrations in tight soils that are more difficult to treat. In September 1991, the Air Force Center for Environmental Excellence at Brooks AFB, Texas, contracted Halliburton NUS Environmental Corporation (now Brown & Root Environmental) to conduct pilot scale demonstrations of two different, patented, radio frequency heating techniques at Site S-1 at Kelly AFB, Texas.

The project was divided into three phases the Preplanning Phase, Phase I, and Phase II. The Preplanning Phase, completed in September 1992, included literature review, conceptual cost estimations, design plans and specifications preparation and review, and publication of a final report documenting the results. Phase I included two integrated pilot tests and the preparation of this final technical report evaluating the results of Phase I and the conceptual planning of Phase II. Phase II will include the complete planning and design of a full-scale commercial demonstration of radio frequency soil decontamination.

Radio frequency soil decontamination is essentially a heat-assisted vapor extraction process. Radio frequency energy applied to the soil causes polar molecules, including water and many organic compounds, to vibrate. This vibrational energy is lost as heat. The resulting rise in soil temperature vaporizes both water and contaminants, which may then be removed by application of a vacuum. Extracted vapors may be treated by a variety of methods, depending on the site and the nature of the contaminants. Vapors extracted during the demonstrations at Site S-1 were burned in a flare.

Two types of radio frequency soil heating were demonstrated at Site S-1 from January to August 1993 and 1994. In 1993, a technique developed by the IIT Research Institute that uses a series of exciter and ground electrodes placed in the soil was demonstrated. This technique was tested previously at Air Force sites. In 1994, a technique developed by KAI Technologies, Inc. which uses

an antenna-like device that may be placed in a vertical or horizontal borehole was demonstrated. Halliburton NUS Environmental Corporation provided site preparation services, the vapor extraction system, and supervised and coordinated all other aspects of the demonstrations.

Armstrong Laboratory, Kelly AFB, and the US Department of Energy have contributed funds and guidance for the work completed to date which includes the Preplanning Phase and Phase I. In addition, the Phase I demonstrations are part of the US Environmental Protection Agency's Superfund Innovative Technology Evaluation Program.

Halliburton NUS Environmental Corporation concludes that data gathered during the pilot demonstrations is invaluable to the development of radio frequency heating for the enhancement of soil vapor extraction and can be used to design a commercial scale system and implement remedial activities in accordance with United States Air Force procedures. From lessons learned during the Site S-1 demonstrations, criteria for technology implementation have become apparent that allow the selection of a site better suited to the unique physical and chemical phenomenon inherent in the process. To date only six field tests have been completed. These tests have addressed situations with a wide variance of soil and contaminant characteristics. A phased approach is recommended which would include more demonstrations to plug data gaps and define unknowns followed by commercial scale application. A smaller site with a simpler (more homogenous) soil and contaminant matrix, relative to Site S-1, would simplify the evaluation of results and better define technology applicability.

1.0 INTRODUCTION

1.1 BACKGROUND

The objective of the United States Air Force (USAF) Installation Restoration Program (IRP) is to assess past hazardous waste disposal and spill sites at USAF installations and develop remedial actions consistent with the US Environmental Protection Agency (EPA) National Contingency Plan (NCP) for those sites that pose a threat to human health and the environment. The development, testing, and demonstration of innovative restoration technologies are important phases of the IRP under the direction of the Site Remediation Division of the Environics Directorate (AL/EQW) of the USAF's Armstrong Laboratory at Tyndall Air Force Base (AFB), Florida.

Site S-1 (Figure 1-1) at Kelly AFB, Texas, was selected by Armstrong Laboratory for a Radio Frequency (RF) Soil Decontamination Demonstration. The site formally served as an intermediate storage and transfer area for wastes to be reclaimed off-base. The wastes included mixed solvents and petroleum, oils, and lubricants. Inadvertent spills during this operation resulted in soil and groundwater contamination. Halliburton NUS (HNUS) conducted a remedial investigation at the site to determine the nature and extent of soil and groundwater contamination (HNUS, 1994). The general types of organic compounds found in soil samples and common examples of each type are shown below:

Types of Organic Compounds	Examples
Volatile aromatics	Acetone, chlorobenzene
Chlorinated aliphatic volatiles	Methylene chloride, trichloroethane
Phthalate esters	Bis(2-ethylhexyl)phthalate
Polychlorinated biphenyls	Aroclor-1260
Polynuclear aromatic hydrocarbons	Benzo(a)anthracene, pyrene

Groundwater beneath the site contains many of the same contaminants. The variety of contaminants, while presenting a remedial challenge, offers an interesting opportunity for a technology demonstration.

This project report will summarize and document the project's Phase I efforts for a field demonstration of the IIT Research Institute's (IITRI) tri-plate capacitor and the KAI Technologies, Inc.'s (KAI) antenna radio frequency heating (RFH) techniques for the enhancement of soil vapor extraction (SVE) for the in-situ decontamination of soils.

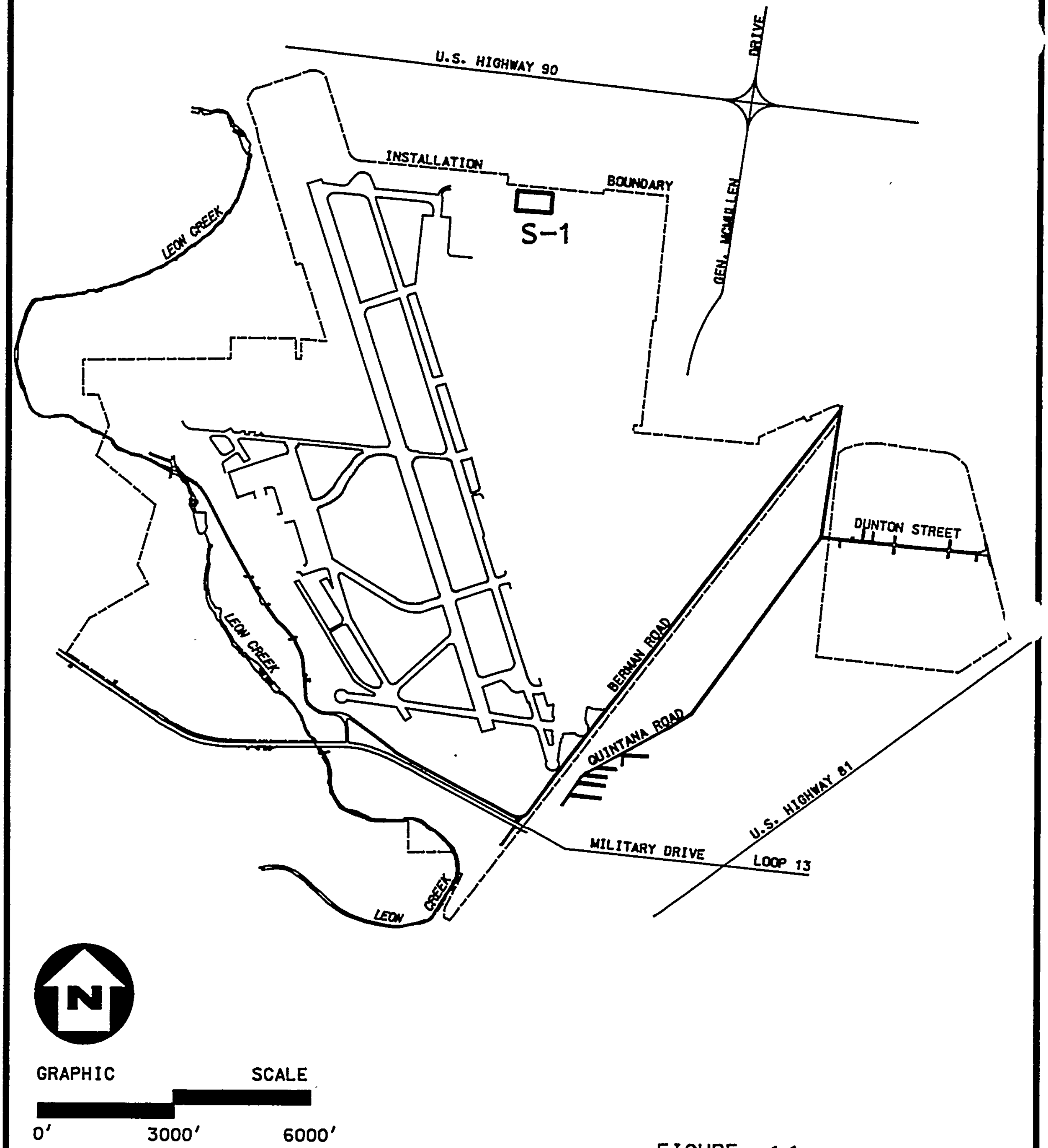


FIGURE 1-1

HALLIBURTON NUS
Environmental Corporation

TITLE

SITE S-1 LOCATION MAP
RF DEMONSTRATION
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

DRAWING NO. 3688G001

DATE 4-30-92

1.2 AUTHORITY

HNUS was contracted by the Air Force Center for Environmental Excellence (AFCEE) to perform an RF Soil Decontamination Demonstration at Kelly AFB under the direction of the AL/EQW. Notice to Proceed was issued on September 28, 1991. The project was divided into three phases the Preplanning Phase, Phase I, and Phase II. The Preplanning Phase, completed in September 1992, included literature review, conceptual cost estimations, design plans and specifications preparation and review, and publication of a final report documenting the results. Phase I, complete with the final publication of this report, included two integrated pilot demonstrations, an evaluation of the results, and the conceptual planning of Phase II. Phase II, planned for 1995, will include the complete planning and design of a commercial scale system for RF soil decontamination.

1.3 OBJECTIVES OF PROJECT

The primary objectives of the project are as follows: (1) to broaden the proven range of RF technology applicability in clayey soil and (2) to more accurately assess the implementation requirements of commercial-scale systems. Secondary purposes to be addressed during the demonstration project include validation of scale-up parameters, the use of electrodes as vapor recovery vents, evaluation of vertical and horizontal transport of contaminants through soil, and the removal of semi-volatile organic compounds (such as phthalates) from soil.

Project results and evaluations will be documented in technical reports at the end of each Phase. This report for Phase I includes the following:

(a) Data gathered during the two pilot tests,
(b) Results of the evaluation of that data,
(c) A summary of lessons learned during the Preplanning Phase and Phase I,
(d) Recommendations for design/operational modifications to facilitate Phase II,
(e) Comparison of the two different techniques,
(f) An up-dated cost projection for Phase II,

This report is divided into nine sections and 18 appendices which document all design, field implementation, and evaluation activities and include requirements from the SOW as listed above. Sections 2 through 9 contain the HNUS evaluation of the demonstrations and conceptual design and cost information for a full-scale test. Appendices A and B contain reports from IIT and KAI and operational data from the two demonstrations.

1.4 PROJECT HISTORY

RF energy causes polar molecules in dielectric materials to vibrate, and the resulting mechanical energy is lost as heat. Early applications included industrial drying and the medical process known as diathermy. Radio frequency-enhanced petroleum recovery from oil shale and tar sands was demonstrated in the 1970s. Field tests proved the feasibility of heating rock formations to temperatures of 200° to 400° Celsius (C) (Dev et al, 1989). In 1984 the USAF began the research and development of RFH for in-situ soils decontamination that has led to this field demonstration.

IITRI applied the technique to the decontamination of soils containing hazardous chemicals in EPA-funded laboratory tests. Bench and pilot scale tests demonstrated the need for an in situ field demonstration. During a field test of the IITRI method in November 1988 at Volk Field Air National Guard Base, Camp Douglas, Wisconsin (Dev et al, 1989), a 500 cubic foot volume of sandy soil was heated to a temperature range of 150° to 160°C. Analysis of numerous soil samples indicated a significant removal of volatile and semivolatile contaminants. The results of that field test warranted further scaled-up demonstrations to determine the feasibility of commercial application.

Site E-3 at Kelly AFB was initially proposed as a demonstration site for the IITRI method. The site was an open evaporation pit located near the old Industrial Waste Treatment Plant (IWTP) in the southern part of Kelly AFB. Unfortunately, the site geology was found to be unsuitable for the IITRI method because of the presence of a high water table and extensive gravel beds.

In September of 1991, during the Preplanning Phase, geologic evaluations indicated that Site S-1 Kelly AFB would be suitable for a demonstration of the IITRI method. HNUS, the prime contractor, subcontracted IITRI to provide technical assistance for the Preplanning Phase and Phase I.

In September 1993, after the conclusion of the IITRI demonstration, AFCEE modified the HNUS contract to include a demonstration of the KAI technique at Site S-1 Kelly AFB as part of Phase I. In addition, the technical evaluation is to include a comparison of the two technologies.

1.5 INSTALLATION LOCATION AND HISTORY

Kelly AFB lies approximately 150 miles west of the Gulf of Mexico, in Bexar County, 7 miles southwest of the center of San Antonio. The base consists of 4,660 acres, bounded on the West by Lackland AFB and on the South by Military Drive. The eastern and northern boundaries of Kelly AFB are the Missouri-Pacific Railroad yards and US Highway 90, respectively (Figure 1-1).

Kelly AFB was founded in 1917 as the first military air base in Texas. Since 1954, Kelly AFB has been involved in logistics and aircraft maintenance. The primary mission of Kelly AFB is to support the San Antonio Air Logistics Center (SA-ALC) of the Air Force Materiel Command. SA-ALC is the system support manager for the Military Airlift Command's C-5 Galaxy jet transport fleet. In addition, SA-ALC is responsible for depot maintenance for the Strategic Air Command's B-52 bomber fleet. SA-ALC also manages more than half of the Air Force engine inventory. SA-ALC manages the fuels, oil, and petroleum program for the Air Force, including liquid oxygen, nitrogen, and special fuels. Kelly AFB also acts as host to approximately 56 tenant organizations representing the USAF, the US Army, DOD, and other government agencies.

1.6 THE EPA SITE PROGRAM

EPA established the Superfund Innovative Technology Evaluation (SITE) Program to expedite the development and evaluation of innovative remedial technologies. The agency supported this project by providing analytical laboratory services for the analysis of pre-test and post-test soil samples.

2.0 IITRI DEMONSTRATION

2.1 BACKGROUND

This section presents a brief description and chronology of the IITRI pilot-scale demonstration. Results of the IITRI demonstration are presented in Section 4 (Geology and Hydrogeology), Section 5 (Radio Frequency Soil Heating), Section 6 (Soil Vapor Extraction and Treatment), Section 7 (Soil and Vapor Chemical Data), and applicable Appendices.

2.2 PREPLANNING

Due to the innovative nature of RFH technology an extensive Preplanning Phase was required for the IITRI demonstration. IITRI prepared technical reports for review by USAF and HNUS project personnel. A decision to proceed to Phase I was made based on the Preplanning Phase effort.

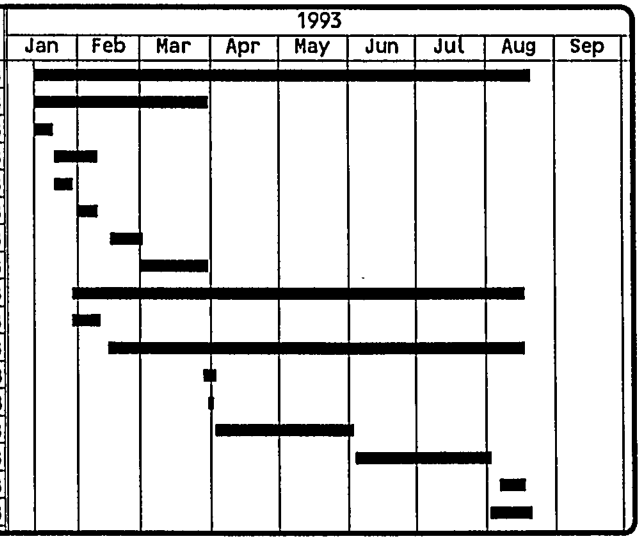
IITRI performed a Soil Treatability Study and prepared Demonstration Test and Detailed System Design Plans during the Preplanning Phase of the project. The Soil Treatability Study was performed to measure the dielectric properties of site soils in order to predict heating and power requirements and contaminant removal rates. The Demonstration Test Plan (or Work Plan) included project goals and objectives, schedule, technique-specific health and safety requirements, data collection recommendations, and results predictions. The Detailed System Design presented regulatory issues, hardware details, operational criteria, and manpower requirements. These reports were included as appendices in the Preplanning Phase technical report (HNUS, November 1993).

2.3 PHASE I DEMONSTRATION

The effort was divided into design and planning, mobilization, site preparation (including system installation), operations, and demobilization. See Figure 2-1 for a schedule of field activities. IITRI's efforts for the demonstration consisted of the design, construction, and operation of the RFH system. IITRI reviewed the HNUS Work, Health and Safety, and Sampling and Analysis Plans (HNUS, May 1993) and coordinated all design activities and operational procedures for system integration with HNUS. HNUS efforts consisted of site preparation, the design, construction, and operation of the ejector and VT system, health and safety monitoring, and site management. In addition, HNUS supported IITRI during the RFH system set-up. Routine OSHA (health and safety) working procedures for hazardous wastes were followed as dictated in the site-specific Health and Safety Plan (HNUS, March 1993).

Figure 2.1 - IITRI RFH Demonstration

Task Name	Duration	Start	End
RF HEATING Phase I - IITRI	220.00 d	Jan/13/93	Aug/21/93
SITE PREPARATION AND SYSTEM SET-UP	78.00 d	Jan/13/93	Mar/31/93
GENERAL CIVIL CONSTRUCTION	9.00 d	Jan/13/93	Jan/21/93
DRILLING	20.00 d	Jan/22/93	Feb/10/93
DEWATERING SYSTEM INSTALLATION	9.00 d	Jan/22/93	Jan/30/93
SOIL SAMPLING AND ELECTRODE INSTALLATION	10.00 d	Feb/01/93	Feb/10/93
RF SYSTEM SET-UP	15.00 d	Feb/16/93	Mar/02/93
SVE SYSTEM SET-UP	31.00 d	Mar/01/93	Mar/31/93
SYSTEM TESTING AND OPERATION	200.00 d	Jan/30/93	Aug/18/93
DEWATER TESTING	13.00 d	Jan/30/93	Feb/11/93
DEWATERING	184.00 d	Feb/15/93	Aug/18/93
SVE TESTING	6.00 d	Mar/29/93	Apr/03/93
RF TESTING	3.00 d	Mar/31/93	Apr/02/93
HEATING	61.00 d	Apr/03/93	Jun/03/93
COOLDOWN	61.00 d	Jun/04/93	Aug/03/93
POST SAMPLING & WELL ABANDONMENT	12.00 d	Aug/07/93	Aug/18/93
DEMOBILIZATION	19.00 d	Aug/03/93	Aug/21/93



2.3.1 Design and Planning

Due to changes in project scope a downsizing of the RFH design as envisioned during the Preplanning Phase was required and performed by IITRI (see Appendix A.1). IITRI also specified the procedure for the installation of the electrode wells. HNUS designed the ejector assembly used to provide SVE vacuum, the VT system, and the dewatering system (see Appendices A.8 and D).

2.3.2 Mobilization

IITRI efforts consisted of procurement, fabrication, and site delivery of the RFH system and the vapor manifold and barrier components for the SVE system. HNUS coordinated the procurement, fabrication, and delivery of the ejector assembly used to provide SVE vacuum and the VT system. HNUS also coordinated the procurement and delivery of all rental and disposable materials.

2.3.3 Site Preparation

Site preparation tasks performed by HNUS included:

- Civil construction (i.e., fencing, grading, office set-up, project sign, storage bin placement, personnel decontamination station, and transformer set-up),
- Site and safety management,
- Pre-demonstration soil sampling and installation of in-ground system components (see Appendix C).
- Dewatering system installation and operation (Appendix A.8), and
- Ejector and vapor treatment (VT) component (i.e., diesel air compressor, carbon steel transfer pipe and flare) set-up, testing, and operation (Appendices A.6 and D).

The flare was moved to the site, set up, modified, and tested by the manufacturer. IITRI constructed the vapor manifold and barrier, the RF shield, and RFH system with HNUS support.

Contaminated groundwater removed by dewatering was temporarily stored on site in a 21,000 gallon "frac tank" and regularly transferred to a 6000 gallon tanker truck for transport to the Kelly AFB EPCF for treatment and discharge (see Appendix A.8). All soil cuttings not placed over the heated zone were drummed and transported to the Kelly AFB Drum Yard for disposal (see Appendix C). See Figure 2-2 for site layout.

2.3.4 System Operation

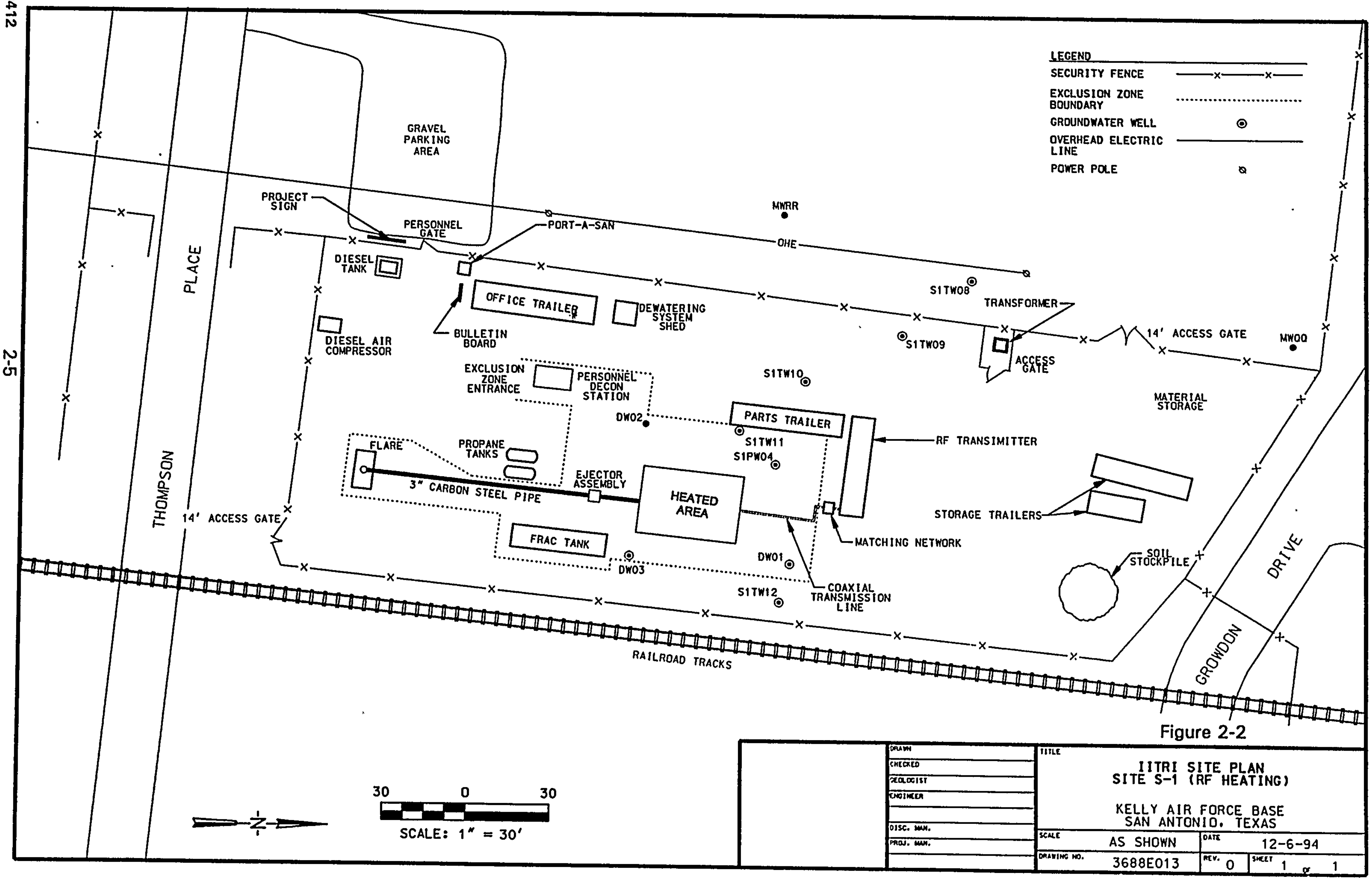
System operation tasks consisted of SVE operation (see Appendix A.6), RFH testing and operation (see Appendix A.1), dewatering (see Appendix A.8), vapor sampling (see Section 7), tracer test RF shutdown, and cooldown (see Appendix A.1). IITRI and HNUS teamed for the operation of the RFH/SVE system. Using the "buddy system" for safety, the system was attended by two workers at all times during heating. IITRI personnel operated the RFH system and the in-ground portion of the SVE system. HNUS personnel operated the above ground portion of the SVE (including vapor sampling), the VT and the dewatering systems, and coordinated all fuel deliveries.

2.3.5 Demobilization

Demobilization of the RFH system began with RFH system shutdown. The RFH system exterior components (except the shield) were dismantled and packed for transport. The IITRI RF trailers remained on site during cooldown because one housed the temperature measurement system. These trailers were later transported to the location of the next IITRI field effort, Sandia National Laboratory. By the end of the IITRI demonstration, the USAF had modified Phase I to incorporate a demonstration of the KAI RFH technique. Therefore, demobilization did not include restoration of the site to pre-demonstration conditions. Miscellaneous support facilities like the office, signs, fence, electric distribution system, the ejector assembly, and VT system were left in place for the KAI demonstration.

HNUS began complete disassembly and demobilization with the shutdown of the SVE and VT systems at the end of the cooldown period. The VT diesel air compressor and fuel tanks were removed from the site. The RF shield and components of the dewatering system were disassembled, decontaminated, and turned over to base Civil Engineering. The vapor manifold was disassembled, decontaminated, and sold as scrap aluminum. The vapor barrier was rolled up, cut in half, and drummed for delivery to the Kelly AFB Drum Yard for disposal.

Soil boring and well abandonment tasks began next. Soil boring for post-demonstration soil sampling was performed first, followed by electrode, temperature measurement, and tracer well abandonment. The ground electrodes were decontaminated and sold as scrap aluminum. The excitor electrodes had melted in place and were removed by over reaming. Cutting and debris from the excitor electrode borings were drummed and delivered to the Kelly AFB Drum Yard for disposal.


LEGEND
SECURITY FENCE
EXCLUSION ZONE BOUNDARY
GROUNDWATER WELL
OVERHEAD ELECTRIC LINE
POWER POLE
GRAVEL PARKING AREA
PROJECT SIGN
PERSONNEL GATE
PORT-A-SAN
MWRR
OHE
DIESEL TANK
OFFICE TRAILER
DEWATERING SYSTEM SHED
BULLETIN BOARD
DIESEL AIR COMPRESSOR
S1TW08
S1TW09
TRANSFORMER
14' ACCESS GATE
MW00
ACCESS GATE
MATERIAL STORAGE
EXCLUSION ZONE ENTRANCE
PERSONNEL DECON STATION
S1TW10
DW02
PARTS TRAILER
S1TW11
S1PW04
RF TRANSIMITTER
FLARE
PROPANE TANKS
3" CARBON STEEL PIPE
EJECTOR ASSEMBLY
HEATED AREA
FRAC TANK
DW03
DW01
S1TW12
COAXIAL TRANSMISSION LINE
MATCHING NETWORK
STORAGE TRAILERS
SOIL STOCKPILE
DRIVE
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PLACE
THOMPSON
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GEOLOGIST
ENGINEER
DISC. MAN.
PROJ. MAN.
TITLE
IITRI SITE PLAN
SITE S-1 (RF HEATING)
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
SCALE
AS SHOWN
DATE
12-6-94
DRAWING NO.
3688E013
REV. 0
SHEET 1 OF 1

Figure 2-2

The dewatering system disassembly began with the completion of post-demonstration soil sampling and well abandonment. The dewatering ejectors and head controls were decontaminated and stored with the control panel. PPE, dewatering hose, and miscellaneous plastic, wire, wood, and pipe contaminated during operations were drummed and delivered to the Kelly AFB Drum Yard for disposal. Small quantities of various uncontaminated disposables (i.e., scrap metal, wood, pipe, and wire) were placed in a Kelly AFB trash receptacle for disposal.

Final demobilization included return of rented equipment. The portable toilet, one of two portable storage bins, cellular phones, and health and safety equipment (i.e., OVA, LEL, calibration gas tanks, stretcher, first aid kit, and personnel respirators with spare oxygen tanks) were returned to their respective vendors.

3.0 KAI DEMONSTRATION

3.1 BACKGROUND

This section presents a brief description and chronology of the KAI pilot demonstration. Results of the KAI demonstration are presented in Section 4 (Geology and Hydrogeology), Section 5 (Radio Frequency Soil Heating), Section 6 (Soil Vapor Extraction and Treatment), Section 7 (Chemical and Physical Data), and applicable Appendices.

Due to the experience and knowledge gained during the Preplanning Phase and the IITRI demonstration, detailed design and demonstration plans were not required for the KAI demonstration.

3.2 PHASE I DEMONSTRATION

The effort was divided into design and planning, mobilization, site preparation (including system install), operations, and demobilization. See Figure 3-1 for a schedule of field activities. KAI's efforts for the demonstration consisted of the design, construction, and operation of the RFH system. HNUS efforts consisted of site preparation, design, construction, and operation of the SVE and VT systems, and providing the Site Manager (SM) and Site Safety Officer (SSO). In addition, Halliburton NUS supported KAI during the RFH system set-up. Routine OSHA (health and safety) working procedures for hazardous wastes were followed as dictated in the site-specific Health and Safety Plan (HNUS, March 1993).

3.2.1 Design and Planning

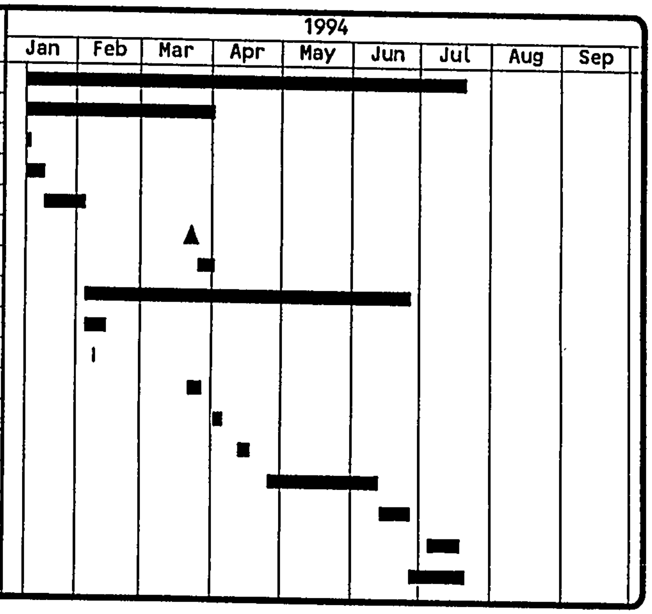
KAI reviewed the HNUS Work, Health and Safety, and Sampling and Analysis Plans, and coordinated all design activities and operational procedures for system integration with HNUS. KAI designed the RFH system. HNUS designed the SVE system to incorporate existing ejector and VT components.

3.2.2 Mobilization

KAI's tasks included the procurement, fabrication, and site delivery of the RFH system. HNUS tasks included the procurement, fabrication, and site delivery of the SVE system and the procurement and delivery of all rental and disposable materials.

Figure 3.1 - KAI RFH Demonstration

Task Name	Duration	Start	End
RF HEATING Phase I - KAI	193.00 d	Jan/10/94	Jul/21/94
SITE PREPARATION	83.00 d	Jan/10/94	Apr/02/94
GENERAL CIVIL CONSTRUCTION	3.00 d	Jan/10/94	Jan/12/94
DRILLING (Sampling & Partial Set-Up)	9.00 d	Jan/10/94	Jan/18/94
SVE SYSTEM SET-UP	19.00 d	Jan/18/94	Feb/05/94
ANTENNA SLEEVE DELIVERY	0.00 d	Mar/23/94	Mar/23/94
RF SYSTEM SET-UP	8.00 d	Mar/26/94	Apr/02/94
SYSTEM TESTING & OPERATION	143.00 d	Feb/05/94	Jun/27/94
SVE & VT TESTING #1	10.00 d	Feb/05/94	Feb/14/94
EPA/SITE SVE TESTING	1.00 d	Feb/09/94	Feb/09/94
SVE TESTING #2	7.00 d	Mar/22/94	Mar/28/94
RF TESTING	5.00 d	Apr/02/94	Apr/06/94
SVE TESTING #3 (Optional)	6.00 d	Apr/13/94	Apr/18/94
HEATING	49.00 d	Apr/26/94	Jun/13/94
COOLDOWN	14.00 d	Jun/14/94	Jun/27/94
POST SAMPLING & WELL ABANDONMENT	15.00 d	Jul/05/94	Jul/19/94
DEMOBILIZATION	25.00 d	Jun/27/94	Jul/21/94



3.2.3 Site Preparation

Site preparation tasks performed by HNUS included civil construction (i.e., grading and transformer set-up), site and safety management, pre-demonstration soil sampling and well installation (i.e., antenna, temperature, vapor extraction, and field measurement wells) (see Appendix C), vapor manifold and barrier construction (see Section 6 and Appendix B.3), and SVE and VT component testing (see Appendix B.4). KAI set up the RFH system with HNUS support. All drill cuttings were drummed and transported to the Kelly AFB Drum Lot for disposal. See Figure 3-2 for site layout details.

An initial SVE/VT test was performed to define operational procedures. During the initial test HNUS personnel assisted EPA/SITE in the performance of a series of SVE tests utilizing a computerized transducer system. A second test of the SVE/VT systems was performed to fine-tune the procedures, but due to a clogged ejector results were meaningless and a third SVE/VT test was required.

3.2.4 System Operation

System operation tasks consisted of the initial SVE testing and operation (Appendix B.4), RFH testing and operation (Appendix B.1), vapor sampling (Section 7), RF shutdown, and cooldown. KAI and HNUS teamed for the operation of the RFH/SVE system. Using the buddy system for safety, the system was attended by two workers during daylight hours. The site was unattended during the evening and early morning periods and on Sundays. KAI personnel operated the RFH system. HNUS personnel operated the SVE (including sampling) and VT systems and coordinated all fuel and material deliveries.

3.2.5 Demobilization

The demobilization task restored the site to pre-demonstration conditions. Demobilization of the RFH system began with RFH system shutdown. The RFH system exterior components were dismantled and packed away for transport. The RF trailer housed the soil temperature measurement system and, therefore, remained on site during cooldown.

HNUS began complete disassembly and demobilization with the shutdown of the SVE and VT systems at the end of the cooldown period. The ejector assembly and VT system were removed from the site with the associated diesel air compressor, fuel tanks, piping, and scaffolding.

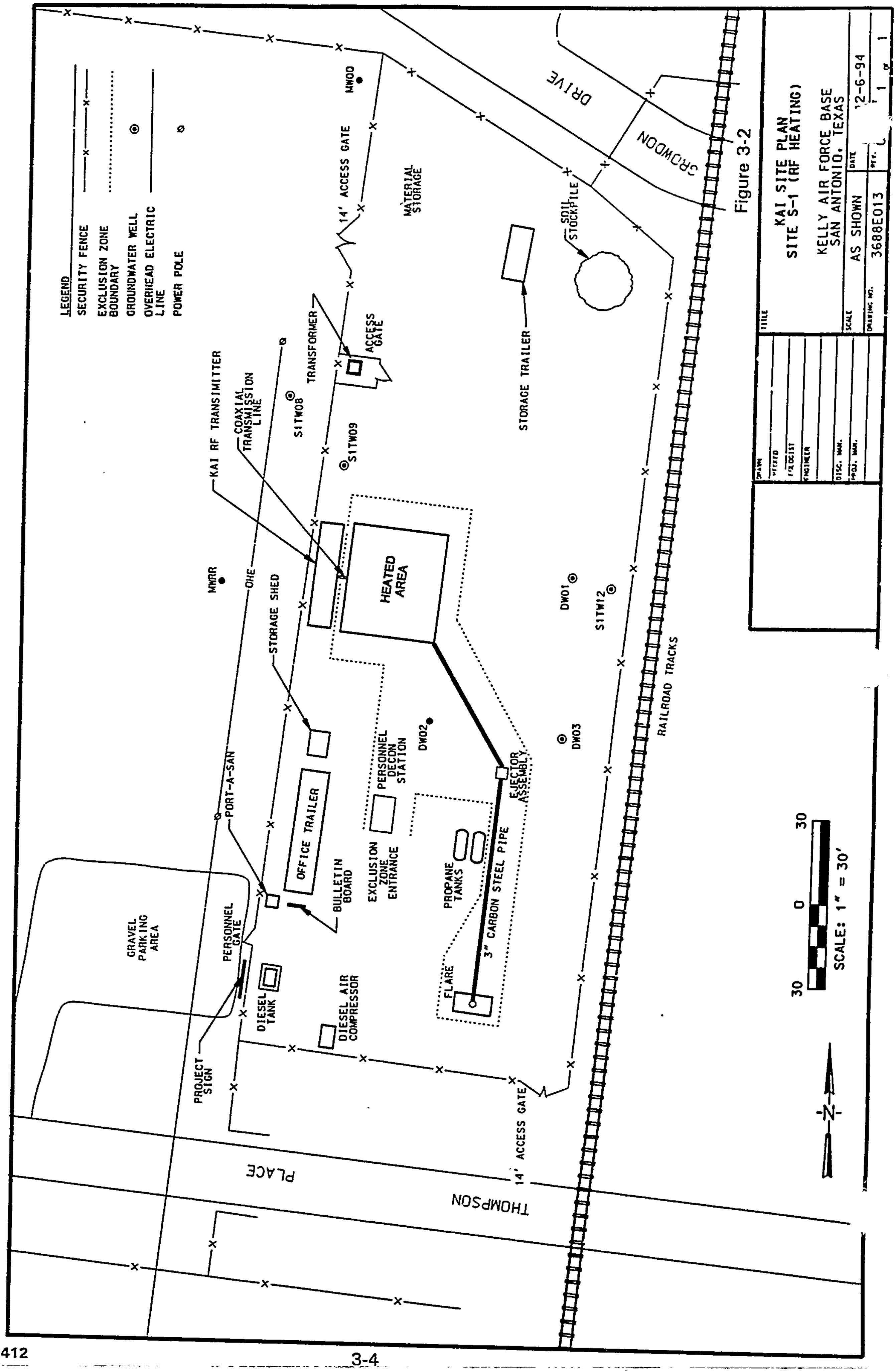

LEGEND
SECURITY FENCE
EXCLUSION ZONE BOUNDARY
GROUNDWATER WELL
OVERHEAD ELECTRIC LINE
POWER POLE
MW00
14' ACCESS GATE
MATERIAL STORAGE
DRIVE
CROWDON
SOIL STOCKPILE
STORAGE TRAILER
TRANSFORMER
ACCESS GATE
KAI RF TRANSIMITTER
COAXIAL TRANSMISSION LINE
S1TW08
S1TW09
HEATED AREA
MWRR
OHE
DW01
S1TW12
STORAGE SHED
DW02
DW03
PERSONNEL DECON STATION
EJECTOR ASSEMBLY
RAILROAD TRACKS
PORT-A-SAN
OFFICE TRAILER
BULLETIN BOARD
EXCLUSION ZONE ENTRANCE
PROPANE TANKS
3" CARBON STEEL PIPE
FLARE
GRAVEL PARKING AREA
PERSONNEL GATE
DIESEL TANK
DIESEL AIR COMPRESSOR
PROJECT SIGN
14' ACCESS GATE
PLACE
THOMPSON
30 0 30
SCALE: 1" = 30'
N
TITLE
KAI SITE PLAN
SITE S-1 (RF HEATING)
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
SCALE
AS SHOWN
DRAWING NO.
3688E013
DATE
12-6-94
REV.
1 of 1
DRAWN
CHECKED
GEOLOGIST
ENGINEER
DISC. MAN.
PROJ. MAN.

Figure 3-2

The VT flare, property of Kelly AFB, was disassembled and stored on site. The vapor manifold was disassembled, decontaminated, and placed in a trash receptacle for disposal. The vapor barrier was drummed and delivered to the Kelly AFB Drum Lot for disposal.

Soil boring and well abandonment tasks began next. Soil boring for post-demonstration soil sampling was performed first, followed by antenna, extraction, and temperature and ground pressure measurement well abandonment. Drill cuttings were drummed and delivered to the Kelly AFB Drum Lot for disposal.

PPE and small quantities of miscellaneous plastic sheets, bags, wire, wood, hoses, and pipe contaminated during operations were drummed and delivered to the Kelly AFB Drum Lot for disposal. Various uncontaminated disposables (i.e., scrap metal and wood, pipe, and wire) were placed in a trash receptacle for disposal.

Final demobilization included return of rented equipment. The office, transformer, portable toilet, portable storage bin, cellular phones, and health and safety equipment (i.e., OVA, LEL, calibration gas tanks, stretcher, first aid kit, and personnel respirators with spare oxygen tanks) were returned to their respective vendors. The sign and bulletin board were dismantled and removed.

4.0 DEMONSTRATION ENVIRONMENTAL SETTING

4.1 REGIONAL SETTING

4.1.1 Geography

Kelly AFB lies in the western portion of the Gulf Coastal Plain, a gently undulating prairie with elevations ranging from 450 feet to approximately 700 feet above the National Geodetic Vertical Datum (NGVD). The plain slopes to the Southeast toward the Gulf of Mexico. Elevations at Kelly AFB vary from 730 to 620 feet above NGVD. Lower elevations lie along Leon Creek at the southern boundary of the base.

The San Antonio area lies within two distinct physiographic regions, the Edwards Plateau secondtion of the Great Plains Province and the western Gulf Coastal Plain. The southwest-northeast trending Balcones Escarpment divides the two regions. The plateau serves as a recharge area for surface waters flowing to aquifers and streams extending through the San Antonio area.

4.1.2 Geology

The region surrounding Kelly AFB is underlain by Quaternary alluvium over a thick stratigraphic sequence of Cretaceous sediments. The alluvium consists of mixtures of clay, silt, sand, and gravel. These deposits are typically 10 to 35 feet thick. The Cretaceous unit is the Navarro Group clay. The Navarro Group clay and other limestone and shale units form a thick aquitard sequence between the alluvium and the underlying Edwards Group limestone (NUS, 1991).

4.1.3 Hydrology

4.1.3.1 Surface Drainage

Surface runoff at Site S-1 drains eastward to Apache Creek, approximately 2.5 miles away. Apache Creek flows into San Pedro Creek, which in turn flows into the San Antonio River.

4.1.3.2 Groundwater

Kelly AFB lies above two groundwater aquifers. The uppermost aquifer lies within the lower strata of the Quaternary alluvium. Although this aquifer is capable of providing potable water, the quality and quantity are variable and questionable. The second aquifer is contained within the Edwards Group and is separated from the first aquifer by the Navarro Clay (HNUS, 1992). The Texas Legislature established the Edwards Aquifer Underground Water District in 1959 to provide for the systematic planning and protection of groundwater in this aquifer. The EPA designated the Edwards a sole source aquifer in 1975 (40 CFR 149).

4.2 SITE S-1

4.2.1 Topography and Drainage

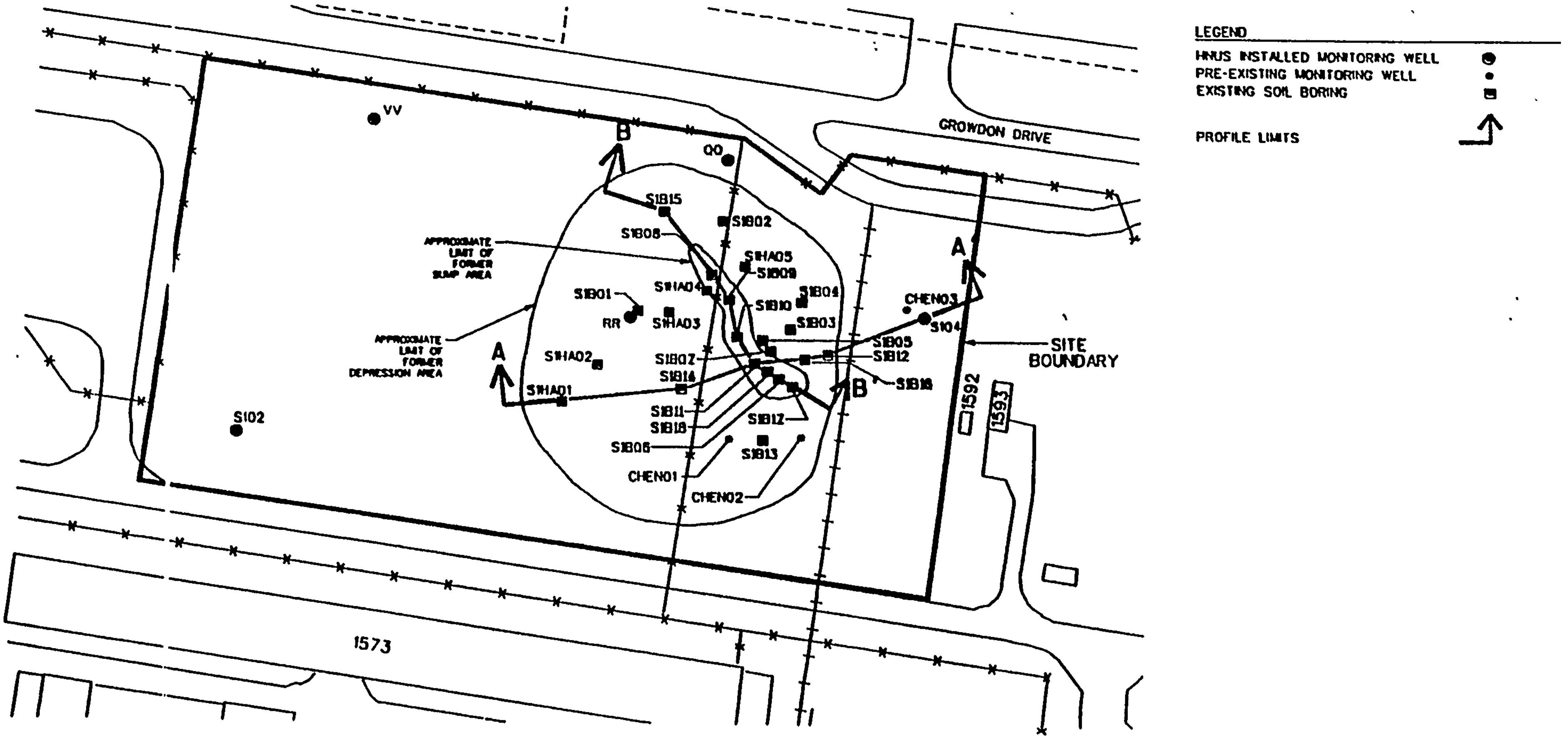
Site S-1 (See Figure 4-1) is generally flat, with surface elevations ranging from 690 to 691 feet above NGVD. Gravel covers the area over the former sump, but grass covers most of the remainder of the site. Rainfall at the site is likely to pool on the surface because of the slight topographic relief and low infiltration rates.

4.2.2 Geology

The alluvial material at Site S-1 consists of an upper layer of dark brown to black clay typically 7 feet thick overlying either a reddish brown silty clay or a clayey gravel, sand/gravel unit. The reddish brown silty clay lies in the southeast corner of the site and is usually 7 to 10 feet thick. The coarse-grained unit underlying the remainder of the site consists of subrounded to subangular limestone and chert (Figures 4-2 and 4-3).

Much of the alluvium was removed and replaced by fill material in the former depression area. The fill material is dark brown to black gravely clay with occasional zones of sand and silt covering an area approximately 150 by 300 feet. The depth ranges from 0 feet at the edge of the sump to 25 feet at its center. Large limestone and chert gravels up to 3 inches in diameter are scattered throughout much of the unit. Included in the fill material was trash, broken glass, wire, metal fragments, plastic, cans, wood fragments, and concrete rubble. Several pieces of concrete were large enough to obstruct the augers and had to be removed by a backhoe at the IITRI site.

The regional aquitard, the Navarro Group clay, lies 28 to 33 feet below the former depression area. Under Site S-1, the Navarro clay is a mottled, orange-brown to gray, stiff, plastic clay with crude laminae. A few borings have revealed silty horizons within the clay.



NOTES:

1. BASE MAP ADAPTED FROM DRAWINGS PROVIDED BY KELLY AIR FORCE BASE.
2. SOIL BORING S1B06 WAS CONVERTED TO PUMPING WELL S1PW03; SOIL BORING S1B07 WAS CONVERTED TO PUMPING WELL S1PW04; CHEN01, CHEN02, AND CHEN03 WERE USED TO OBTAIN ADDITIONAL INFORMATION ON DEPTH TO THE NAVARRO CLAY LAYER; AND REMAINING BORINGS WERE USED PRIMARILY FOR ANALYTICAL PURPOSES.

Figure 4-1

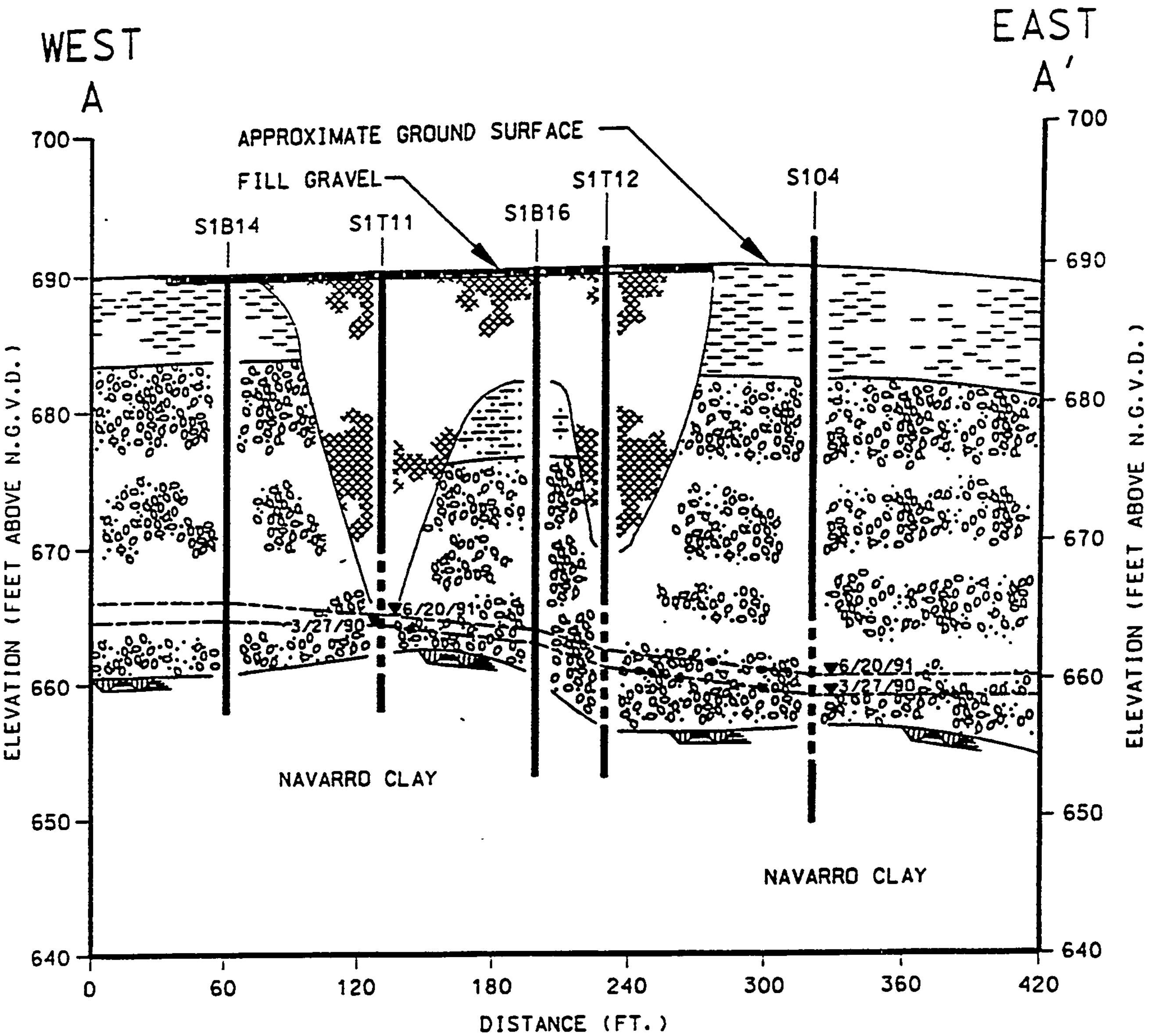
HALLIBURTON NUS
Environmental Corporation

TITLE

PROFILE LOCATION MAP

SITE S-1
KELLY AIR FORCE BASE

DRAWING NO.	DATE
3688G004	10-6-92



CROSS-SECTION A-A'

HORIZONTAL EXAGGERATION = 6 X VERTICAL

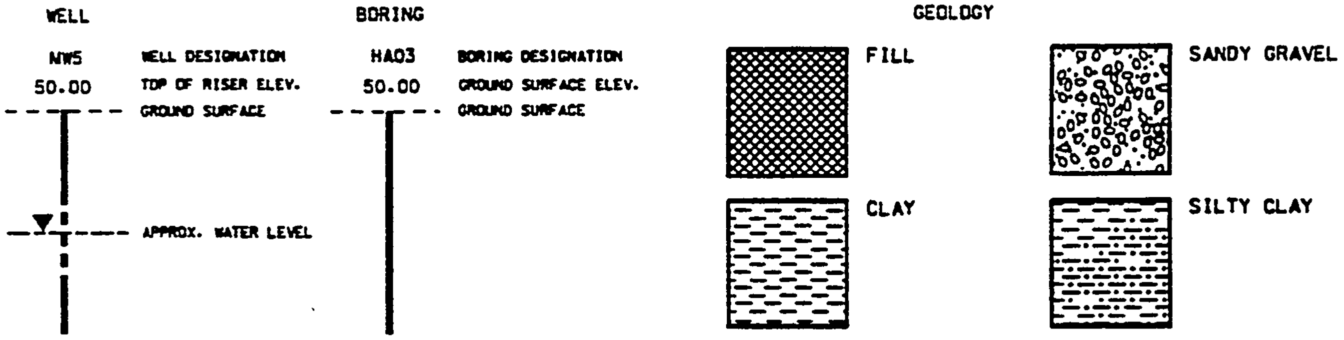


Figure 4-2

HALLIBURTON NUS
Environmental Corporation

TITLE

GEOLOGIC CROSS SECTION A-A'

SITE S-1
KELLY AIR FORCE BASE

DRAWING NO. 3688G005

DATE 10-6-92

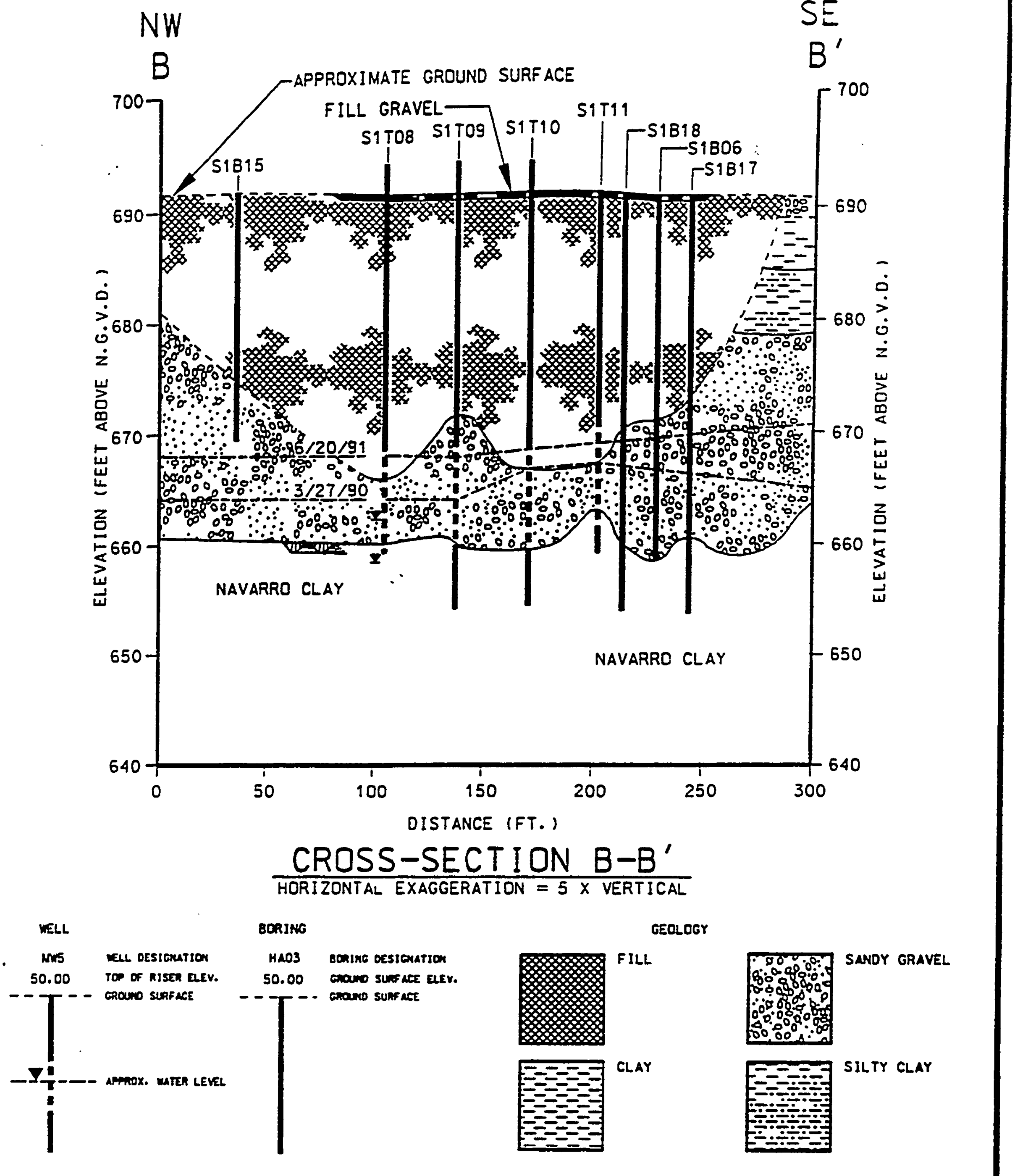


Figure 4-3

HALLIBURTON NUS
Environmental Corporation

TITLE

GEOLOCIC CROSS-SECTION B-B'

SITE S-1
KELLY AIR FORCE BASE

DRAWING NO.	DATE
3688G006	10-6-92

D47119412

4.2.3 Hydrology

Aquifer Characteristics

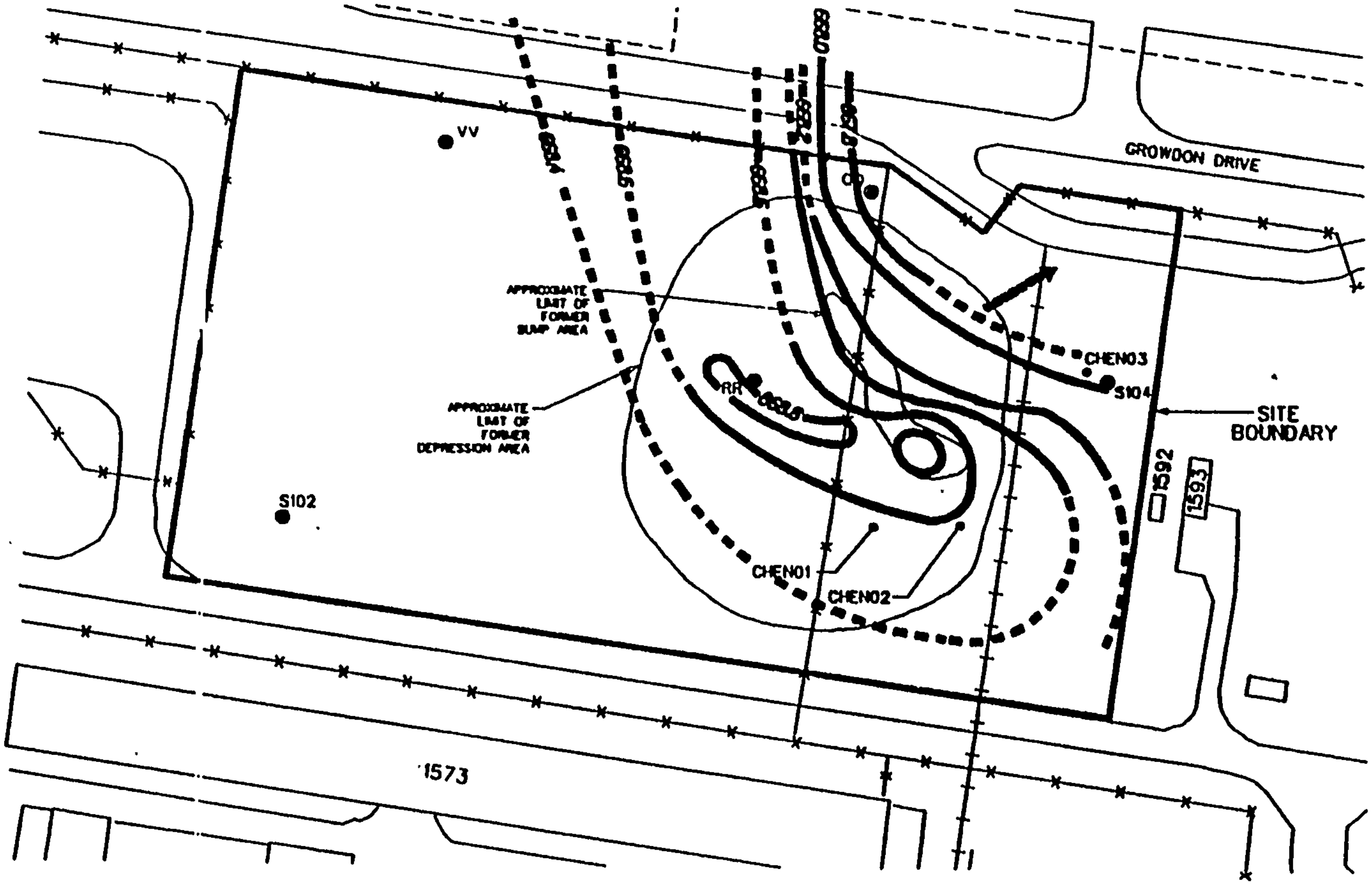
Water level measurements recorded between mid-1989 and late-1990 indicate that the direction of groundwater flow is toward the Northeast. The water table beneath the site ranged from 25 to 30 feet below the surface, with a saturated aquifer thickness of 3 to 6 feet. The maximum water level fluctuation observed in the vicinity of Site S-1 was 3.25 feet. Northeast of the sump, water level measurements made on April 30, 1992 indicated that the groundwater gradient was 0.016 ft/ft, much higher than the 0.003 feet/feet gradient found immediately downgradient of the site. A local high area in the Navarro clay in combination with a groundwater "mound" effect appears to be the cause for the steep gradient across the sump (HNUS, 1991). See Figure 4-4 for details.

Aquifer Testing

Slug tests were performed in 6 Site S-1 wells surrounding the sump area (RR, QQ, VV, S101, S102, and S104) and S1PW04 (HNUS, 1991). Although these wells lie outside the fill and sump area, they are screened across the natural gravely clay, sand/gravel unit. The calculated average hydraulic conductivity at those wells is 5.4×10^{-3} centimeter/second (1.8×10^{-4}feet/second). Data from dewatering activities during the demonstration is presented in Appendix B.8.

Aquitard Characteristics

The Navarro clay aquitard inhibits the groundwater movement both vertically and horizontally underneath the alluvium at Site S-1. The calculated mean hydraulic conductivity of 7 wells screened across the Navarro Group clay is 8.9×10^{-6}centimeter/second.



LEGEND

HNUS INSTALLED MONITORING WELL	●
PRE-EXISTING MONITORING WELL	•
GROUNDWATER CONTOUR[1] (DASHED WHERE APPROX.)	——100——
GROUNDWATER FLOW DIRECTION	▬▬▬▶

[1] ELEVATION IN FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM

NOTES

1. BASE MAP ADAPTED FROM DRAWINGS PROVIDED BY KELLY AIR FORCE BASE.
2. SOIL BORING S1B06 WAS CONVERTED TO PUMPING WELL S1PW03; SOIL BORING S1B07 WAS CONVERTED TO PUMPING WELL S1PW04; CHEN01, CHEN02, AND CHEN03 WERE USED TO OBTAIN ADDITIONAL INFORMATION ON DEPTH TO THE NAVARRO CLAY LAYER AND REMAINING BORINGS WERE USED PRIMARILY FOR ANALYTICAL PURPOSES.

GRAPHIC SCALE
0 150' 300'

Figure 4-4

HALLIBURTON NUS
Environmental Corporation

TITLE

GROUNDWATER ELEVATION CONTOUR MAP
APRIL 30, 1992

SITE S-1
KELLY AIR FORCE BASE

DRAWING NO.	DATE
3688G004	10-6-92

5.0 RADIO FREQUENCY SOIL HEATING

The major electrical processes employed in the RF soil decontamination demonstrations at Site S-1 are described below. The text begins with a brief discussion of the electrical phenomena involved, describes some common electrical heating techniques, and concludes with more detailed descriptions of the IIT and KAI techniques. Additional details on both techniques are provided in Appendices A.1 and B.1. Some of the discussion below is very basic, presented for readers who are not familiar with electrical phenomena. Other readers may wish to move directly to Section 7 for results of the two demonstrations at Kelly AFB.

5.1 GENERAL

Two technologies, RFH and SVE, are required for RF soil decontamination. RFH increases the vapor pressure of contaminants and soil moisture, increasing their rate of evaporation. SVE removes contaminant and water vapors for treatment, assuring that vapors do not pose health or environmental risks above ground level.

RFH of soils has evolved from techniques that were developed to increase the yield of oil wells. Investigators at IIT and elsewhere have demonstrated the feasibility of heating low-yielding oil deposits by application of RF energy. More recently, IIT, KAI, and others have modified these techniques for near-surface use.

SVE is becoming widely used as an alternative to more expensive soil treatment technologies such as incineration. It is most effective for highly volatile soil contaminants such as gasoline. Many less volatile contaminants may be removed if the soil is heated, and soil heating can extend the utility of SVE into very cold climates. Recent SVE innovations include the use of steam injection and solar heating of injected air or water. SVE and the system used in these demonstrations are discussed in more detail in Section 6.

The near-surface soils at Site S-1 were heated to temperatures exceeding 100 degrees Celsius by application of RF energy. Heating vaporized many volatile site contaminants because the soil temperature exceeded their boiling points. Heating increased the vapor pressure of all contaminants, so heavier compounds that boil at higher temperatures vaporized more quickly.

5.2 ELECTRICITY AND ELECTRIC FIELDS

5.2.1 Basic Electrical Phenomena

An electric current is a flow of electrons through a material and is measured in amperes. Voltage is a measure of the electrical potential between two points in a circuit and is measured in volts. Water flow in a pipe is a good analogy, with water pressure being analogous to voltage and water flow rate being analogous to electric current. Direct current (DC) flows at a constant voltage, as in most battery-powered devices. The voltage in alternating current (AC) applications changes rapidly. For example, the voltage in most homes varies sinusoidally at a frequency of 60 cycles per second, or 60 Hertz (Hz). Most home appliances operate at voltages of 110 or 220 volts. The RF sources used in these RF demonstrations operated at frequencies of 6.78 (IIT) and 27.12 (KAI) megahertz (MHz, or Hz x 10^6). Power, usually expressed in watts (W) or kilowatts (kW), is a measure of electrical energy. In the simplest cases, DC or AC power is calculated by multiplying the voltage (volts) by the current (amperes). The rate of energy use is measured in watt-hours or, more commonly, kilowatt-hours (kW-hr). The electric meter on the supply line records kilowatt-hours.

5.2.2 Conductors, Insulators, and Dielectrics

Conductors

The electronic structure of a material determines its ability to conduct electric currents and its behavior in electric fields. Copper atoms, for example, form a rigid lattice, but many electrons are free to move about within the lattice. The free electrons in copper move readily in response to an applied voltage, making copper an excellent conductor of electricity. The following important phenomena result from the movement of free electrons in conductors.

- A flow of electrical current in a conductor creates an electric field around the conductor. The electric field intensity varies in response to changes in the current.
- Changes in electric fields create magnetic fields. The magnetic field intensity changes in response to changes in the electric field intensity.
- A flow of electrical current is induced in a conductor when the conductor is moved through a magnetic field. The magnitude of the current varies with changes in the intensity of the magnetic field.

These phenomena are the functional bases for electric motors and generators. Magnetic fields are critical in many electrical operations, but have much less importance in the discussions that follow.

Solutions containing many ions, like the dilute acid in an automobile battery, also conduct electricity well. Many gases conduct electricity if the applied voltage is sufficient to ionize them. Lightning, for example, occurs when sufficient static electricity accumulates to ionize air in a path between a cloud and the earth or between clouds. The accumulated static electricity flows along the ionized path, creating the brief flash we see as lightning.

Insulators

The molecules of most glasses and ceramics also form rigid lattices. The electric charges of the nuclei and electrons are evenly distributed throughout the structure, binding both the nuclei and electrons in the lattice. The absence of free electrons prevents current flow through such materials, making them good insulators.

Dielectrics

The structure of dielectric materials, including many plastics, waxes, and oils, is similar to that of insulators, but the distribution of electric charge on the individual molecules is not evenly distributed. Slightly positive or negative portions of the molecules result in the molecules behaving like small magnets. They are said to be polar, and are sometimes referred to as dipoles. The relative strengths of these small magnets are measured and recorded as dipole moments. The molecules move in an electric field much as a compass needle moves in the earth's magnetic field. Most dielectrics are nonconductors or poor conductors of electricity.

Water is a critical compound in the RFH of soils, and its electrical properties may vary widely. Very pure water is a nonconductor, but is rarely encountered outside the laboratory. Water containing ions of salts or other materials is a good conductor. Water is also strongly polar. Soil containing water is a dielectric, a property fundamental to RFH.

RFH of soil results from the behavior of dielectrics in electric fields. Magnetic fields have little effect in a properly designed system. A full discussion of the mechanism by which the energy of an electric field agitates dielectric materials is beyond the scope of this report and is not required for an adequate understanding of the demonstrations at Kelly AFB.

Technical literature usually discusses the transfer of energy to a dielectric in terms of the loss tangent, δ. Materials that heat easily are described as "lossy". Soil impedance is a complex function consisting of a real component that describes the degree to which the soil is lossy and a reactive component that describes the soil's ability to store energy. The loss tangent, δ, is the ratio of the lossy component to the reactive component. These discussions may lead to confusion because:

- Dielectric "loss" or "lossy" have negative connotations for many people, but "lossy" soils are the easiest to heat with RF energy.
- Complex discussions of impedance may intimidate readers. They may feel that complex concepts must reflect complex operational problems.

Most soils are suitable for RFH (δ is sufficiently large). Sand, gravel, or rock (low δ) require much more careful consideration. In most applications, the primary concern is to the operator, who must select an operating frequency, design his applicator for site conditions, and adapt to changes in δ as soils become dry. Recent articles on RFH of soils illustrate the difficulty that radio engineers experience explaining this concept to a more general audience. Authors often speak of depositing, dissipating, or transferring energy. For simplicity, this report describes the process as dielectrics "absorbing" energy from an electric field.

5.2.3 Resistance, Inductance, and Capacitance

Resistance

All conductors offer some resistance to the flow of electrical currents at temperatures above absolute zero. The resistance of power distribution lines results in some waste of energy, while the resistors in electronic circuits are critical to the circuits' operation. Ohm's Law describes the relationship between voltage, current, and resistance:

$$E = IR$$

where:

E = the voltage difference, or potential, across a resistor (volts)
I = the current flowing through the resistor (amperes)
R = the resistance (ohms)

Inductance

The henry is the unit of measure of inductance. Inductance is associated with the creation of a magnetic field around a conductor carrying an electric current. Coils, such as those in transformers, are the most common inductors, but all current-carrying devices exhibit inductance. As discussed below, the inductance inherent in RF application systems must be closely monitored. The application of RF energy to soil does not rely on inductive phenomena, however.

Capacitance

The simplest capacitor is two parallel plates separated by an air gap. Capacitors may have other shapes, may consist of multiple, interleaved plates, and the plates may be separated by a wide variety of dielectric materials. Capacitors are used to block DC currents, adjust the frequency of tuned RF circuits, and reduce or offset inductance in circuits. The farad is the unit of capacitance.

Inductive and Capacitive Effects on Alternating Currents

The voltage in household AC circuits rises sinusoidally from zero to a peak of 110 volts, falls to minus 110 volts, and returns to zero at a frequency of 60 Hz. RF sources used for soil heating supply a similar current at much higher voltages and at frequencies of several megahertz. If the inductance and capacitance of the circuits receiving such currents are negligible, the voltage and current rise and fall synchronously and are said to be "in phase". Strongly inductive or capacitive circuits change the voltage/current phase relationship.

In inductive devices like transformers and motors, the voltage rises before the current. The current is said to "lag" in such devices. The current "leads" the voltage in capacitive devices. The voltage and current are "out of phase" in both cases, and the power delivered to these circuits is not a simple function of voltage and current. Power is also a function of the phase difference between voltage and current. Peak power must be less than the product of voltage and current because voltage and current do not reach their peak values simultaneously.

Inductive and capacitive effects cause potential, but correctable, losses of efficiency. For example, the electrical efficiency of an installation containing large motors (an inductive load) may be improved by placing capacitors on the incoming power line. The rows of electrodes in the IIT electrode array behave like the plates of a large capacitor with soil acting as a dielectric. Power is supplied to the array through an adjustable matching network to minimize undesirable capacitive effects.

Applicator systems like IIT's electrode arrays or KAI's antennae exhibit a complex combination of resistance, inductance, and capacitance called impedance. RF sources are designed to deliver power into a prescribed impedance. At radio frequencies, a large portion of the power applied to the soil may be reflected back along the distribution line to the RF source unless the impedance of the applicator matches the prescribed impedance of the source. The impedance match is never perfect in practice because:

- An ideal coaxial line connecting the source to the applicator should, in theory, carry RF energy any desired distance with no losses. Actual coaxial systems and other components exhibit slight impedance irregularities that preclude a perfect impedance match.

- The properties of the soil being treated change throughout the heating process. The progressive soil drying changes its dielectric properties and, consequently, its impedance.

  Excessive reflected power results in inefficient heating and can cause serious damage to the RF source. The IIT and KAI systems monitor the efficiency of power delivery and adjust automatically to normal impedance changes. Larger changes, like those that might occur if a component fails, activate alarms to alert operators or turn off power to the system.

5.3 ELECTRICAL HEATING TECHNIQUES

5.3.1 Ohmic Heating

Three electrical heating techniques are widely used in industry and by individuals. Ohmic, or resistive, heating is the most common, and a cooking eye on an electric kitchen range is a very familiar example. Ohmic heating may be used to heat soils by applying a high voltage, 60-Hertz current to electrodes driven into the soil. The simplicity of the technique makes it attractive, and it may be useful for small, shallow contaminated zones. There are two drawbacks, however. Large quantities of soil cannot be treated without the use of very high, and therefore dangerous, voltages and currents. Also, this technique relies on soil moisture to provide a conductive path through the soil. The moisture is removed when soil temperatures reach about 100 degrees Celsius, breaking the conductive path and stopping the heating process.

DOE investigators at Pacific Northwest Laboratories and the DOE Savannah River Site have developed and demonstrated a novel improvement on this technique (Gauglitz, 1994). They applied six-phase AC to six electrodes equally spaced on 15-foot radii around a central SVE well. This approach creates constantly changing voltage differences between pairs or groups of pairs of electrodes. The observed heating pattern was sufficiently uniform to warrant further testing. Even if water must be added to site soils periodically, the technique may prove useful for removal of very volatile compounds.

5.3.2 Inductive Heating

Inductive heating employs an electrical current applied through a coil to produce an intense magnetic field inside the coil. The field acts only on magnetic materials and has little effect on dielectrics. This technique is widely used to produce metals of extremely high purity and to heat metal bars for annealing or forging. The heated volumes are typically quite small, offering little utility for soil heating.

5.3.3 Dielectric Heating

Dielectric heating employs a high-frequency alternating electric field to heat the desired volume. Polar molecules such as water are caused to vibrate at the applied RF frequency, and the resulting mechanical energy is released as heat. Diathermy, a medical technique that is several decades old, is used to heat small portions of the human body by stimulating the body's fluids. The microwave oven is the most popular current application of dielectric heating; food is heated rapidly and efficiently when ultra-high frequency energy agitates water molecules in the food. Dielectric soil heating and microwave food preparation are also similar in that metal objects must not be placed within the heated zone. Such objects absorb RF energy very strongly, resulting in extremely high temperatures near the objects and possible damage to the RF source.

The RF soil decontamination demonstrations discussed in this report are examples of dielectric soil heating. In the IIT demonstration, RF energy was applied to rows of electrodes in soils at Site S-1, where the soils, water, and other materials between the electrode rows behaved like the dielectric medium in a capacitor. KAI applied RF energy with an antenna-like device inverted and lowered several feet into a well.

RF soil decontamination proceeds in three steps. First, soil moisture and contaminants are heated by the application of RF energy, vaporizing both the moisture and contaminants. The vapors are then removed by vacuum extraction techniques similar to those used in commercial SVE and soil organic vapor (SOV) sampling processes. Finally, the extracted heated vapors may be treated, destroyed, or recycled by a variety of commercially available processes.

Successful application of RFH of soil requires consideration of two complicating factors. First, the electrical properties of the soil may vary greatly as treatment proceeds. These changes require careful monitoring and tuning of the RF source to optimize the transfer of electrical energy to the soil. Second, soil moisture and contamination may vary greatly within the treated volume. These variations may produce short-term changes in the composition of the extracted vapor stream. The vapor treatment system must be designed to accommodate such changes and monitored to assure that vapors are properly contained.

5.4 THE PROPAGATION OF RF ENERGY

5.4.1 RF Propagation in Free Space

RF energy is usually represented as perpendicular electric and magnetic vectors, as shown in Figure 5-1. The electric and magnetic field intensities vary sinusoidally at a frequency determined by the RF source. The distance along the path of propagation required to complete each cycle is called the wavelength. Frequency and wavelength are related by the expression:

$$\lambda f = c$$

where

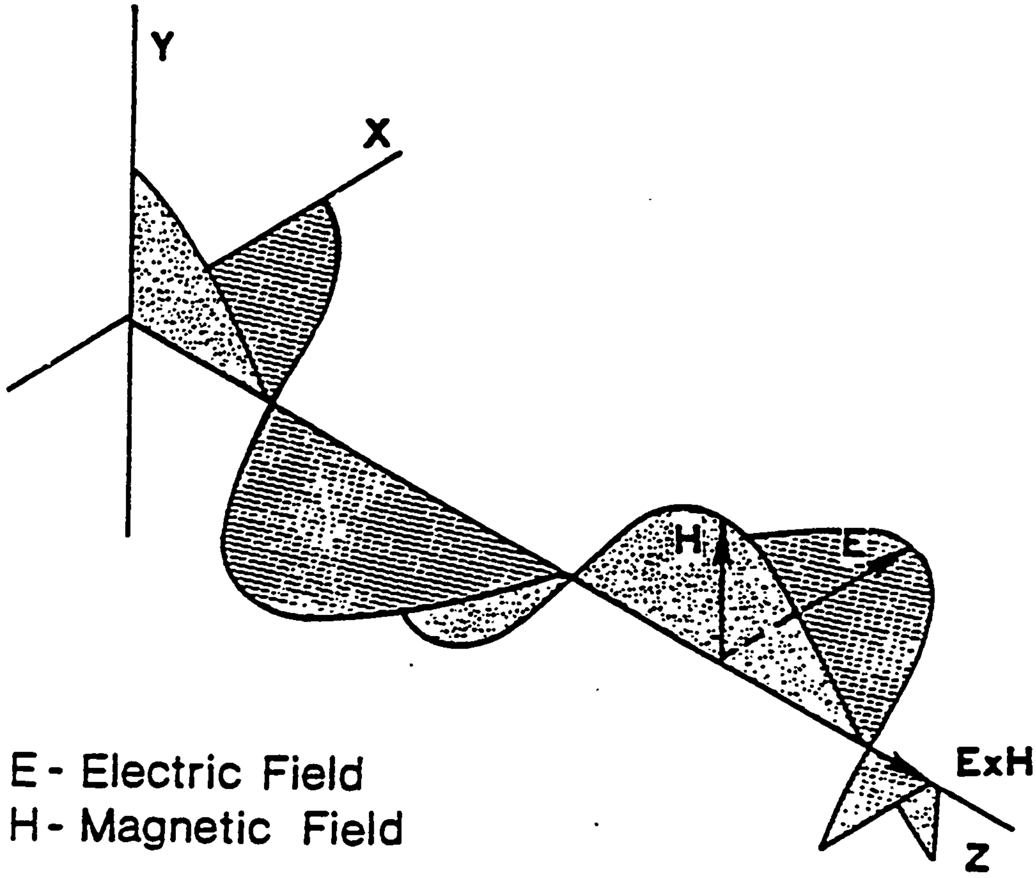
λ = the wavelength of the radiation in free space in meters

f = the frequency of the radiation in Hertz

c = the speed of light, approximately 300,000,000 (3×10^8) meters per second

A frequency of 6.78 megahertz, the frequency IIT used for the demonstration at Site S-1, corresponds to a wavelength of 44.2 meters in free space. The relationship of radio frequency radiation to other forms of electromagnetic radiation is shown in Figure 5-2.

The use of RF energy described above must not interfere with communications, radar, or other RF applications. IIT and KAI operate their systems at frequencies in the Industrial, Scientific, and Medical (ISM) frequency bands established by The Federal Communications Commission (FCC). Unlicensed users may operate RF equipment within these frequency bands at very high power



E - Electric Field
H - Magnetic Field

(Source: AFOSH Standard 161-9)

Figure 5-1

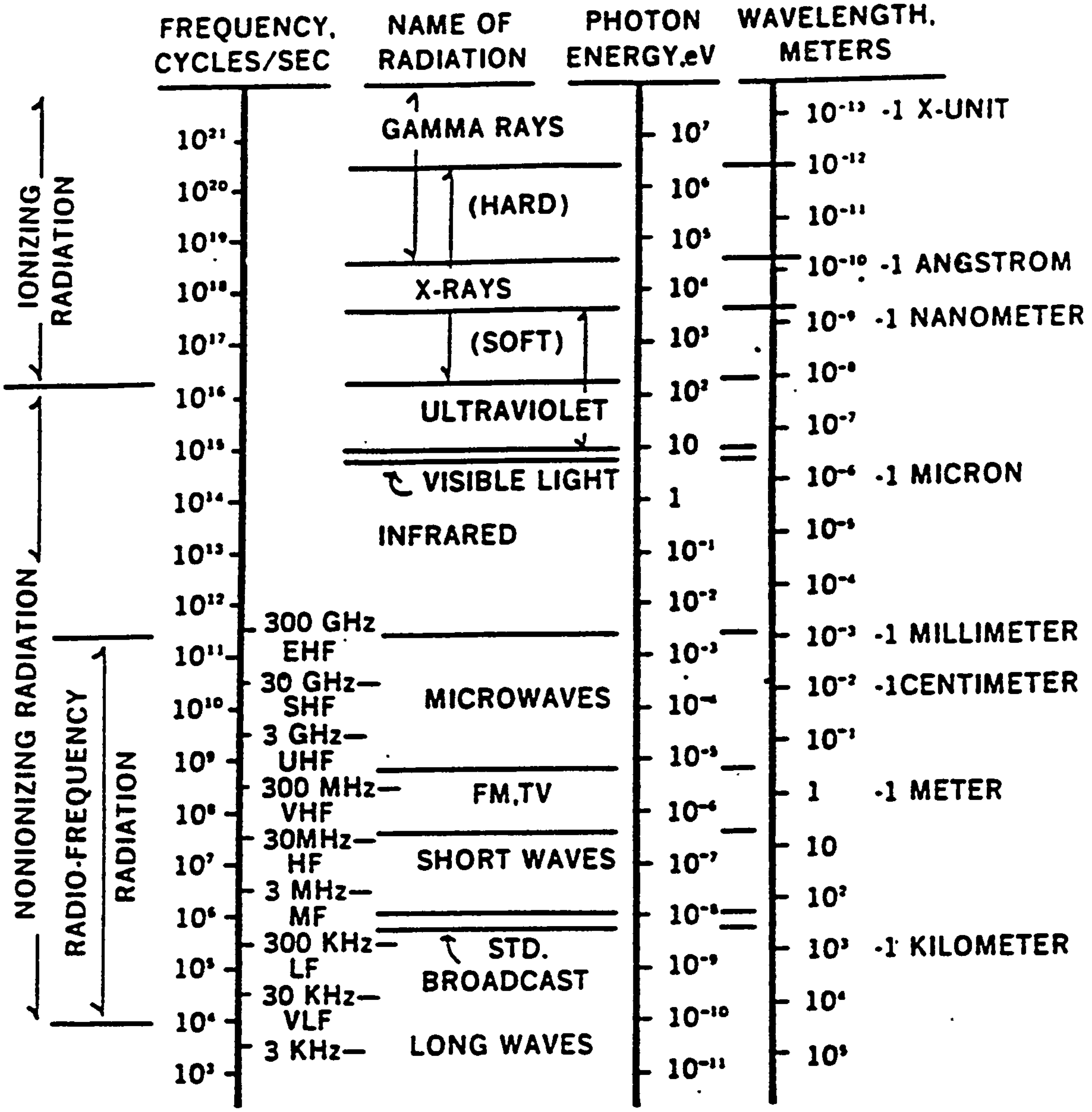
HALLIBURTON NUS
Environmental Corporation

TITLE

PROPERTIES OF ELECTROMAGNETIC WAVES

DRAWING NO.

DATE



(Source: AFOSH Standard 161-9)

Figure 5-2

HALLIBURTON NUS
Environmental Corporation

TITLE

THE ELECTROMAGNETIC SPECTRUM

DRAWING NO.

DATE

levels and with somewhat broader frequency bandwidth (range of frequencies around the design frequency) than allowed on most communication frequencies. No FCC permit is required, but operation must be coordinated with base communications personnel.

5.4.2 RF Propagation in Dielectrics

Dielectric materials contain polar molecules, or dipoles, which vibrate at the frequency of the applied electric field. The amplitude of the electric field decreases with distance as RF energy is converted to mechanical energy, then lost as heat. The magnetic field decreases in proportion to the reduction of the electric field. The behavior of the magnetic field is relatively unimportant to an understanding of the heating process unless metallic objects lie in the heated zone. Such objects behave like a spoon inadvertently heated in a microwave oven and must be avoided. Ignoring the magnetic field vectors shown in Figure 5-1, the RF energy propagated in a dielectric may be viewed as an electric field varying sinusoidally and diminishing in amplitude as energy is lost to the dielectric material.

Water is the most important dielectric material in the soils at Site S-1, and most of the RF energy expended in the soils served to heat and vaporize soil moisture. As mentioned earlier, the moisture is important in the decontamination process and the energy was not wasted. Most organic compounds that have only covalent bonds, such as simple alkanes, are relatively nonpolar and will not respond strongly to an electric field. Compounds with ionic bonds will respond more strongly, with the energy absorption being proportional to the dipole moment of each molecule.

The following characteristics of dielectric heating are critical in the RF soil decontamination process:

- The energy absorbed is proportional to the square of the electric field intensity.
- The energy absorbed is proportional to the frequency of the applied RF energy.
- The depth of penetration is inversely proportional to the frequency of the applied RF energy.
- The energy absorbed is proportional to the soil conductivity. Conductivity is, in turn, inversely proportional to permittivity, an important soil parameter measured by IIT. IIT's measurements of soil dielectric properties show that the variables change in a dramatic and complex manner as soil heating progresses (see Appendix A.1).

Field intensity and frequency may be varied to optimize the process, within the following limitations:

- Increasing the field intensity too rapidly or too greatly may lead to overheating in some soil volumes or electrical arcing.
- Increasing the frequency will increase the rate of heating, but reduce the depth of penetration.

The selection of startup settings and subsequent optimization of the process requires a thorough knowledge of the process, much of which must be gained by experience. Information IIT and KAI gained in prior tests at other sites was directly applicable to the operations at Site S-1. IIT recommended beginning operations at a frequency of 6.78 megahertz, then shifting to 3.4 megahertz as the soils dried out and became more transparent to RF energy. Budget considerations reduced the time available for the KAI demonstration. KAI selected on operating frequency of 27.12 mHz to take advantage of more rapid heating at higher frequencies.

The following documents provide excellent, detailed discussions of RF propagation in free space and contain important details about the Health and Safety aspects of operating RF equipment:

- Air Force Technical Order 31Z-10-4. Chapter 6 is enclosed as Appendix G.
- AFOSH Standard 161-9, Exposure to Radio Frequency Radiation. This document is enclosed as Appendix H.

5.5 BASIC COMPONENTS OF RF HEATING SYSTEMS

An RF heating system consists of the eight major components described below. The first five components would be very similar in a new design for use of either the IIT or KAI technique. The major differences in the techniques lie in the RF transmission and application components. Appendix A.1 contains a demonstration report prepared by IITRI. It includes details about their RF system and soil test data from their laboratory.

AC Power System

Existing power lines, as used at Site S-1, or portable generators are suitable power sources. Single-phase current (110 and 220 volts) is required for lights, instruments, and light power tools. Three-phase current (typically 440 or 480 volts) is required for the RF source and cooling system. Step-down transformers may be required, depending on the line voltage available at a site. Rental transformers are economical alternatives to purchasing enough transformers to suit many situations. The AC wiring to an RF system is similar to standard commercial wiring. Aerial or underground lines are suitable, and a watt-meter may be placed at a power pole or at the AC distribution panel.

A high-voltage power line lies immediately west of Site S-1. Power to the RF sources was delivered through overhead air breakers, an underground line to a rental step-down transformer, and underground lines to the trailers housing the sources. Two AC power problems developed during the tests. First, base electrical diagrams show the high-voltage line as part of a 13, 800-volt grid. Measurements indicated that the actual voltage was closer to 13, 200 volts. Second, aluminum underground power lines between the transformer and the RF source worked well during the IIT test and were installed at the beginning of the KAI demonstration. The IIT RF source, a few decades old, was designed to operate under adverse conditions and worked well on the supply line. The KAI source is a much newer, more efficient unit, and the four percent voltage drop was immediately apparent in the power output. The voltage drop resulted in an increase in current, and the aluminum-to-copper spices at each end of the underground line overheated and failed. Replacing the aluminum lines with copper ones stopped the overheating, but the KAI test continued at slightly reduced available power.

Following the KAI demonstration, HNUS personnel encountered power line problems during the installation of a groundwater treatment system at Site S-1. A large, three-phase compressor motor burned out shortly after being placed in service. The electrical subcontractor observed large fluctuations in voltage between the three phases. Kelly AFB Exterior Electric workers found a burned splice in one of the lines providing high voltage to the site, and repairing the splice returned service to normal.

KAI and HNUS had measured the voltages from ground to each of the three legs (ground to Phase 1, ground to Phase 2, and ground to Phase 3). Small, but acceptable variations appeared in those measurements. The subcontractor located the problem by measuring the voltage differences between phases (phase 1 to phase 2, phase 2 to phase 3, and phase 3 to phase 1). Kelly AFB personnel confirmed that the variations originated in the high-voltage line and worked backward along the line to locate the defective splice. The date the line was damaged is unknown, but it could explain the difficulty KAI experienced in maintaining proper line voltage.

RF Source

RF sources are like standard radio transmitters, but simpler and more rugged. The equipment must withstand travel from site to site and may be subject to a wide range of environmental conditions. Unlike radio transmitters, RF sources for soil heating require no audio frequency amplifiers or modulators. The principal components include:

- A power supply that converts AC to DC at a wide range of voltages.
- A crystal-controlled oscillator that generates an RF current at the desired radio frequency.
- Two or more stages of amplifiers that increase the strength of the RF current from the oscillator.
- A final amplifier that increases the RF current to the desired output level.
- A tuning network that matches the output of the source to the impedance of the transmission line and applicator system.

Semiconductors have replaced vacuum tubes in most active circuits in RF sources except in the final stage of amplification. Fully solid-state sources are available with outputs of 40 kW or more. Some vendors suggest that such units may be more prone to damage in harsh environments or when subjected to rapidly changing loads. Vacuum tube final amplifiers are still widely used in communications and are suitable for RF heating applications. General Electric investigators reported frequent failures with their vacuum tube source (Edelstein et al, 1994), but the IITRI and KAI sources worked well during the demonstrations at Site S-1.

The IIT RF source was a converted radio transmitter capable of providing 40 kilowatts of RF power. The physical size of the source was somewhat larger than necessary because it contained unneeded audio amplifiers, a modulator, and other equipment once used for voice transmission. Those components were turned off during the test and consumed no power.

KAI used a newer, more efficient, and more compact 25-kilowatt source.

Cooling System

All components in an RF source generate heat, especially the power supply and final amplifier. Cooling system design must be guided by both the electronic design and the anticipated operating environments. Air cooling may be adequate for sources of 20 kW or less, while substantially larger units may require refrigeration units. A system designed for year-round operation in Texas will need more cooling capacity than one dedicated for use in Oregon. In very hot climates, cooling may require ten to fifteen percent of the total AC power consumed. The IIT and KAI systems operated with no cooling malfunctions during the demonstrations.

Monitoring and Control System

Simple voltmeters and ammeters are used to monitor critical voltages and currents in the source. Other instruments display the operating frequency, the percent of RF power reflected from the applicator, operating hours, and similar basic measurements. All critical measurements should be available as digital signals recorded by computer. The computer and sensors in the source may turn off RF power if a potentially dangerous or damaging condition develops.

Much of the operation, including output tuning, should be automated. Both IIT and KAI have developed automated monitors with the capability to perform small adjustments, alert operators if other adjustments are needed, and contact operators by pager if a more serious condition develops. The systems may be interrogated by telephone modem, and data can be transmitted to remote locations. Recent developments in communications permit economical automation and reduction of labor on site.

The electric field at the site should be monitored as a safety measure, and measurements should be recorded for documentation. Routine measurements of the electric field and any radiation occurring at spurious frequencies can document that the system does not interfere with communications, television, or other RF systems.

Shelter

IIT operates their RF source from a small semi-trailer. KAI uses a custom-built trailer that can be towed behind a pickup truck with a heavy-duty rear axle. Both provide permanent housing for an RF source, an AC distribution system, a cooling system, the monitoring and control system, and a small office and storage area. Systems can be assembled in a wide variety of vehicles or in rolloff boxes that can be moved by flatbed truck, train, or airplane.

RF Transmission Line

IIT and KAI used rigid, copper coaxial transmission line which is available in lengths up to twenty feet. Universal couplings allow the coaxial line to be placed in nearly any configuration. Flexible coaxial line is available, but expensive compared to the rigid line. Either must be purged with dry nitrogen to eliminate internal moisture and prevent arcing.

The transmission line used by IIT included a matching network to compensate for the capacitance of their applicator system and RF chokes to reduce reflected radiation. The KAI transmission line contained only a switch that allowed operation of either of two applicators from a single feed line.

Applicator System

IIT and KAI used proprietary applicator systems that are described more fully below and in Appendices A.1 and B.1. Briefly, the IIT applicator system consisted of three rows of copper pipes installed in borings. The electrodes, with the soil in between as a dielectric, simulated a large capacitor. KAI used antenna-like applicators inserted into non-metallic casings. Small towers allowed KAI to move the applicators up and down in the casings as desired to heat soils at different depths.

RF Shielding

A grounded metal shield over the heated volume is required to prevent exposure of site workers to excessive RF radiation. IIT used a tunnel-like shield made of corrugated aluminum. The shield provided protection for sensors inside, and its height was sufficient to eliminate electrical arcing inside. The KAI applicator was completely below grade, so a flat grid of grounded cables and expanded aluminum sheet could be placed directly on the surface of the heated zone.

5.6 RF SOIL HEATING TECHNIQUES

The proprietary RFH techniques developed by IIT and KAI are the most prominent in current use. Both companies have performed several pilot-scale and field demonstrations. IIT is preparing a 100-

kW system, and KAI plans to build additional 25-kW units. The increases in power output will allow each to demonstrate RFH on a larger scale.

The RF sources currently used by IIT and KAI are similar in most respects. Each has a crystal-controlled oscillator that generates a low-voltage signal at the desired frequency. Two or more stages of amplifiers are typically used to amplify the signal before it reaches the final amplifier. The final amplifier provides the high power necessary for soil heating. Each system includes large power supplies, automatic monitoring and logging equipment, and cooling systems. Semiconductor devices have replaced tubes in most components of modern systems. Tubes are still used in the final amplifiers of many RF sources, including those used by IIT and KAI.

The IITRI and KAI systems reflect the nature of the parent organizations. IITRI is a not-for-profit organization, and their interests lie in the research and development of technologies. KAI, a for-profit business, has focused more closely on assembling a system that can be set up quickly and operated with a minimum of manpower. Both technologies are suitable for commercial operations. IITRI is capable of building a more fully automated system.

5.6.1 The IITRI Capacitor Technique

The IITRI technique, as demonstrated at Site S-1, uses rows of electrodes in the soil to heat a volume of rectangular cross-section. Heated volumes at Site S-1 were bounded by two rows of vertical ground electrodes, and RF energy was applied to a third electrode row midway between the ground rows. The three electrode rows acted as a large, buried, tri-plate capacitor, with soil serving as a dielectric medium between the plates. As RF energy was applied to the electrode array, soil heating began at the center, then proceeded outward and downward as designed.

The electrical impedance of the electrode array must match that of the RF source, just as the impedance of a television antenna is matched to that of the receiver. The impedance of the array changes sharply as the soils are heated to the boiling point of water, then remain relatively constant until most soil moisture is removed. The soil temperature will begin to rise again as the soils become dry, resulting in another large change in impedance. Much of the energy will be reflected back toward the RF source if the impedances are not matched. A large mismatch can result in a waste of energy and possible damage to the RF source. IIT's measurements indicated that the range of impedances that must be matched were large, requiring two matching networks to assure efficient transfer of energy to the soils.

HNUS and IITRI originally planned to incorporate the exciter electrodes into the SVE system. The objective was to remove vapors through hotter, more permeable soils. A Pyrex® tube and an additional RF choke were to be installed between the electrodes and the vacuum source to insulate the vacuum source from dangerous RF currents. However, IITRI experienced difficulty keeping the glass tube intact in a previous test at Rocky Mountain Arsenal, and the idea was not tried at Site S-1. The concept has merit and could be tested if suitable materials can be found.

IITRI has demonstrated the ability to heat a well-defined volume uniformly. Drawbacks include the need for a large number of electrode and sensor borings and the potential difficulty of matching a wide range of impedances. However, the IITRI matching equipment tracked impedance changes well during the demonstration and relatively few manual adjustments were necessary.

HNUS and IITRI elected to observe the effects of continued heating after much of the soil volume had reached the target temperature. Portions of the heated volume were heated to nearly 1000 °C and the system was turned off when power fluctuations indicated that electrical arcing might be occurring below grade. Post-test drilling revealed molten pieces of electrodes and thermocouples.

5.6.2 The KAI Antenna Technique

KAI Technologies, Incorporated, uses an antenna-like applicator inserted in a single boring to heat a cylindrical soil volume. The antenna is an end-feed dipole that can be tuned by adjusting its length, inserting or removing ceramics blocks inside the antenna, or both. The technique is less sensitive to changes in soil dielectric properties. Energy from multiple applicators can be electrically phased to heat larger volumes of soil. An antenna can be moved along a horizontal borehole to treat soils beneath structures, roads, or runways. In vertical applications, the antenna may be positioned to preferentially heat a layer or layers of contaminated or relatively impermeable soils. Drawbacks include the need to treat overlapping cylindrical volumes and the possible need to construct site-specific antenna applicators.

The system deployed at Site S-1 included two antennas suspended from aluminum towers. KAI planned to switch RF power from one antenna to another and move the antennas up and down periodically to heat a soil volume similar to that enclosed by IITRI's electrodes. However, full-power operation began later than planned because of a delay in receiving permission to operate and the need to replace the main power line to the system. Most of the demonstration was conducted using a single antenna at a single depth because of time and budget constraints.

System setup proceeded very quickly. All mechanical work and most electrical work was completed in three days. Full-power testing could have begun in less than a week if permission had been granted.

The delays mentioned above left little time for full-power operation or testing different configurations of the RF equipment. With the exception of some minor problems, the equipment performed well with little operator attention. Exceptions include:

- A coaxial line developed a nitrogen leak immediately before a holiday weekend, when deliveries were unavailable. The nitrogen loss eventually led to internal arcing that damaged the antenna's central conductor.
- KAI found that the spare central conductor had broken in shipment to the site. The stress fracture indicated the need for improved packing.
- The reduced line voltage described above revealed that some subsystems in the KAI RF source were sensitive to low voltage. KAI has installed an uninterruptable power supply to maintain proper operation when the final amplifier is switched on.

The KAI system includes extensive monitoring devices and a central control computer. When off site, operators can communicate with the system by telephone or radio. For example, Mr. Faust used a variety of communications equipment including two-way radios, pagers, cellular and land-line telephones, and a notebook computer. He could interrogate the RF system from his truck or motel room, and the system alerted him by pager if a monitored parameter exceed pre-set limits.

5.7 DESIGN CONSIDERATIONS

This section presents elements that must be considered in designing a system. Most components are readily available or relatively simple to build, but the design still requires the expertise of engineers with broad training and experience. An Air Force or HNUS team, for example, could prepare an excellent design, but the process could be greatly expedited by incorporating the experience of workers who have thoroughly investigated the mechanisms of soil heating.

5.7.1 Time and Energy Requirements

The following relationships are useful in estimating electrical heating costs:

1 kilowatt	≈	56.9 Btu per minute
1 kilowatt-hour	≈	3,413 Btu

Knowing the unit cost per kilowatt-hour, one could calculate the energy cost and heat output for a simple resistive heater with reasonable accuracy. Calculating more realistic time and energy requirements for RF soil heating requires additional knowledge of electrical conversion efficiencies and soil characteristics.

Two examples below illustrate useful procedures for estimating time and energy requirements for RF soil heating. Each may also be used to determine the RF power required to complete a heating task within a predetermined schedule. The first example is appropriate for use early in a project to provide initial estimates of RF power and manpower needs. The second example provides more realistic estimates, but requires more specific knowledge about the electrical properties of the soil. In situ measurements could be made during an SVE pilot test to minimize time and labor.

1) Kasevich et al presented the following simple example in seminars sponsored by the University of Wisconsin (Kasevich et al, 1991):

   Assume that the objective is to remove 1,2 dichloroethene (DCE) from 400 cubic yards (10,800 ft^3) of soil. Assume an efficiency of 95% for the applicator (KAI), a 70 % thermal efficiency for the soil heating, and energy costs of $0.06/kW-hour The boiling point of 1,2 DCE is 60° C, and investigators plan to heat the soil to 70° C. The thermal energy required to heat one cubic foot of soil to 70° C is 0.934 kW-hour/foot^3 (from literature search). Small heat losses at the surface and variations in contaminant and soil moisture distribution are ignored.

$$\text{Thermal energy required} = 0.934\ \text{kW-hr/ft}^3 \times 10{,}800\ \text{ft}^3 = 10{,}087\ \text{kW-hr}$$

   Allowing for application efficiencies:

$$\text{Thermal energy required} = \frac{10{,}087\ \text{kW-hr}}{(0.95)(0.7)} = 15{,}168\ \text{kW-hr}$$

The time required to heat with a 20-kW RF source is:

$$15{,}168 \text{ kW-hr} \div 20 \text{ kW} = 758 \text{ hours} = 31.6 \text{ days}$$

Assuming an RF source efficiency of 50% (including cooling and other ancillary systems):

$$\text{Energy costs} = \frac{(15{,}168 \text{ kW-hr})(\$0.06 / \text{kW-hr})}{0.5} = \$1{,}820 = \$4.55 / \text{yd}^3$$

The actual time may vary, and supplying the energy in pulses may be more efficient than continuous heating. The example still illustrates two points. First, 1,2 DCE will be quickly desorbed. Second, the electrical energy costs are low.

Additional time and energy will be required if the target temperature is at or above the boiling point of water (soil moisture). Cost estimates must include the time and energy required to raise the water temperature to 100° C, then supply additional energy to boil the water to evaporation. However, water removal often expedites contaminant removal, as discussed in other sections.

2) A more site-specific approach includes determining the dielectric properties of the soil and, concurrently, monitoring the energy required to heat a discrete soil volume. This approach is particularly valuable in optimizing an electrode design for application of the IITRI technique. The measurements may be performed in situ or in a laboratory. In situ measurements are more reliable because the soil is relatively undisturbed and moisture and contaminants are not lost in handling. In either case, a small soil volume is monitored during exposure to an electric field to determine its conductivity, resistivity, and specific heat.

The following equation indicates the power (P), in watts, absorbed per cubic meter (W/m^3) of the soil matrix:

$$P = \sigma[E_{rms}]^2 = [E_{rms}]^2 / \rho$$

where:

E_{rms} = the root mean square of the applied voltage (volts)

σ = the apparent conductivity of the material at a given frequency (mho/meter)

ρ = the apparent resistivity of the material at a given frequency, moisture content, and temperature (ohm-meter).

The specific heat (measured) and the power absorption (calculated above) permits calculation of the required RF energy (W_R) as in the example above. The system-specific efficiency, E, is determined from data gathered during the pilot studies. The time (t) required for heating is then calculated as follows:

$$t = (W_R/P_A)\ E_f$$

where:

t = time required for heating (hours)
W_R = energy required (kW-hr)
P_A = power available (kW)
E = efficiency (%)

Early plans for the demonstration phase of this project included purchase of a 120-kW RF source. One 120-kW RF source would require approximately 1100 hours (48 days) of uninterrupted heating to heat 500 cubic yards of soil (similar to the soils at Site S-1) to 150° C (IITRI, July 1992). In the example below, the time and energy costs for heating the demonstration volume are computed assuming that use of a 240-kW RF source will reduce the heating time by half (i.e., Scale-up to larger volumes results in directly proportional heating times). IITRI also suggested that the transmission and RF conversion efficiencies should be 65% and 80 %. Energy costs for continuous heating of the entire site, about 6230 yd^3 or 10,000 tons, are as follows (using two sources):

Time to heat = (6230 yd^3 / 500 yd^3) x 1100 hr / 2 = 6853 hours (285 days)
Energy required = 240 kW / (0.65 x 0.8) x 6853 hours = 3,162,923 kW-hr
Energy cost (assuming $0.06 / kW-hr) = $189,775
Unit cost for AC energy = $189,775 / 6230 yd^3 = $30.46 /$yd^3$ or $18.98/ton

The vapor extraction and treatment system, plus lighting and office power, add relatively small costs.

The second cost estimate is noticeably higher (by a factor of 6 or 7) than the first, although Kasevich assumed a more conservative overall heating efficiency. A major reason for the disparity is that literature values of specific heat (as used in the first example) are usually for dry soil, whereas the measured values used in the second include soil moisture. Also, the second example includes dielectric losses not included in the first.

The treatment cost per ton must be evaluated in terms of specific project objectives, including the significance of in situ treatment. Like most remedial technologies, RFH has certain fixed costs, including equipment amortization and mobilization/demobilization costs. These costs are more significant in very small projects than in very large ones. However, RFH might be very economical for small projects if the contaminated soil lies in a critical location. A technique with a relatively high treatment cost per ton might be a very economical solution if the tons to be treated lay beneath a building or a busy runway.

5.7.2 The RF Source

As mentioned earlier, tube-type sources have functioned well for IITRI and KAI. Many vendors offer a wide variety of units rated up to 200 kW or more. All-semiconductor sources are available in smaller sizes, and larger units will be available in a few years. Selection is complicated by factors other than total power output:

- Two hundred kilowatts can be delivered by a single large sources, eight 25-kW units, or other combinations of sources. Systems maybe connected by fiber optic lines and controlled from a central computer/logger. A 200-kW source can be used to deliver 10 or 20 kW for small applications, but hardware and amortization costs might be prohibitive. Relative costs are explored further in Section 8.
- Semiconductor sources are much more efficient, but vacuum tube amplifiers are more tolerant of voltage and current excursions. The greatest AC to RF conversion efficiency is available in state-of-the-art sources with semiconductor amplifiers operating a temperatures near room temperature. Cooling requirements are stringent, however, and cooling costs and higher purchase price may offset the savings of RF conversion efficiency. As noted in Section 5.7.1 and Section 8, energy costs for RFH are low compared to labor and equipment costs.
- The type of service anticipated could influence source selection, and housing equipment destined for extremes of climate or vibration could add substantially to hardware costs.

5.7.3 Applicator Selection

The IITRI and KAI systems differ most below grade, at the applicator system. With appropriate licenses, an RF system could be built to use either the IITRI capacitor and the KAI antenna applicators. The IITRI systems heats fairly regular blocks of soil. The shape of the KAI treatment zone is less regular, but fewer borings are required. Additionally, the KAI antenna may be moved to assure full vertical coverage or additional heating of clay lenses. A horizontal application would require the use of an antenna.

5.7.4 Ancillary Equipment

Labor has been the major cost in the development of RFH. Monitoring, logging, and communications equipment costs little compared to maintaining a large, skilled crew on site. Equipment should be selected to perform the following functions:

- A central system must collect and record data. This data should include operational data (temperatures, power usage, etc.) and the data need to document safe operations, such as periodic, aboveground electric field measurements.
- The data collection and logging functions must include controls to turn off the RF source if operating parameters exceed preset limits.
- The computer must also be able to alert off-site personnel of alarm conditions and report operational measurements. Recent advances have reduced the cost of most of the communications equipment.

Additional equipment is required for routine monitoring of voltages, currents, voltage standing wave ratio, and frequency. Some items are costly, but have long useful lives. When amortized, they do not add greatly to a system's costs.

5.8 LESSONS LEARNED AT SITE S-1

IITRI and KAI demonstrated the ability to effectively heat soils containing dense clays. Neither demonstration produced optimal heating due to minor correctable problems Other lessons are discussed. below

5.8.1 Preplanning Phase

- HNUS asked for bids for a 120-kW RF source for use in Phase 2 of the project. The range of costs received was so large as to be meaningless. The large range resulted from vendor's misunderstanding of requirements and indicated that the specifications were too broad. Prior to formally requesting bids, a potential user should discuss his needs at length, perhaps by teleconference, with all potential bidders. Requests for bids must be sufficiently specific to ensure a fair comparison.

- All parties underestimated the effort required to obtain permission to operate an RF source at a military facility. The concerns of the base communications personnel were understandable; their mission is to maintain secure communications and flight operations. Two factors complicated the application process. First, a typographical error indicated a requested frequency in kilocycles instead of megacycles, leading in turn to an inquiry to the FCC. The error was corrected promptly, but the resulting confusion caused a few day's delay. Second, some personnel were somewhat confused about an antenna that appeared to be upside-down (underground). Problems like these will stop when the technology becomes more well-known. Even on military reservations, clearance should consist of documenting ISM frequency use and assuring that proper aboveground monitoring will be conducted.

5.8.2 The IITRI Demonstration

- One of the project goals was to extend the heating as deep as possible into a clayey soil. HNUS installed four dewatering wells and pumps to depress the water table during the demonstration. Dewatering was generally successful, but shorting at the bottoms of the electrodes may have occurred late in the IITRI demonstration. Dewatering may be useful to prevent shorting at sites where groundwater levels vary widely, but the pumping is probably not a useful way to extend the depth of heating.
- Recent developments in soil and groundwater sampling include tubes that can be pushed into the ground without drilling. Some require a drill rig to advance the tubes, while others may be pushed with a backhoe. By potentially eliminating the need for drilling, they offer substantial cost savings for electrode installation. These devices are unlikely to work well at Site S-1, but could substantially reduce installation costs in sandy or loamy soils.
- The IITRI demonstration showed that an old source in a semi-trailer shelter can provide very useful soil heating. Such units are inexpensive, rugged, and able to withstand large voltage and impedance changes. Users who anticipate purchasing several sources should buy new, interchangeable components, but others might be wise to investigate surplus sales for obsolete commercial or military gear.

- The corrugated shield over the heated soil served two purposes, preventing stray RF emissions and capturing vapors that might escape to the surface. Vapor monitoring showed that the SVE system captured soil vapors effectively, so the additional capture volume was unnecessary. However, the corrugated metal provided an effective and reusable RF shield.
- Extracting vapors through the exciter electrodes is desirable because vapors are unlikely to condense in the hot soil near the center of the array. Further materials research may lead to an electrically insulating material suitable for use with hot vapors.

5.8.3 The KAI Demonstration

- KAI elected to use small aluminum towers to support their antennas and move them vertically. If rigid coaxial line is used, the height of these towers must be approximately the same as the depth of the antenna wells. The towers can present a hazard in high winds, and operations might be curtailed in stormy weather. The antenna depth can be adjusted by adding or removing sections of coaxial line. However, changing rigid sections requires reestablishing the nitrogen purge and retuning the RF source. Flexible coaxial line is more expensive, but would allow the antenna to be supported by a shorter, simpler structure while maintaining a constant feed line length.
- KAI showed that off-site monitoring of a relatively complex operation is both feasible and practical. KAI had no difficulty maintaining telephone communication with the system from a motel room, about five miles from the site. A pager received alarm messages and routine status reports. In commercial use, a remote operator could interrogate systems at several sites daily, perform any required data reduction, and prepare a status report for each.
- The two composite casings that housed the KAI antennas were costly. Less expensive materials that tolerate higher temperatures were available by special order, but the lead time between placing an order and delivery to the site was unacceptable for the project. Preparations for a large project should include a reevaluation of available products and allowance in the schedule for any extended deliveries.

5.8.4 Both Demonstrations

- IITRI and KAI demonstrated RFH while meeting health, safety, and communications requirements for surface RF emissions. On-site radios, cellular telephones, and television sets operated without interference, and no stray emissions were detected on incoming power lines.
- IITRI and KAI attempted to monitor subsurface temperatures with fiber optics probes. The probes could be especially useful to monitor temperatures near the KAI antenna casings or other objects subject to very localized and potentially damaging high temperatures. These devices have provided excellent results in many applications, including medical and nuclear laboratories, but the results at Site S-1 were disappointing. Both vendors reported only limited success with the probes. The devices offer so much utility that improvements will probably follow quickly.
- Both vendors used strings of thermocouples successfully. The devices are inexpensive and easy to use, but not very accurate near ambient temperatures. The accuracy is probably no better than ± 10%, but that range should be adequate for most measurements during RFH.
- IITRI and KAI turned their RF sources off periodically for measurements or repairs, and both vendors experienced shutdowns due to measured parameters that activated alarms. Power failures during storms occasionally shut down all site operations except the SVE system. These outages, which rarely lasted longer than a few hours, had little negative impact on soil temperature patterns (see Appendices A and B). On the contrary, shutdowns may tend to smooth out temperature variations caused by local "hot spots". If so, periodic maintenance operations could be scheduled to improve the uniformity of heat patterns.
- Many functions in an RF soil heating project, including plan development, site preparation, sampling, air monitoring, and reporting, are very similar to those required for other remedial technologies involving equipment of similar size. The RF source operators need special skills and experience, but other site workers need only routine hazardous waste site training.

6.0 SOIL VAPOR EXTRACTION

This section includes background information on SVE systems, a brief description of the systems used during previous RFH tests, and detailed descriptions and evaluations of the systems used during the demonstrations at Site S-1, Kelly AFB. The background sections provide basic information necessary for a general understanding of the processes that occurred during the demonstrations. The design and operation of the systems used at Site S-1 by IITRI and KAI are discussed in subsections for each heating method. The lessons learned from the evaluation of data and field experience conclude this section.

Although often SVE has become widely accepted for the removal of VOCs from high permeability soils, SVE is not an efficient process for remediating lower permeability soils or less volatile compounds. Using RFH to enhance SVE should increase the vapor pressures of the contaminants and improve the soil permeability, making SVE a more attractive treatment option. Section 6.1 includes a discussion of the theories behind SVE with an emphasis on how RFH affects the design and operation of an SVE system. The lessons learned by operating the systems described in Section 6.4.

6.1 BACKGROUND

The following subsections discuss the basic concepts of SVE and the design and operation of an SVE system. The subsection on the basic concepts includes a description of contaminant phases and transport. Although these concepts may sound complex, SVE is a rather simple solution for in situ soil remediation.

6.1.1 Basic Concepts

SVE removes contaminants in the vapor phase from the vadose zone by inducing a vacuum at an extraction well and pulling air through the contaminated zone to the extraction well. However, contaminants exist not only as a mixture of vapors in the vadose zone but also as thin films or globules of solution (aqueous or organic) and nonaqueous phase liquids (NAPLs), as solids, and sorbed to the soil particles. Under static conditions contaminant concentrations in each phase are at equilibrium. The equilibrium concentrations are determined by the chemical and physical properties of the contaminant.

The vaporization of NAPLs, free-phase or in solution, is governed by Raoult's law and Henry's law respectively. Raoult's and Henry's laws describe the relationship between the partial pressure of a contaminant and the mole fraction of the contaminant as shown in equations (6-1) and (6-2) respectively (Felder and Rousseau, 1986).

Raoult's Law: $$p_A = y_A P = x_A p^*_A(T) \tag{6-1}$$

Henry's Law: $$p_A = y_A P = x_A H_A(T) \tag{6-2}$$

where:

p^*_A = partial pressure of compound A in the gas phase

y_A = mole fraction of A in the gas phase

P = total pressure exerted on the liquid

x_A = mole fraction of A in the liquid phase

$p^*_A(T)$ = vapor pressure of the pure liquid at temperature T

$H_A(T)$ = Henry's law constant for A in a specific solvent at temperature T

Since Raoult's law is only applicable for almost pure substances, it can be used to describe the relationship between the contaminant in the gas phase and the NAPL phase. Henry's law is applicable for substances in solution such as a contaminant dissolved in the moisture in the soil. These laws state that the partial pressure of a substance is directly proportional to the concentration of the substance in the vapor phase. However, in cases where more than one substance is present the partial pressure of the mixture equals the sum of the partial pressure for each substance. Since the vapor pressure of a pure substance and the Henry's law constant for contaminants in solution increase with temperature, more of the contaminant will be in the vapor phase as the temperature increases. Heating the contaminated volume increases the rate at which the contaminant volatilizes into a mixture of vapors from the liquid phase.

If the contaminant is in the solid phase, vapor pressure will control the amount that will vaporize, or sublime. Therefore, an equation similar to Raoult's Law would describe the sublimation. Again, a temperature increase causes the vapor pressure to increase and more of the contaminant to vaporize into the gas phase.

The rate at which a contaminant adsorbs to a soil particle is released is described by a desorption isotherm. A desorption isotherm is a graphical description based on column tests in a laboratory. Since these column tests are performed under controlled conditions, the results may differ from the reactions that take place in the field.

Once the contaminant is in the vapor phase, induced air flow moves the contaminated vapors to an extraction well. A blower or ejector system induces a vacuum at the extraction well(s). The pressure gradient in the soil leads to a flow of air from the surrounding soils to the extraction well(s). The flow rate through the soil to the extraction well(s) can be estimated, assuming the equations for steady-state, compressible, radial flow are applicable, and using the following equation (Johnson et al, 1990):

$$Q = H\pi\left(\frac{k}{m}\right)P_w\,\frac{[1-(P_{atm}/P_w)^2]}{\ln(R_w/R_I)} \tag{6-3}$$

where:

Q = vapor flow rate [SCFM]
H = well screen length [centimeter]
k = permeability to air flow [centimeter^2] or [darcy]
μ = viscosity of air = 1.8×10^{-4} g/centimeter·s or 0.018 cp
P_w = absolute pressure at the extraction well [g/centimeter·s^2] or [atm]
P_{atm} = absolute ambient pressure ≈ 1.01×10^6 g/centimeter·s^2 or 1 atm
R_w = radius of the vapor extraction well [centimeter]
R_I = radius of influence [centimeter]

According to this equation, changes in the screen length, the permeability, and the vacuum induced at the well will result in potentially significant changes in the flow rate through the soil. After the SVE and treatment systems are operating, the soil permeability will increase due to the evaporation of the soil moisture and the removal of condensed contaminants. The permeability changes gradually during the operation of typical SVE systems. However, the increased permeability should occur more rapidly with RFH/SVE.

Unlike the screen length, permeability, and induced vacuum, the radius of influence has little significance in this equation. The radius of influence can vary several orders of magnitude and not change the flow rate significantly. Therefore, it is important to remember that this equation only provides an estimate of the flow rate through the soil. This is particularly true when the soil is as heterogeneous as the soils at Site S-1.

Since the air will flow through the paths of least resistance to the extraction wells, heterogeneities in the soil lead to preferred pathways. Some areas will be remediated by advective transport of the contaminants. Diffusion transports contaminants from areas of lower flow to areas with higher flow rates. Since transport via diffusion is much slower than advective transport, preferred pathways should be avoided by installing wells in lower permeability soils, utilizing vapor barriers, and varying the extraction pattern during operations. Screening some of the wells over the bottom half of the volume and others over the top half of the volume may help minimize the development preferential pathways. When using RFH, preferential pathways are expected to develop in the heated area.

The transfer of contaminants from soil pores to the vapor stream may be limited by phenomena other than diffusion (Reinhart et al, 1994). The rate at which contaminants trapped in soil pores diffuses into the vapor stream limits the concentration of the contaminant in the vapor stream. If the flow rate is too high, the contaminant may not be detected in the vapor stream even though the concentration in the soil may be above the treatment goals. This phenomenon has occurred numerous times at sites using typical SVE systems. The contaminant concentration in the vapor stream indicates that the soil is clean, but soil sampling reveals that the soil concentrations are still above action limits. The flow rate should be decreased when vapor stream concentrations have decreased. The diffusion rate will be higher at higher soil temperatures than at ambient temperatures.

6.1.2 Design and Operation

Extraction, Monitoring, Passive, and Injection Wells

The most basic SVE systems utilize extraction wells to remove the contaminants and monitoring wells to observe the subsurface pressures. Some systems utilize passive or injection wells to increase the flow of clean air through the soil or to create a barrier to flow entering the treatment zone. The difference between passive and injection wells is that passive wells are open to the atmosphere and clean air is injected through the injection wells into the treatment zone. The path of least resistance to air flow from the surface would be the passive or injection well. Thus the passive and injection wells form the edge of the treatment zone. The change in the pressure gradient creates a barrier to the flow of air through the soil, across the line of passive or injection wells.

The SVE system can be designed so that any well can serve as extraction, passive, or injection wells. This allows the system to be operated at a variety of configurations but requires that the wells be of the same construction and properly manifolded. A flexible SVE system allows the extraction configurations to be altered to prevent preferential pathways and adjusted to current site conditions. However, the wells must be constructed of the same size and type of casings. The casing material must be compatible with the contaminants and the soil. When using RFH/SVE the casing materials must also withstand the design temperatures.

Since the induced vacuum will locally raise the water table, the bottom of the screens must be above the water table. In order to prevent pulling groundwater through the extraction wells, they should be installed such that the maximum vacuum at the well (in inches of water) is the minimum distance between the bottom of the screen and the water table.

Although most SVE systems use vertical wells, horizontal wells and trenches are also used. Horizontal wells allow extraction systems to be installed in locations where objects such as buildings prevent installation of vertical wells. When using a RFH/SVE system, horizontal wells at the surface provide a way to quickly extract vapors that rise to the surface and collect under the vapor barrier. The pressure at these wells should be monitored. As long as the horizontal wells are under the influence of the vertical extraction wells, the vapors should not be collecting at the surface.

Number and Location of Extraction Wells

Although the radius of influence has little impact on the flow rate, the radius of influence and the geometry of the contaminated zone typically determine the number and location of the extraction wells. The minimum number of wells required equals the minimum number of circles with radii equal to the radius of influence of the extraction well that will cover the contaminated volume. The extraction wells would be located at the centers of the circles. Although a rule-of-thumb radius of influence [30 to 100 feet (Johnson and Ettinger, 1994)] will provide a rough estimate of the number of wells required, a pilot scale field test provides a more accurate estimate of the radius of influence and a better estimate of the number of wells required to remediate the site.

The site-specific radius of influence is determined by performing a field test in which the vacuum induced at a single extraction well and the subsurface pressure responses at monitoring wells are recorded. Existing monitoring wells can be used for this test if they are screened above the water table and are not located too far apart. Usually the test is performed over an expected range of operating vacuums. During the test the following data is collected:

- flow rate from the extraction well,
- vacuum at the extraction well,

- subsurface pressures (vacuums),
- atmospheric pressure, and
- vapor stream temperature.

The screened length of the extraction well and the distances from the extraction well to the pressure monitoring wells are known. The subsurface pressures are plotted versus the distance from the monitoring well to the extraction well. The point where a line fit to these points intersects the axis representing the distance from the extraction well indicates the radius of influence. For practical purposes the radius of influence is assumed to be between 0.1 and 1 inch of water or 1 percent of the induced vacuum.

Current efforts attempt to base the number of wells on the contaminant concentration and desired remediation time (Johnson and Ettinger, 1994). Johnson and Ettinger use the following equation to determine the number of wells:

$$N_{wells} = \frac{\alpha M_{cont}}{Q_{well} T_R} \tag{6-4}$$

where:

N_{wells} = minimum number of wells required to remediate the site
α = min. volume of air per unit mass of contaminant required for remediation (m^3/kg)
M_{cont} = mass of contaminant present (kg)
Q_{well} = estimated flow rate to a single well (m^3/s)
TR = desired time for remediation (s)

However, if Reinhart's theory that diffusion controls the desorption rate is correct, estimating the number of wells required to remediate a site is very difficult because the time of remediation is controlled by the diffusion rate. The result of equation (6-4) should be compared to the number of wells determined using the geometry-based method. The method that results in the greater number of wells should be used.

When integrating an RFH and SVE system, the location and number of wells may be based on the requirements of the RFH technology. IITRI's system limits the extraction wells to the ground electrode rows that bound the heated area. Thus with IITRI's system the contaminants must be pulled from the middle of the heated zone to the ground electrodes. Another option with KAI's system is to install the extraction wells near the antenna well and pull the contaminants to the middle of the heated zone. In both cases the geometry of the heating system or the heated zone influence the location of the extraction wells.

Extraction Force

Typically some type of blower will be used to induce the vacuum at the extraction wells. The blower must be sized to provide the desired vacuum and flow rate at that vacuum. In order to meet health and safety standards, the blower must be explosion proof if there is any risk of an explosive mixture. The blower materials must also be compatible with the vapor stream, which may be corrosive. If the vapors condense into droplets, the droplets can cause excessive blower wear.

Although most designers use blowers to induce the vacuum for a SVE system, other options are available. An ejector assembly was used to induce a vacuum at Site S-1. An ejector is a specially designed venturi with a tee in the narrow section. Forcing air through the narrow section of a venturi induces a negative pressure at one end of the venturi. The Site S-1 system is discussed in Section 6.1.3 and Appendix D.

Manifold System

The headers from the extraction wells should be manifolded in such a way that each well can be controlled individually. This does not mean that the vacuum at each well must be controlled separately but that any well can be used as an extraction, passive, or injection well at any time. The use of flexible hose to connect the header manifolds to the extraction force increases the flexibility of the system. However, the materials used in the piping system must be compatible with the contaminants in the vapor stream. Materials used for any heat enhanced SVE system must be able to withstand the maximum anticipated vapor temperatures. When using RFH the pipes from the wells to the manifold must also be nonconductive.

Instrumentation and Monitoring

The following parameters should be monitored with any SVE system:

- vapor stream flow rate from the wells
- vapor stream flow rate to the treatment system
- pressure (vacuum) at each extraction well

- pressure (vacuum) at each monitoring (passive) well
- pressure at each injection well
- inlet and outlet pressure at blower or ejector

The flow meters and pressure gauges must be compatible with the vapor stream and the expected conditions. The expected flow rates and pressures should be in the middle of the range of the meter or gauge.

When using RFH to enhance vapor extraction, temperature gauges should be used to monitor the vapor stream temperature from each extraction well, the inlet to the blower, and the outlet from the blower. The moisture content and temperature of the vapor stream will change as the soil temperature increases. Since most flow meters are designed to be accurate over a narrow range of temperature, the change in temperature makes it difficult to find a flow meter for this application. The density of the vapor stream changes in moisture content and temperature change. Thus flow meters that operate based on the mass flow of air will not be accurate over the full range of temperatures and moisture contents expected during operation of RFH/SVE.

Vapor Barrier

Depending on the site conditions, the SVE design may include a vapor barrier. The vapor barrier is a flexible, impermeable barrier that serves the following functions:

- prevents fugitive emissions from the contaminated zone,
- prevents air from short circuiting from the surface to the wells,
- prevents water from infiltrating from the surface through the contaminated zone, and
- assists in maintaining the vacuum within the contaminated zone.

By reducing the vertical flow of air through the contaminated volume, air will be forced to flow horizontally through the through the contaminated volume.

The impermeable material may be a paved surface or any plastic with appropriate properties. Plastic vapor barriers should be designed to be compatible with the surface contaminants and to be reused. The plastic must be stabilized so that ultraviolet light will not degrade the material. If the ground surface is rough, a layer of topsoil placed on the ground surface beneath the vapor barrier will prevent tears in the plastic. In some cases the soil cuttings generated on site may be used instead of buying topsoil. Any vapor barrier should have as few seams as possible.

In the case of RFH/SVE the vapor barrier also prevents fugitive emissions from the surface of the heated zone. The vapor barrier material must be capable of resisting maximum expected surface temperatures. A layer of insulation by be placed between two pieces of plastic to reduce heat loss at the surface.

6.2 HISTORY WITH RF HEATING

IITRI and KAI had performed earlier tests which utilized different approaches to SVE. The results of these earlier tests were considered when designing the SVE systems for the demonstrations at Site S-1.

6.2.1 IITRI

The treatment zone for the IITRI test performed at Volk Field Air National Guard Base (Dev et al, February, 1989) was in shallow, sandy soils. IITRI collected vapors rising to the surface. This approach was not applicable for removing contaminants from the depths of the treatment zone at Site S-1. Therefore, an active vapor extraction system with extraction wells screen as deep as 24 feet below the surface was utilized at Site S-1.

During the IITRI test performed at Rocky Mountain Arsenal, IITRI measured subsurface pressures and attempted to incorporate the exciter electrodes into the vapor extraction system (Roy F. Weston, 1992). IITRI included a section of glass pipe in the line to the treatment system and attempted to prevent condensation in the pipe by circulating warm air around the glass pipe. Condensate formed and the glass tubes broke (Roy F. Weston, 1992). Therefore, extracting from the exciter electrodes was not attempted the Site S-1 test.

6.2.2 KAI

During a test at DOE's Savannah River Site, KAI used a single horizontal well to house the antenna and serve as an extraction well (Jarosch et al, 1994). The final report recommended using separate antenna and extraction wells. The design for Site S-1 utilized separate antenna and extraction wells in a vertical well system.

6.3 SVE SYSTEMS USED AT SITE S-1

The SVE systems installed for the IITRI and KAI demonstrations utilized the same ejectors to provide the extraction force. However the well systems were installed in different patterns and operated differently for the IITRI and KAI demonstrations. IITRI designed the "effluent containment and collection" system for the IITRI demonstration. HNUS designed the SVE system for the KAI test to create a treatment zone similar to IITRI's, but incorporated the lessons learned during the IITRI demonstration design and operation to isolate the treatment volume. HNUS tried several extraction patterns and monitored subsurface pressures during the KAI demonstration to evaluate the SVE system.

The ejector system was designed by Brown and Root Braun and is discussed in Appendix D. Two ejectors were plumbed in parallel so one could be in service and the other was cleaned or served as a spare. Strainers were installed upstream of the ejectors to prevent clogging of the ejectors. A diesel compressor supplied the compressed air for the system. Each ejector could provide a 30 inches H_2O vacuum at 60 SCFM. Although Brown and Root Braun selected the ejectors based on IITRI's request for 10 inches H_2O, the two ejectors were capable of pulling vacuums up to 40 inches H_2O during the early phases of the KAI demonstration. The combined flow from the treatment zone and the air compressor was mixed with propane and burned in a flare.

HNUS monitored the temperature and pressure gauges and flow meters listed in Table 6-1 during the IITRI and KAI demonstrations.

TABLE 6-1

INSTRUMENTATION AND MONITORING DEVICES

Parameter to be Measured	Device	Range
Pressure on inlet line to ejectors (from the air compressor)	McDaniels Control - Tube and Socket Pressure Gauge	0-200 psi
Flow Rate through the ejector inlet line (from the air compressor)	ERDCO (Model 3211-06 TI) Flow Meter	0-200 SCFM
Vacuum in the suction line to the ejectors	Dwyer Magnehelic® Pressure Gauge (Model 2050C)	0-50 in. H2O
Pressure in the discharge line from the ejectors	Dwyer Magnehelic® Pressure Gauge (Model 2050C)	0-50 in. H2O
Temperature of vapor in suction line	Reotemp Temperature Probe	50-400 °F
Pressure in mixed vapor line (at the flare)	Dwyer Magnehelic® Pressure Gauge (Model 2205C)	0-5 psi
Flow Rate of mixed vapor to the flare	ERDCO (Model 3211-06 TI) Flow Meter	0-400 SCFM
Temperature of mixed vapor at the flare	Reotemp Temperature Probe	50-400 °F

The flow meters were selected as a cost effective way to provide relative flow rates. An extensive search by Brown and Root Braun did not find flow meters that would provide consistently accurate data for the wide range of conditions at Site S-1. Most flow meters are based on the mass flow of the vapor stream. Since the mass flow is based on the density of the vapor stream, which is a function of temperature and moisture content, measuring the flow rate is difficult with flow meters. Humidity sensors for the wide range of expected conditions at Site S-1 were not available. The flow rate could be calculated based on the pressure difference across an orifice plate. However, this calculation also requires a vapor stream density measurement.

In addition to the flow meters not reading accurately, the flow rates below 40 SCFM were not easy to read because the flow meters had logarithmic scales. The flow meters require periodic cleaning to remove corroded material from the needle mechanism.

6.3.1 The IITRI Demonstration

Design

IITRI designed their SVE system, which they called an "effluent containment and collection system". Their system was designed based on the assumption that the vapor will rise to the surface or be pushed out of the treatment volume. They also incorporated the ground electrode array into the design. IITRI's SVE system included two horizontal extraction wells (one pipe on each side of the treatment volume embedded in pea gravel at the surface) and 12 screened ground electrodes (all the ground electrodes except the four end ground electrodes). IITRI's SVE system layout is shown in Figures 8, 9, 10, 11, 12, and 13 of IITRI's Draft Final Report included as Appendix A.1 of this report.

Installation

The ground electrodes were installed as described in Appendix C. Each electrode was screened by drilling holes in the 2-inch diameter aluminum pipe. Holes were drilled the full 29-foot length of the ground electrodes. IITRI required that the ground electrode boreholes be backfilled with a mixture of sand and clay. Some of the soil cuttings from pretest sampling and electrode installation were spread over the treatment site to be treated. These cuttings formed a slight crown on the site so water would run off. The horizontal wells were placed on the ground surface and covered with pea gravel.

IITRI installed a three-layer vapor barrier over the treatment zone. The bottom layer was fiberglass-reinforced silicon rubber. A middle layer of insulation reduced the heat lost to the atmosphere. The final layer was a nylon-reinforced plastic. This barrier extended 10 feet beyond the treatment zone. The edges of the barrier were buried in a shallow trench that was backfilled with bentonite.

Operation

The dewatering system described in Appendix A.8 was operated prior to and during the operation of the RFH and SVE systems. Since the bottom of the ground electrodes was below the water table, ground water would have been removed if the SVE system had been started prior to dewatering.

HNUS tested the ejectors and extraction system and collected vapor stream samples on 24 March 1993. Site personnel experimented with the ejectors to observe the vacuums could be achieved during final RFH system checks. When IITRI started heating on 3 April 1993, the vacuum at the ejectors was set at approximately 12 inches H_2O. The average vacuum at the ejectors during the test was approximately 8 inches H_2O. The vapor extraction system was off for 4 days during cool-down. The system was restarted at a vacuum of 4 inches H_2O. Both the horizontal extraction wells and the ground electrodes were used throughout the test.

During the IITRI demonstration, a tracer test was performed to determine whether the contaminants were migrating outside the treatment zone. Halon 2402 was injected in a well nine feet from the western ground electrode array at a depth of seven feet. After the tracer was not detected at significant concentrations in the vapor stream after four hours, a second, higher dose of the tracer was injected. The tracer was detected in the vapor stream 104 minutes after the second injection. A detailed discussion of the tracer test is included in Section VIII.C in IITRI's Draft Final Report included as Appendix A.1.

6.3.2 The KAI Demonstration

Design

HNUS designed the SVE system for the KAI demonstration. This design was based on Equation (6-3), experience with typical SVE systems, and lessons learned during IITRI's demonstration. The ejectors used during IITRI's demonstration provided the extractive force. The design included eight vertical vapor extraction wells, two horizontal extraction wells, eight transducer wells (subsurface pressure monitoring wells), manifolds, and a vapor barrier. Drawings showing the layout and well construction details are included in Appendix B.3.

The extraction wells were designed so the wells could be used as extraction, passive, or injection wells. Three extraction wells were located on each side of the expected heated volume to allow vapors to be extracted from either or both sides or to pull vapors across the heated volume by using the wells on one side as extraction well and the wells on the other side as passive or injection wells. Since the middle of the volume would be heated first, two extraction wells were located in the middle of the heated zone to remove heated vapor during the early stages of the demonstration. HNUS decided to use 2-inch diameter extraction wells based on flow rate calculations. These flow rate calculations were made using a spreadsheet based on Equation (6-3). The spreadsheet shows the expected flow rate for a range of well diameters, permeabilities, and vacuums. An example of this spreadsheet is included in Appendix B.4. The horizontal extraction wells were included to provide a way to remove vapors near the surface. If air monitoring indicated increased concentrations of contaminated vapors at the surface, the horizontal wells could be used to remove the contaminated vapors. The transducer wells were installed to monitor pressure during vapor extraction testing and operations to estimate the radius of influence.

Installation

Extraction, transducer, field measurement, antenna, and horizontal wells were installed as shown in the drawings included in Appendix B.3. The extraction, transducer, and horizontal wells make up the SVE system. The installation of these wells is discussed below.

HNUS constructed the transducer wells using 1-inch diameter PVC pipe and drilled to create a screened section. Transducer wells 1 and 7 were installed in the same boreholes as transducer wells 2 and 8, respectively. Transducer wells 1 and 7 were screened from approximately 21 to 25 feet below the ground surface in a sand pack. The borehole was then filled with a 6-foot deep bentonite plug. Transducer wells 2 and 8 were screened from approximately 11 to 15 feet below the ground surface in a sand back. The remaining 8 feet of annulus was backfilled with bentonite. Transducer wells 3 through 6 were screened from approximately 10 to 14 feet below the ground surface in a sand pack. The remaining 11 feet were backfilled with bentonite.

HNUS constructed the 8 vertical extraction wells using 2-inch diameter fiberglass with holes drilled in the pattern shown in the well detail drawing included in Appendix B.3. All the extraction wells except wells 2 and 7 were screened from approximately 11 to 20 feet below the ground surface.

Extraction wells 2 and 7 were screened from approximately 3 to 12 feet below the ground surface. The extraction wells were backfilled with sand and plugged at the top with 3 feet of bentonite.

The horizontal extraction wells were constructed from two 4-foot long sections of 2-inch diameter fiberglass screened by drilling holes in the pipe. These sections of screened fiberglass were placed in shallow trenches (less than 2-feet deep) on each side of the treatment zone.

As shown in Drawing Number 3688G012, included in Appendix B.3, three manifolds connected the following groups of wells:

- Wells E1, E2, and E3
- Wells E4 and E5
- Wells E6, E7, and E8

These manifolds and the line from the horizontal wells were 2-inch fiberglass pipe. The line from the horizontal wells was also run along the eastern edge of the vapor barrier. These manifolds were connected to the header pipe using 2-inch hoses with quick-connect couplings. The hoses, couplings, and ball valves at the line to each extraction well allowed operation in several extraction configurations.

HNUS used plain polyethylene sheet as a vapor barrier during the February field test of the SVE system. This vapor barrier was replaced with a nylon-reinforced polyethylene sheet after the antenna sleeves were installed. Any tears during installation and places where the transducer, field measurement, and antennae wells extended through the vapor barrier were sealed with nylon-reinforced polyethylene tape.

SVE Testing

HNUS performed on SVE test, as described in the "Vapor Extraction Test Plan" included in Appendix B.3, during February 1994. During this test, the SVE system was operated at vacuums of 15, 20, and 25 inches H_2O at the ejectors. This test indicated that a vacuum higher than 20 inches H_2O (less that -20 inches H_2O pressure) would be necessary to affect the treatment area during the early stages of the KAI demonstration.

During the February SVE test, EPA SITE used transducers to measure the subsurface pressures. the extraction well configurations used during this test are presented in Table 6-2. The data reported by EPA SITE is included in Appendix B.3 and approaches the sensitivity limitations of the equipment. Therefore, this data is inconclusive and indicates that the tests should have been operated at a vacuum of approximately 40 inches H2O at the ejectors. The tests were operated at a 20 inches H2O at the ejectors so that the data collected by HNUS using Magnehelic gauges could be compared to the data from these test.

TABLE 6-2

EXTRACTION WELL CONFIGURATIONS FOR THE TRANSDUCER TESTS

HNUS Test No.	Vacuum at the Ejectors (inches H_2O)	Extraction Wells in Use
1	20	E4, E5
2	20	E1, E2, E3
3	20	E3
4	20	E2
5	20	E1

HNUS performed additional SVE tests during March and April 1994. These tests indicated that a vacuum at the ejectors of 40 inches H_2O would influence the treatment zone during the early stages of the KAI demonstration.

Operation

During the KAI demonstration, the SVE system was operated not to achieve a specific removal rate but to observe a variety of extraction patterns. HNUS hoped to learn which extraction configurations effectively covered the treatment zone by monitoring the subsurface pressure in the transducer wells and the vacuums in the extraction well lines. For inactive extraction wells the vacuum in the line represented subsurface pressure.

In order to learn about different configurations and to try to control the flow of contaminants from outside the treatment zone, HNUS operated the SVE system in the configurations and at the vacuums listed in Table 6-3.

TABLE 6-3

SUMMARY OF SVE OPERATING CONDITIONS

Operating Condition	Starting Date	Ending Date	Extraction Wells	Passive Wells	Vacuum at Ejectors (in. water)
1	4/21/94	5/9/94	E2, E4, E5	NA	40
2	5/9/94	5/12/94	E2, E3, E4, E5	NA	40
3	5/12/94	5/13/94	E2, E3, E4, E5	E8	40
4	5/13/94	5/16/94	E2, E3	E8	40
5	5/16/94	5/21/94	E2, E3, E5	E8	40
6	5/21/94	5/22/94	E5	E8	25
7	5/22/94	5/23/94	E1, E2, E3, E4, E5	E6, E7, E8	25
8	5/23/94	6/8/94	E4, E5	E1, E2, E3, E6, E7, E8	20
9	6/8/94	6/14/94	E4, E5	E1, E2, E3, E6, E7, E8	15
10	6/14/94	6/24/94	E1, E2, E3	E6, E7, E8	15

Generally, extraction took place from the middle of the heated zone. Wells E1, E2, and E3 were used to create a flow across the treatment zone from wells E6, E7, and E8.

HNUS tried to operate the SVE system so contamination would not be drawn into the treatment zone. Therefore, the vacuum was reduced when vacuums of 0.5 inches H_2O were measured in the outer transducer wells. If measurable positive pressures had been detected in the horizontal wells or contaminant concentrations around the vapor barrier had increased, the horizontal extraction wells would have been put on line. The subsurface pressures, the compressed air, flow rate for the inlet to the ejectors, the mixed vapor flow, the pressure of the suction and discharge lines, and the temperature of the vapor and mixed vapor stream were monitored twice a day. The collection and analysis of vapor stream samples are discussed in Section 7.

The radius of influence was estimated at different times during the demonstration using subsurface pressure contour maps. These maps were based on the subsurface pressure readings. The change in permeability was estimated using these radii of influence, the flow rates estimated by Radian Corporation, and equation 6-3. The permeability increased by approximately an order of magnitude. These calculations and the contour maps are included in Appendix B.4.

6.4 LESSONS LEARNED AT SITE S-1

During these demonstrations many lessons were learned about integrating the RFH and SVE systems. Some of the lessons learned during the IITRI demonstration were taken into account when designing and operating the KAI system. The lessons learned from these demonstrations are discussed below. Conclusions and recommendations are included in Section 9.

6.4.1 The IITRI Demonstration

The SVE system used during the IITRI demonstration was designed based on the assumption that the heated vapors would be forced toward the ground electrodes and to the surface. Therefore, IITRI's SVE system relied on the ground electrodes and the horizontal wells at the surface to remove the contaminated vapors. This system used low vacuums to remove high air flows. A better approach would be to design the SVE system using standard engineering practices while considering the limitations and requirements of the heating system. Using standard engineering practices would change IITRI's SVE system in the following ways:

- Only a few ground electrodes would be used as extraction wells.
- A higher vacuum would be used initially and decreased later.
- Subsurface pressures would be monitored inside and outside the heated volume.
- Extraction patterns would be changed periodically to reduce the impact of preferential pathways.
- The horizontal wells would only be used if contaminated vapors collected beneath the vapor barrier.

Monitoring subsurface pressures may not provide conclusive data on the migration of contaminated vapor but will allow the volume influenced by the SVE system to be estimated. Monitoring wells should be located both inside and outside the heated volume.

6.4.2 The KAI Demonstration

Measurements made during the demonstration show that the radius of influence of the extraction wells and the flow rate through the heated zone can be controlled by adjusting the vacuum. If the vacuum is decreased, the radius of influence of that well and the flow rate from that well will decrease. The flow rate will respond to changes in the vacuum more than the radius of influence.

Extracting from the middle of the heated volume appeared to be more effective than extracting from the edges of the heated volume. However, the most effective extraction location will be dependent on site-specific characteristics and the objectives of the project.

Fewer wells could have been used to influence the same heating volume. The number of subsurface pressure monitoring wells could have been drastically reduced because extraction wells that are inactive or in use as passive wells can be used to monitor the subsurface pressures.

6.4.3 Both Demonstrations

The well casings must be nonconductive material capable of withstanding the expected maximum temperature of the heated volume. This material must also be noncorrosive if the surrounding soil or the vapor stream is expected to be corrosive.

Ejectors are well suited for use in the explosive and/or corrosive environments.

Selection of instrumentation devices such as flow meters may be difficult due to the range of temperatures, moisture contents, and contaminant concentrations expected in the vapor stream. The expected vapor stream temperatures will be less than the expected soil temperatures.

Horizontal wells should only be used during the following situations:

- when the treatment zone is shallow,
- when the contaminated volume is not accessible from the surface directly above the contaminated soil, and
- when vertical extraction wells fail to prevent contaminated vapors from collect beneath the vapor barrier.

For shallow treatment volumes and cases when vertical extraction wells fail to prevent migration of contaminants to the surface, the horizontal wells should be buried in shallow trenches.

7.0 CHEMICAL AND PHYSICAL DATA

7.1 INTRODUCTION

Results of the IITRI and KAI demonstrations are evaluated from data collected before, during, and after RFH system operation. Data was collected to define pre- and post-demonstration soil (Appendix A.3 and B.5) and pre-, during, and post-demonstration vapor stream physical and chemical characteristics (Appendices A.5, A.7, B.4, and B.6), treatment volume temperatures (Appendices A.1 and B.1), and electrical use and efficiencies (Appendices A.1 and B.1).

7.2 SOIL

HNUS collected pre- and post-demonstration soil samples for both the IITRI and KAI demonstrations. EPA/SITE provided analyses for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and total recoverable petroleum hydrocarbons (TRPH) through the Radian laboratory in Austin, Texas. In addition, EPA/SITE provided moisture and sieve analyses of the soil for physical classification.

Soil samples were collected from three soil horizons (7, 12, and 17 feet deep) and analyzed to determine the type and numbers of microorganisms present.

IITRI performed a tracer test to confirm that vapors were drawn into the heated volume. A small amount of Halon® was injected into subsurface soils outside the heated soil volume and detected in the SVE system. Inward movement of the Halon® confirmed that the SVE system collected heated vapors for treatment as planned.

7.2.1 Sampling Strategy

The primary objective of a sampling strategy for the RFH demonstrations was to collect samples that would accurately and precisely characterize the chemical properties of the soil. The recommended procedure for achieving acceptable sampling accuracy and precision, recommended in Test Methods for Evaluating Solid Waste, SW-846 (US EPA, 1986), was followed.

Sampling accuracy is normally achieved by using a three-dimensional random sampling strategy. An imaginary three-dimensional grid of sampling points is established in the soil and a random number generator is used to select points to be sampled. Sampling precision is achieved by taking an appropriate number of samples from the population. The appropriate number of samples is the least number of samples required to generate a precise estimate of the true mean concentration of the chemical contaminants.

A confidence interval (CI) of 80 percent, based on a paired t-test, was selected for evaluating the soils at Site S-1. The values of a normally distributed contaminant that are outside the limits of an 80 percent CI are equally distributed between the left (lower) and right (upper) tails of the normal curve. Since only the upper portion of the curve is of interest, the CI employed to evaluate solid wastes is, for all practical purposes, a 90 percent interval.

A statistical analysis of contaminant concentrations representative of the southeast corner of the Site S-1 sump area indicated that 48 samples would ensure accurate characterization of the site contaminants. Demonstration activities included collecting 48 soil samples before (pre-) and 37 after (post) the IITRI demonstration to assure an adequate data base. Nine samples were taken from the saturated zone (below 24 feet) during the predemonstration sampling, but were not repeated during the post demonstration sampling. Soil samples from the saturated zone were used to characterize the volume under the heated zone. Samples were not obtained from two sampling intervals EB02-0812 and EB02-1214 due to poor recovery.

The final sampling strategy required slight modifications. To minimize drilling costs, most soil samples were collected from the bores required for IITRI's electrodes. That biased sampling pattern somewhat toward the centerline and sides of the heated zone. This small reduction in sampling accuracy was offset by the number of samples collected.

The sampling strategy for the KAI demonstration was similar in most respects. Fewer samples were collected near the water table because the estimated heating time was insufficient to heat the deeper soils. As in the IITRI demonstration, the sampling locations were positioned to utilize the borings needed for antenna sleeves, extraction wells, and monitoring equipment.

The soil samples were collected by placing four 6-inch long, stainless steel liners in a 2-foot long split spoon and advancing the spoon to the target depth. The second liner from the bottom was retained for analysis. When duplicate samples were required, the third liner was retained. The site geologist covered the ends of each liner with Teflon® tape and capped the liners with polyethylene caps to prevent the loss of volatile compounds. Site personnel used the following procedure to decontaminate the liners and spoons:

- thoroughly scrub with Alconox detergent,
- rinse with potable water,
- rinse with pesticide-grade methanol,
- rinse again with ASTM Type II water, and
- place on a clean surface to air dry.

The liners and spoons were then wrapped in aluminum foil for storage. EPA personnel observed decontamination, drilling, and sample preparation activities to assure proper handling.

EPA provided analytical services through the agency's SITE Program. HNUS personnel collected and labeled samples, prepared Chain-of-Custody forms, and surrendered the samples to Science Applications International Corporation (SAIC) personnel for transport to the laboratory. The Radian Corporation laboratory in Austin, Texas, performed the analyses and reported the results to SAIC. SAIC chemists reviewed the data and reported the results to HNUS. EPA methods were used for the soil analyses (Table 7.1).

TABLE 7-1

EXTRACTION AND ANALYTICAL METHODS FOR SOIL ANALYSES

PARAMETERS	EXTRACTION METHOD*	ANALYTICAL METHOD
VOC	Method	8240
SVOC	3540	8270
TRPH	Method	418.1

*"Method" indicates that the extraction method is defined as part of the analytical method. See SW-846 for details about the procedures.

EPA's VOC, SVOC, and TRPH data are presented in this section and the Appendices. Additional TPH data are presented in IITRI's final report (see Appendix A.1).

7.2.2 Results

Evaluation of analytical data from the soil samples proved to be difficult. Some contaminants occurred at very low concentrations (near detection limits). The laboratory diluted some samples to accurately measure a few compounds occurring at higher concentrations, so other compounds were reported below the resulting, higher detection limits. The HNUS laboratories have observed matrix interferences in many Kelly AFB soil analyses, and Radian may have had similar difficulties. Several compounds, including acetone, 2-butanone, methylene chloride, and some solvents and fuel fractions were reported in trip blanks. Some, but not all, of the compounds reported in trip blanks are common laboratory contaminants. Reports from SAIC stated that the data had been validated and no data qualifiers were required. At a minimum, the concentrations reported for compounds detected in trip blanks are suspect. The data are not suitable for the statistical analysis originally planned, but do offer insights into contaminant movement during soil heating.

Radian laboratory personnel are reported to have removed gravel from some samples collected during the IITRI and KAI demonstrations prior to analysis. None of the following data were reported:

- sample numbers of the screened samples (if any),
- screening criteria (gravel size, etc.),
- matrix sampled, and
- weight or volume of the removed gravel.

Reported concentrations in such cases are representative of the selected material, not the entire sample matrix.

Site operations may have caused other artifacts in the soil data. HNUS changed SVE operations several times during the KAI demonstration to observe the effects of vacuum changes and changing soil permeabilities. The changes were a necessary part of planning for a full-scale demonstration, but they resulted in less than optimum vapor removal. HNUS dewatered the lower portion of the soil heated by IITRI to heat as deeply as possible and prevent electrical shorting at the electrode tips. The dewatering may have resulted in groundwater contaminants being swept into the heated soil and the SVE system. The locations selected for the demonstrations were within a larger area of documented contamination. In both demonstrations, the SVE system drew air from the surrounding contaminated soils, because the heated zones were covered with impermeable vapor barriers. The effects of soil cooling after RFH cannot be quantified with existing data. These operational variables were anticipated and can be mitigated in a full-scale operation.

The non-homogeneous distributions of site contaminants prevent a meaningful statistical analysis of some soil data. Some of the data are characterized by fairly consistent concentration distributions interrupted by single detections at least two orders of magnitude greater than the mean. The patterns are typical of the centers of sites at which a few, small "hot spots" exist, and the concentrations do not appear in normal or log-normal distributions. Such data fail "goodness of fit" tests, and the mean concentrations must be evaluated with caution.

Broad patterns emerge in the data in spite of these and other difficulties. Arithmetic means are presented for simplicity. The discussions below focus on the following patterns:

- A few compounds, such as benzene, chlorobenzene, bis-2(ethylhexyl)phthalate, and pyrene, exhibited consistent movement through both the soil and SVE system. Both volatile and semivolatile compounds are represented.
- TRPH and TPH concentrations decreased significantly in the heated soil (similar decreases were measured by two different analytical methods during the IITRI demonstration).
- A comparison of concentrations in heated soils versus those in lower, cooler soils shows the beneficial effects of heating.

7.2.2.1 IITRI Demonstration

A report prepared by IITRI, enclosed in Appendix A.1, describes all phases of their operations, including the routine measurements recorded manually and by a data logger. Heating began on April 3, 1993, and soil temperatures near the center electrodes reached 150° C by April 19, 1993. Some soil volumes reached temperatures exceeding 900° C by May 20, 1993. The higher temperature measurements are probably inaccurate because temperatures exceeded the working limit of the thermocouples (899° C). The temperatures did exceed the melting point of the copper excitor electrodes (1083° C), as documented during the post-demonstration drilling.

Appendix A.3 contains the pre- and post-demonstration analytical results from the IITRI demonstration. Examples are discussed below in greater detail. The geometry of the heated soil volume and the extraction of heated vapors through the ground electrodes led to data aberrations in addition to those described above. Cool, contaminated vapors moved from soil and groundwater outside the heated volume to the electrodes. Overall removal was less effective in the corners and bottom of the rectangular volume.

Volatile Organic Compounds

The analytical data for volatile organics in the soil samples illustrates the problems encountered in evaluating the data. The following table shows the percent removal for chlorobenzene based on pre- and post-demonstration sample pairs from the heated volume:

TABLE 7-2

CHLOROBENZENE CONCENTRATIONS IN SOIL SAMPLES (PPB)
IITRI DEMONSTRATION

SAMPLE GROUP	INITIAL MEAN CONCENTRATION	FINAL MEAN CONCENTRATION	PERCENT REMOVAL
ALL SAMPLES	4,117	4,856	-18
0' TO 18' DEEP	162	791	-388
18' TO 24' DEEP	15,543	16,598	-7

The eight concentrations reported as detection limits indicate that the detection limits were low. Two explanations for the reported increases may be suggested, but neither can be confirmed. First, more complex compounds might have been destroyed, leaving chlorobenzene as a by-product. A second, more likely explanation is that the SVE system drew chlorobenzene into the edges of the heated volume from the surrounding soils and the contaminated groundwater beneath the site (which had concentrations of 12,000 to 25,000 ppb).

Observed acetone concentrations are more puzzling. The means of all pre- and post-demonstration samples indicate an increase of 1,061 percent, with an increase of 2,601 percent in soils above a depth of 18 feet. One sample pair indicated an increase of 7000 percent in soil that was heated to several hundred degrees Celsius (acetone boils at 56.2° C). Only six of the 27 concentrations reported as below detection limits are less than the practical quantitation limit (PQL) of 100 ppb. Four of those 27 concentrations exceed the PQL by more than an order of magnitude. Low concentrations of acetone and other common lab contaminants were detected in some trip blanks. These and similar considerations preclude any meaningful evaluation of these highly volatile compounds.

The difficulties involved in evaluating the VOC data for soil samples may be summarized as follows:

- Some sample results are reported as below elevated detection limits.
- Some VOC concentrations reported far exceed any reported during a RI conducted at Site S-1.

- Some high concentrations near the ground electrodes may be the result of vapors from surrounding soils or contaminated groundwater condensing near the electrodes during cooldown.

- High temperatures near the excitor electrodes may have destroyed some compounds, leaving increased concentrations of lighter compounds. However, it is unlikely that acetone remained in soils at temperatures that melted copper.

Such problems led investigators to perform more precise vapor sampling during the second (KAI) demonstration.

Semivolatile Organic Compounds

Removal of SVOCs is especially important in an evaluation of heating-assisted SVE. Compounds with very low vapor pressures are difficult to remove by SVE at ambient ground temperatures. The following table shows the percent removal for three SVOCs based on pre- and post-demonstration sample pairs from the heated volume:

TABLE 7-3

COMPOUND CHARACTERISTICS
IITRI DEMONSTRATION

COMPOUND	CARBON ATOMS	MOLECULAR WEIGHT	SAMPLE DEPTH (feet)	PERCENT REMOVAL*
Bis(2-ethylhexyl)phthalate	24	390.57	All Samples	37
			0-18	64
			18-22	22
Pyrene	16	202.26	All Samples	68
			0-18	87
			18-22	-52
Benzo(a)anthracene	18	228.30	All Samples	25
			0-18	65
			18-22	-281

*See Appendix A.3 for details.

Results indicate the mobilization/removal of bis(2-ethylhexyl)phthalate (a liquid at ambient ground temperatures), pyrene, and benzo(a)anthracene (solids at ambient ground temperatures). The poor removal efficiencies at depths below 18 feet suggest that vapors moved downward to cooler soils or moved up from soils in the saturated zone. In either case, additional attention is required to assure adequate SVE at those depths.

Total Recoverable Petroleum Hydrocarbons

The means of all TRPH pre- and post-demonstration sample results indicate a removal of 22 percent during the demonstration. The removal efficiency is 50 percent for samples above a depth of 18 feet and -14 percent for samples below that depth.

Seven sample pairs from the four excitor borings indicate a removal of 94 percent. Four of the seven post-demonstration results were below detection limits (<25 to 28 ppb). Seven samples is a small population that represents a small portion of the total volume, but the results are encouraging.

Total Petroleum Hydrocarbons

For consistency with past laboratory and field efforts, IITRI performed in-house TPH analyses for diesel range organics (DRO) using the California DHS method. The California method is a modification of EPA Method 8015 that employs a gas chromatograph and flame ionization detector, whereas Method 418.1 employs infrared spectroscopy. Either may be calibrated to the diesel range (C_{10}-C_{28}) of organic compounds. Some researchers have reported that Method 418.1 consistently overestimates TPH concentrations if soils contain natural fatty materials (e.g., cedar wax or pine resin). However, IITRI's results compared favorably with results reported by Radian during this demonstration. Appendix A.1 (Section VII B) contains additional details about the IITRI analyses.

An average of all samples indicated a TPH decrease of about 53 percent, while samples collected above a depth of 20 feet showed a decrease of about 63 percent. These results are consistent with the knowledge that initial TPH concentrations generally increased with depth and the deeper, more moist soils are more difficult to heat.

Moisture

IITRI reported soil moisture measurements for both pre- and post-demonstration samples (see Appendix A.1, Section VII-B). Pre-demonstration results ranged from about 9 to 26 percent moisture, with most samples in the 18 to 21 percent range. Most of the samples exhibiting low soil moisture were from 20 to 22 feet below grade. That elevation is near the water table, but a few feet above the dense, underlying Navarro clay. Boring logs indicate a greater gravel content below a depth of about 20 feet, which may explain the lower soil moisture.

Classification

Grain size analyses were performed for the pre-demonstration samples. The full report is enclosed as Appendix A.5. Results are presented as the percent of gravel, sand, and fines (silt and clay) in each sample. The analyses confirm that greater quantities of gravel lie below a depth of 18 to 20 feet. Gravel comprised less than 30 percent of most samples above that interval and greater than 60 percent of samples below that interval. A single sample from the underlying Navarro Clay was 75 percent silt and clay and included colloidal material.

Temperature

The temperature patterns observed during the soil heating and cooldown are presented in Appendix A.1. The heating progress may be summarized as follows:

- Soil heating began near the surface, at the center of the heated volume. Soil heating then proceeded outward and downward, as IITRI predicted.
- Near-surface soils in the center of the heated volume reached the target temperature of 150° C in less than two weeks. This zone eventually reached a temperature of several hundred degrees, and heating was stopped when underground arcing seemed to occur. Portions of the copper excitor electrodes melted.
- Temperatures near the ground rows of electrodes rarely exceeded 100° C. The SVE system drew cooler vapor from surrounding soil to those zones, and unusually heavy rainfall probably kept the soil moisture high.

IITRI turned the RF source off periodically for service or to allow site personnel to make measurements under the RF shield structure. Continuous monitoring indicated that the heat loss was less than expected during such periods. Often, the temperature distribution patterns improved significantly after such a break. Schedule pressures dictated almost continuous full-power operation, but these observations suggest that an intermittent mode of operation might result in more uniform heating.

Tracer Test

IITRI conducted tracer tests on May 30, 1993, to document movement of soil vapors from outside the heated soil volume toward the SVE system. A small quantity (about 5 ml) of Halon® 2402 was injected into soils about seven feet below grade at a point about nine feet from the western edge of the electrode array. Low detected concentrations led to a second test in which about 25 ml were injected. A strong detection was obtained, showing the desired movement of soil vapors toward the SVE system. No further tests were conducted because using greater quantities of Halon® raised environmental concerns. Additional details are provided in the IITRI report (Appendix A.1).

7.2.2.2 KAI Demonstration

Volatile Organic Compounds

Chlorobenzene was detected most frequently. As the Tables in Appendix B.5 show, removal rates were highly dependent on the depth and position in the heated soil volume. This pattern was not unexpected; KAI did not have sufficient time to heat the entire volume. Samples below 17 feet deep show a removal rate of -24 percent (a marked increase). This result is consistent with observations from the IITRI demonstration and indicates that the removal of heavy vapors from the lower gravely soil requires additional attention. The removal rate for all sample pairs is also -24 percent, reflecting the lack of deep heating and, again, operation of the SVE system. Removal rates for other sample groups range from -76 percent to 62 percent. As with the IITRI demonstration, data evaluation requires caution because:

- Soil contamination at the site is highly heterogeneous.
- Some detection limits are very high.

As a result, soil VOC data are of little use in an evaluation. Vapor analyses probably provide a more reliable record of contaminant movement for the KAI demonstration.

Semivolatile Organic Compounds

The analytical results for bis(2-ethylhexyl)phthalate and pyrene are also somewhat confusing, but offer insight into the effects of heating. The removal rates for these compounds, based on all samples, are 6 percent for bis(2-ethylhexyl)phthalate and 50 percent for pyrene. As tables in Appendix B.5 show, different volumes exhibit a wide range of change. The most important point, is that these compounds are difficult to impossible to mobilize with conventional SVE because they have low vapor pressures and Henry's Law constants.

Total Recoverable Petroleum Hydrocarbons

Tables in Appendix B.5 show the TRPH removal rates for several sample combinations. Rates ranged from -7 percent (all samples) to 36 percent for samples above a depth of 17 feet. The variables in the heating process were discussed above. Considering the brief heating in a small volume, TRPH removal compares favorably with results from the IITRI demonstration.

Moisture

Radian analytical reports indicate that soil moisture varied little from that observed during the IITRI demonstration. Soils above a depth of 18 to 20 feet exhibited moisture contents of about 20 percent and the moisture content of deeper soils was typically 8 to 10 percent.

Classification

Soil classification measurements were not repeated for the second demonstration. Boring logs for the IITRI and KAI demonstrations indicate that the lithologies were similar, with a substantial increase in gravel content below a depth of 18 to 20 feet. Also, the logs indicate the capillary fringe starts between 18 feet and 20 feet.

Temperature

The total energies delivered during the IITRI and KAI demonstrations are not directly comparable for two reasons. First, unexpected delays in receiving permission for KAI to operate delayed the start of full-power operations by nearly three weeks. Second, the original budget limited heating time and did not permit delivery of an equivalent amount of RF energy to the soil. As discussed in Sections 5 and 8, RFH system operation and cost have a low sensitivity to electrical power efficiency.

The temperature patterns observed during the soil heating and cooldown are presented in Appendix B.1. The heating progress may be summarized as follows:

KAI began by using an antenna (A1) in the southernmost antenna well. The goal was to begin heating at depths of about 10 to 14 feet, then move downward and periodically switch operation to the northernmost antenna (A2). Given time to switch antennas and move them vertically, the volume heated should have been approximately equal to that heated by IITRI.

The shorter, revised schedule was interrupted by two minor malfunctions:

- The nitrogen purge line to antenna A1 developed a small leak at the beginning of a three-day, holiday weekend. Under normal circumstances, KAI could get prompt delivery of additional nitrogen. However, none was available during the weekend and a small electrical short damaged the inner coaxial conductor.

- A spare inner conductor was damaged in transport to the site. The repair was simple, but added a brief delay to the project.

KAI delivered the most energy to antenna A1, with sufficient operation of antenna A2 to demonstrate that switching would not require substantial returning. Most of the operations with antenna A1 were at a single depth, and antenna switching proceeded very smoothly.

7.3 VAPOR

7.3.1 IITRI Demonstration

A knowledge of vapor stream properties is important in order to identify process changes critical to system operation. During the IITRI demonstration, temperature, pressure, flow, and chemical composition, and concentration were monitored. Temperature, pressure, and flow data are presented in Appendices B.4 and B.6 and discussed in Section 6.

Procedure

Extracted soil vapors were sampled and analyzed for total petroleum hydrocarbons, VOC's, and SVOC's. The primary purpose was to monitor the release of petroleum hydrocarbons and chlorinated compounds in compliance with the Texas Air Control Board's (TACB) standard exemptions 68, 80, and 118 according to Section 382.057 of the Texas Clean Air Act. Permit exemption No. BG-0108-F was applied for by Kelly AFB ERMO and received on June 25, 1992.

A secondary purpose for the vapor analysis program was to document and develop a reliable, cost efficient method for monitoring emissions and tracking operation effectiveness. Lessons learned during the IITRI demonstration were used to improve the procedures and methods used in the KAI demonstration (see Section 9 for details).

These standard exemptions specify discharge limits and operational criteria, as follows:

- total emissions of petroleum hydrocarbons of less than 1 pound per hour (lb/hr),
- total emissions of chlorinated compounds of less than 24 ppm,
- the discharge must be burnt in a flare,
- the tip velocity must be less than 60 ft/sec, and
- the burn is smokeless.

The required QA level and resulting cost for vapor analysis was purposely lowered to allow frequent collection and analyses. These analyses were originally conceived as a screening tool for operation, but several problems encountered during field implementation prevented this use. However, the results did yield several interesting conclusions.

Extracted soil vapor samples were collected from a sampling port on the vacuum line, upstream of the ejector assembly. A peristaltic pump pulled vapor from the vacuum line through a sampling train consisting of a flask to remove any solids and liquid and a sample vial filled with carbon for VOCs and TPH (NIOSH 1003) or XAD_2 resin for SVOCs (NIOSH 5504). One quarter-inch diameter, silicone tubing was used to connect the assembly. Detection limits were a function of the volume of air pulled through the sampling tubes. Fluctuations in humidity required adjustments in volume based on laboratory results and recommendations. One to ten liters of vapor were pulled through the sample tubes.

VOCs, SVOCs, and TPH were analyzed by EPA methods SW 8010 and 8020, Modified TO-13, and SW 8015, respectively. Level II quality control was achieved by calibration at five (5) point intervals and surrogate recovery analyses. Surrogate data are attached in Appendix B.6.

Several problems and potential solutions were identified during vapor sample collection and evaluation. First, the XAD_2 resin will not adsorb most light SVOCs at elevated temperatures ($>68^{o}F$). Second, analysis by GC instead of GC/MS restricts the types of compounds reported. Third, quantitative results will require the performance of regular spike analyses and increased costs.

Results

As a qualitative screening, vapor stream analyses detected many compounds previously identified during soil sampling (see Appendix A.7). Even at maximum concentrations, air emissions were well below the regulatory limits.

Two distinct trends are readily identified by examination of the data. First, the data show many detections at relatively high concentrations followed by a period of few, low-concentration detections, followed again by a marked increase in detections and concentrations. Second, concentration swings are numerous and large.

7.3.2 KAI Demonstration

7.3.2.1 Screening Data

As with the IITRI demonstration relatively frequent, inexpensive characterization of the vapor stream was performed. Observed contaminant flows were well under the requirements of the flare operating permit exemption.

7.3.2.2 Radian

EPA/SAIC selected Radian Corporation to conduct more sophisticated vapor sampling and analysis. Radian's report is included as Appendix B.6. VOC grab samples were collected directly in SUMMA® stainless steel canisters, while SVOC samples were collected over a four-hour period. SVOC sampling employed a modification of the EPA Method 0010. Since the vapor line was only two inches in diameter and the vapors were already heated, Radian omitted the heated probe normally used for gas sampling. Samples flowed directly to a condenser and a XAD-2 resin cartridge. The control console that monitored flow rate and volume was located downstream of the condenser and cartridge.

The results may be summarized as follows:

- An average SVE flow rate of 30 to 80 cubic feet per minute was maintained.
- Approximately 90 to 120 pounds of VOCs were extracted (removed), including 15 to 20 pounds of chlorobenzene.
- Approximately 5 to 10 pounds of SVOCs were removed, mostly isomers of dichlorobenzene.

7.4 WATER

Site S-1 lies over a contaminated shallow aquifer and contamination in soil moisture above over the aquifer probably reflects soil contamination patterns. The demonstrations created two volumes of contaminated water above ground:

- The aquifer beneath the soil heated by IITRI was continuously dewatered. Water was stored in tanks on the site and periodically delivered to the Kelly AFB EPCF for treatment. No dewatering occurred during the KAI demonstration.
- HNUS kept about 100 gallons of water in a seal pot at the flare to prevent a flashback from the flare through the SVE system. The quantity of water gradually increased while soils dried out, and smaller quantities of water from the seal pot were also delivered to the EPCF. Concentrations of heavier compounds were expected to increase, while the more volatile compounds moved through the flare to be burned.

HNUS coordinated deliveries of water with EPCF personnel to assure that the additional water did not violate flow or chemical concentration provisions of the plant's discharge permit.

7.4.1 Groundwater

EPA's SITE activities included the sampling and analysis of groundwater from three existing wells at Site S-1. Temporary monitoring wells S1-TW09, S1-TW10, and S1-TW11 were sampled (see Appendix F). EPA identified the wells as KRF-09-GW118, KRF-10-GW114, and KRF-DW02-GW119, respectively. VOC and SVOC detections included chlorobenzene (12,000 to 25,500 ppb), benzene (596 and 782 ppb), dichlorobenzene (up to 11,000 ppb), and naphthalene (71 to 121 ppb). Bis(2-ehtelhexyl)phthalate was detected in one sample at 218 ppb.

7.4.2 Dewatering Effluent

EPCF personnel subjected samples to the routine tests required for treatment and discharge before accepting the dewatering effluent. The lab used Methods 8020 and 8070 for the analyses and the results are presented in Appendix A.9. Concentrations of benzene, chlorobenzene, and dichlorobenzene exceeded 1000 ppb. SVOC analyses confirmed the presence of dichlorobenzene, but most other SVOC concentrations were below detection limits. The detection limits for SVOCs were high, typically 660 to 3300 ppb. The chemical concentrations posed no problems, so the main task for delivering effluent consisted of estimating and coordinating flows. Once communications were established, effluent disposal posed no problems.

7.4.3 Seal Pot

The flare incorporated at seal pot partially filled with potable water to prevent backflash. The water in the seal pot was sampled and analyzed before the overflow was delivered to the EPCF (Appendix A.10). VOC, SVOC, and TPH analyses were performed. Concentrations were low, but the presence of bis(2-ethylhexyl)phthalate (95 ppb) was of particular interest.

7.5 HEALTH AND SAFETY AIR QUALITY MONITORING

HNUS conducted routine air monitoring to assure the safety of site workers and to be certain that the VES collected organic vapors for treatment. The company's experience from performing a RI at the site indicated that the site posed little or no risk to workers performing routine tasks if site soils were undisturbed. An increase in measurable vapor concentrations was noted during previous drilling operations, with concentrations generally increasing with increased drilling depth. The site is flat, open on all sides, and usually breezy, so vapors dispersed quickly. IITRI's quonset-shaped RF shield presented the most likely location for vapor buildup, and it was fitted with a blower that moved a constant flow of air through the structure. The blower output exhausted through activated carbon drums.

7.5.1 Procedure

Site personnel used three types of instruments: photoionization detectors, flame ionization detectors, and combination devices that measure the explosive properties and oxygen content of vapors. The HNu model PI-101 is typical of the photoionization devices used. The device is simple to calibrate and use, but required frequent repairs that cannot be readily performed in the field. The Foxboro OVA 128, a flame ionization instrument, requires a hydrogen supply and is somewhat more complicated to use. However, it provided very reliable service and was used most frequently during the tests. The MSA 360 LEL/O_2 monitors the lower explosive limit, oxygen content, and carbon monoxide content of air. The OVA served as the main survey instrument. It was used frequently to monitor working areas and determine if use of the other instruments was warranted. All three devices were used during drilling to monitor soil and borehole vapors. The LEL/O_2 was used periodically to check the air beneath the IITRI RF shield and near the propane tanks and flare. No explosive situations or oxygen deficiencies were noted.

7.5.2 Results

Background vapor concentrations, as determined from measurements near the upwind site boundary, were typically 0 to 3 ppm, with occasional excursions to 8 or 9 ppm. Several factors contributed to background changes. Moderate to strong breezes swept the site nearly every day, then diminished at night. This diurnal effect was less noticeable during cold weather, when winds were more constant. Winds from the West or Southwest often carried vapors from automobiles or aircraft during periods of heavy traffic. Southeast winds carried vapors from fuel transfer and flare operations at the adjacent fuel farm. Daily monitoring confirmed the effects of base operations; concentrations generally diminished on weekends, when the level of activity was low.

The greatest vapor concentrations were observed during drilling and soil sampling. Measurements made in a borehole or directly at a contaminated point on a sample occasionally indicated concentrations exceeding 1000 ppm. Samples nearest the water table exhibited the greatest concentrations. Breathing zone concentrations rarely exceeded background because of the breezes and the open nature of the site.

HNUS personnel checked vapors near the seal pot and storage (frac) tank as part of the daily health and safety checks. Detections exceeding 1000 ppm were occasionally observed in the tops of the storage tanks, but no increase in breathing or working zones was noted. The flare operated without noticeable odor.

IITRI personnel periodically entered their RF shield structure to measure the output of thermocouples in their electrodes. HNUS monitored vapors inside the structure before each entry at the structure's vents and doors. Vapor concentrations rarely exceeded background, but workers wore full-face respirators and worked in pairs for safety.

HNUS also monitored air beneath the vapor barrier used during the KAI test by placing the OVA probe tip under the barrier at several points around its periphery. No detections above background were observed, indicating that soil vapors moved to SVE wells, not to the soil surface.

Toxic characteristic leaching procedure (TCLP) analysis was performed on the activated carbon used in the IITRI demonstration (see Appendix A.11). No compounds exceeded detection limits.

7.6 LESSONS LEARNED

The quality of soil data is inadequate for a statistical analysis of the demonstrations. That is due in part to occasional elevated detections that required sample dilution. Dilution, in turn, elevated the detection limits. This pattern can be overcome in an actual remedial action by focusing analyses on a few critical compounds. Other deficiencies resulted from the unexplained appearance of volatile contaminants in trip and field blanks. Some of the compounds observed in blanks appear to exist in site soils, but the quantitation remains suspect. Heavy SVOC compounds were mobilized and extracted, but the dynamics were not well defined.

Sampling near the sides of the heated volumes probably influenced the soil data greatly. The sampling pattern resulted in analysis of soils at points where contaminants were drawn from surrounding soils.

Routine vapor screening results were poor. An on-site gas chromatograph would assist site personnel in day-to-day operations. Plotting a few critical compounds would help in optimizing SVE system controls.

The SVE system drew vapors from soils surrounding the heated volume as well as vapors from heated soils. Some vapors may have condensed near the sides of the heated volume, skewing both soil and vapor analyses. The inherent effect cannot be avoided when a demonstration is conducted in a small portion of a much larger contaminated volume. The effect could be eliminated in a full-scale remediation by progressively heating from one side of the contaminated zone to the other or from the center to the edges.

8.0 CONCEPTUAL DESIGN AND OPERATION MODEL

8.1 INTRODUCTION

The following narrative presents conceptual plans for the planning and implementation of Phase II at Kelly AFB IRP Site S-1. Phase II is to include the complete planning and implementation of a full-scale demonstration of RF soil decontamination. For the propose of comparison, two RFH/SVE systems, IITRI and KAI, will be modeled. Design and operational plans, equipment lists, costs, and schedules for implementation of the demonstration systems are provided. The conceptual plans are based on conclusions reached in the evaluation of data generated in the Preplanning Phase and Phase I (see Sections 4 - Geology, 5 - Radio Frequency Soil Heating, and 6 - Soil Vapor Extraction and Treatment).

8.1.1 Basis For Action

A Remedial Investigation and Feasibility Study (RI/FS) are usually prepared prior to a remedial action under CERCLA. The RI defines the nature and extent of site contamination, identifies site-specific ARARs, and develops baseline risk assessments. If the results of the RI indicate that a remedial action is required, an FS is prepared. The FS develops and screens remedial alternatives and analyzes those alternatives in detail. In the case of an emergency or priority situation, a Focused Feasibility Study (FFS) can be prepared to facilitate a timely interim remedy. The FS and FFS are based on information gathered for the RI. The RI/FS is then used to recommend an action to remediate the site.

A commercial scale RFH/SVE demonstration requires two assumptions that would normally be dictated by the conclusions and recommendations of a FS or FFS. First, the nature and extent of contamination and resulting risk assessments require action and, second, RFH enhanced soil vapor extraction is the recommended alternative for soils treatment.

8.1.2 Demonstration Goals

The goals of the proposed demonstrations will be to broaden and validate commercial development of a RFH/SVE system while removing volatile and semi-volatile organic compounds from the soil matrices. The demonstrations must satisfy all environmental and human health standards and regulations while meeting these goals. The actual demonstration will be performed using the procedure required for a CERCLA remedial action as guidance. Modifications allowing for the development and research aspects of the demonstrations will be made as appropriate and in cooperation with the Texas Natural Resources Conservation Commission (TNRCC).

8.1.3 Site S-1

Site S-1 served as an intermediate storage and transfer area for wastes to be reclaimed off-base. The site was dominated by a sump which was later filled in with materials from various locations on base. The wastes included mixed solvents and petroleum, oils, and lubricants (POL). Inadvertent spills during this operation resulted in soil contamination. The RI for Site S-1 was completed in October 1994 and a contract for the design and construction of an interim groundwater extraction and treatment system based on an FFS is nearing field implementation. The purpose of the system is to prevent off-base migration of a plume of contaminated groundwater. See Section 4 for a complete site description and additional site characterization data gathered during Phase I. Additional site characterization information is contained in the RI report (HNUS, 1994).

A major consideration in the actual performance of these conceptualized demonstrations is the predicted effectiveness of RFH/SVE in removing and destroying contaminants from the vadose, capillary fringe, and saturated zones and achieving a significant reduction in the ability of the residual to mobilize and contaminate the site's groundwater. The major problem at Site S-1, as identified in the RI (HNUS, 1994), is a contaminated groundwater plume originating from the sump area. Chlorobenzene and benzene are the chemicals of concern.

The sump area contains approximately 28,000 tons (23,333 cubic yards) of contaminated soil in an area 300 feet long by 150 feet wide by 25 feet deep. No attempt will be made to heat the entire volume. RFH will be used to enhance the removal of VOCs (mainly chlorobenzene, BTEX, and dichlorobenzenes). Removal and destruction of lighter SVOCs and POLs will also occur. See Section 7 for details.

8.1.4 Design Limitations

The accuracy of the system design and projected system performance is limited to the accuracy of the information and experience of the personnel used in development of the designs. If actual site and operating conditions vary substantially from the data used in the designs, system performance will vary accordingly. As concluded in Sections 5 and 6:

- The availability of field-proven RFH equipment will have a dominant impact on all other aspects of design and operations.
- A major limiting factor in presenting patented RFH subsystem design information and procedures is the proprietary nature of the knowledge.
- RFH/SVE system design is based on a complex set of electrical, chemical, and physical specifications.

A properly designed system must operate under site specific-conditions, incorporate existing components where possible, and maximize automatic operation for economy and efficiency. To improve efficiency, the design will incorporate development modifications based on lessons learned from the demonstrations at Site S-1 and any new developments from other recent and ongoing RFH/SVE projects. As a result, system design should be viewed as a flexible, iterative process and subject to change during installation and operation to accommodate any field variance from the design specification. In addition actual field-observed conditions at Kelly AFB are known to vary widely from one area to another. Modification of the conceptual design to some degree during final design is considered likely.

8.2 GENERAL DESIGN AND OPERATIONAL SPECIFICATIONS

Design and operational specifications are based on the preceding sections and define component selection, site preparation, and operating conditions. These specifications take into consideration the demonstration project's research and development objectives, site characterizations, expected emissions, regulatory requirements, health and safety concerns, sampling strategies, and potential design modifications for increased system efficiency. General design and operational specifications common to both techniques are, as follows:

- The RFH inground components will be placed between the Phase I IITRI and KAI heated areas.
- One trailer will be required to house the site office and RF control hardware and instrumentation and a GC laboratory.
- One trailer will be required to house the sources and store materials, parts, and tools.
- Power will be available from existing power distribution lines.

- Two telephone lines will be required for personal and computer communications.
- The RF sources will have a total power output of 100 kW.
- Operating frequencies will be the same as for the pilot demonstrations.
- SVE will be accomplished by vertical vented wells, with horizontal wells for back-up and safety.
- Vented wells will be connected to a manifold system for SVE control.
- A system of ground pressure measurement wells will be placed around the perimeter of the heated area to monitor SVE operational parameters.
- SVE will utilize a regenerative blower system to provide extractive force.
- Vapor treatment will utilize a catalytic oxidation (CAT/OX) unit.
- Propane will provide fuel for the CAT/OX unit.
- Soil samples will be collected for analysis before and after operations.
- A gas chromatograph (GC) for vapor stream analysis screening will be housed in the control trailer.
- Four high level vapor stream analyses will be performed during operations to validate and calibrate GC results.

The decision to use a regenerative blower for vacuum power and a catalytic oxidation vapor treatment unit is based on two factors. First, a lesson learned early in Phase I, a custom-designed, full-scale vapor treatment system would be capital intensive and complex to operate and monitor. The ejector and flare VT system used for the Phase I demonstrations was project-specific and designed to be safe, reliable, and economical. This system was highly resistant to corrosion, minimized the explosive potential, and had few moving parts. Also, Kelly AFB already owned the flare. Second, the existing ejector/flare VT is limited by air discharge permitting limitations. Conventional components allow standardization of VT for conceptual model simplification. Both components are well known from extensive operational experience and have a wide selection of vendors. Other systems would require site and project specific evaluation and design beyond the scope of this conceptual design.

8.3 IITRI DESIGN AND OPERATIONAL SPECIFICATIONS

The following sections present system specifications in terms of site specific characteristics and IITRI technique requirements.

8.3.1 Basic IITRI RFH System Specification for Site S-1

- The RF applicator system will consist of two excitor rows and three ground rows.
- Excitor electrode rows will be 32 feet long.
- Excitor electrodes will be 20 feet in length.
- Ground electrodes must be 8 feet longer than the excitor electrodes.
- The ground row will extent, at a minimum, two electrodes (8 feet) beyond the excitor rows.
- Treatment will occur from 0 to 19 feet deep with a 1 foot deep fill of drill cuttings placed over the treatment zone for a total of 20 feet.
- 100% of all drill cuttings will be placed in the one foot layer and treated during operations.
- An insulated vapor barrier will be required.
- RF energy will be generated at a frequency of 6.78 megahertz (mHz).
- Manpower will consist of six people; one senior radio operator with two junior assistants, one site engineer, and two senior technicians.

8.3.2 IITRI System Components

8.3.2.1 RFH

The major components of the IITRI system will be the RF source, coaxial transmission line, matching networks, RF chokes, electrode array, insulated vapor barrier, RF shielding and electrical grounding, and instrumentation. Conceptual specifications for components will be as follows:

- Four 25-kW sources will be linked. A rigid, 6-inch diameter, copper coaxial line will transfer RF energy from the sources to the mid point of the excitor electrode row.

- Two remotely adjustable matching networks will be installed in series between the RF power source and the electrode array. The first will reduce the standing wave ratio to about 7:1, and the second will further reduce it to about 1.05:1.
- Three chokes will be installed in the IITRI system. One will be placed between the two matching networks to suppress currents flowing back toward the RF source. A second choke encircling the thermocouple leads will protect the monitoring equipment. A third will be placed on the conduit connecting the vapor collection manifold and the vapor treatment system to prevent current flow to the VT system and protect persons working on the treatment equipment.
- A ground electrode spacing of 4 feet, an excitor electrode spacing of 4 feet, and a row separation of 8 feet will be used for the proposed demonstrations. The excitor electrodes will be 2-inch diameter copper (excitor at row ends are 3-inch diameter) and will be connected to the coaxial line by a copper manifold at the center of the excitor electrode row. The ground electrodes will be 3-inch diameter aluminum connected as specified below.
- The insulated vapor barrier will consist of three layers; a primary barrier, a insulation barrier, and a secondary barrier. The primary vapor barrier will consist of a 60-mil sheet of silicon rubber reinforced with fiberglass, able to withstand temperatures up to 250°C (475°F), and resist puncture. A 2-inch insulation layer will be placed on the primary barrier. A 20 mil single sheet of nylon-reinforced plastic will then be placed over the insulation as a secondary barrier. The barrier will be fabricated to be dragged on and off the treatment area. The layers will be quilted together to form a one piece blanket 64 feet long and 52 feet wide.
- RF shielding and grounding consists of a ground plane and a 8-foot radius corrugated aluminum connected to the ground row electrodes, each constructed of aluminum. The shield will have aluminum plate end walls with entrance doors. A weather cover or tarp placed over the shield will prevent precipitation and surface run-off from contacting the excitor electrodes and causing short circuiting. For additional personnel safety expanded aluminum mesh plates will be placed on the insulative vapor barrier and physically connected to the ground row electrodes. The shield will have an air evacuation blower to prevent moisture build-up within the shield. Air evacuation reduces possible electrical shock hazards and prevents possible build-up of harmful vapors within the shield.

- RFH subsystem instrumentation will consist of a standing wave ratio meter, an ohmmeter, and a watt meter, each linked to an operation computer (see Section 5). Thermocouples and thermowells will be installed at selected locations to monitor temperatures. These locations will provide temperatures in, around, and beneath the heated volume at three depths.

8.3.2.2 SVE

The SVE system for the IITRI demonstrations will consist of a vapor containment barrier, extraction wells, redundant regenerative blowers, and a collection and transfer manifold.

- Vapor containment will be accomplished by the primary barrier used in the construction of the insulated vapor barrier. The barrier must extend at least 12 feet beyond the outside edge of the heated zone. The outer edges will be secured to prevent air infiltration through gaps between the barrier and soil surface. All RF power conduits, extraction piping, and miscellaneous hardware will be located below the ground surface to simplify barrier construction and adjustment. Required perforations and connections will be overlapped and/or sealed with heat-resistant tape or silicone chalk.
- Selected vertical ground electrodes will serve the dual functions of heating and vapor extraction. Approximately every third ground electrode will be vented for vapor extraction by drilling 0.25-inch diameter holes on concentric patterns over the required length of the electrode. Vent hole frequency will be one per 1.5 inches of vented length. Material requirements prevent the use of conventional screened well casing. The diameters of the vertical electrodes are based on both vapor- and current-carrying capacities. Appropriate connections will be made between the tops of the electrodes and the transfer conduits to provide both vapor conduction paths and electrical grounding. For Site S-1 the end electrodes will be vented from 10 to 20 feet below ground and will alternate with electrodes vented between 2 feet and 10 feet below the ground. To prevent the vented electrodes from acting as conduits capable of draining any condensate into deeper cooler soil, the electrodes will be plugged at the depth of the excitor electrodes. The space between the electrodes and boring walls will be filled with a soil mixture similar to the site soils for electrical connection and structural support.

- Horizontal vapor extraction pipes will be placed at ground surface outside the ground electrodes. Horizontals will be constructed from 2-inch diameter fiberglass epoxy pipe covered by a 1.5 foot layer of drill cuttings. The pipe will be vented with 0.25-inch diameter holes drilled at rate of one every 1.5 inches over the length of the ground electrode.
- The two piping systems will be joined in a collection and transfer piping manifold constructed from rigid fiberglass epoxy pipe with adequate valves and ports for control and monitoring. Vapors will be transferred to the Catalytic Oxidation unit for treatment by a system of flexible hoses. These hoses will be wrapped or buried for insulation depending on use.
- Electric regenerative blowers will be used for extractive force to provide a soil vacuum. The blowers will be explosion proof and corrosion resistant. The blowers will be capable of providing 5 to 50 inches of H_2O vacuum at the extraction well head and a flow rate of between 100 and 300 scfm.

8.4 KAI SYSTEM DESIGN AND OPERATIONAL SPECIFICATION

8.4.1 System Specification

- Eight antenna wells will be required.
- Antenna casings will be placed in a 16 feet by 16 feet square array.
- Treatment will occur from 0 to 19 feet deep with a 1 foot deep fill of drill cuttings placed over the treatment zone for a total of 20 feet.
- 100% of all drill cuttings will be placed in the one foot layer and treated during operations.
- An insulated vapor barrier will be required.
- Antenna wells will be cased to a depth of 24 feet.
- RF energy will be generated at a frequency of 27.58 MHz.
- Manpower will consist of four people; one senior radio operator with junior assistant, one site engineer, and one senior technician.

8.4.2 KAI System Components

8.4.2.1 RFH

The major components of the KAI subsystem will be the source, coaxial transmission line, antenna array, insulated vapor barrier, RF shielding and electrical grounding, and instrumentation. Conceptual specifications for components will be as follows:

- Four 25-kW sources will be linked. A rigid 2-inch diameter copper coaxial line will transfer RF energy from the sources to the antennae.
- Eight antennae, each approximately 10-feet long, will be placed inside antenna wells cased with 4.5-inch ID fiberglass epoxy guide sleeves that are heat rated to 200°C, non-conductive, and invisible to RF energy. Each well annulus will be backfilled with sand and sealed at ground level with a 2-foot bentonite clay plug. The antenna wells will be sealed at the top with rubber gaskets and the hole purged with nitrogen during operation to cool the guide sleeves. Antennae will be constructed from solid copper rods surrounded by an outer aluminum hull. Teflon rings and spacers will be required to structurally support the inner rod and prevent contact between the aluminum hull and the guide sleeve. Light weight 20-foot vertical aluminum frame towers will be required to lower and raise the antennae for positioning and to remove the antennae for maintenance. Tower frames will consist of 1-inch OD aluminum tubes with 0.065-inch wall thickness cross braced with 3/8-inch diameter solid rods. The towers will be supported by 1/4-inch steel base plates connected to the guide sleeves at ground level for foundation and guide wires connected at the tops and staked to the ground in three directions (or as required) for vertical support.
- The insulated vapor barrier will consist of three layers; a primary barrier, a insulation barrier, and a secondary barrier. The primary vapor barrier will consist of a 60 mil sheet of silicon rubber reinforced with fiberglass, able to withstand temperatures up to 250°C (475°F), and resist puncture. A 2-inch insulation layer will be placed on the primary barrier. A 20-mil single sheet of nylon-reinforced plastic will then be placed over the insulation as a secondary barrier. The barrier will be fabricated to be dragged on and off the treatment area. The layers will be quilted together to form a one piece blanket 72 feet long and 40 feet wide.

- A 10 by 10 foot rectangular RF ground plate constructed from flat 12 gauge 2.5 X 5 foot expanded mesh aluminum sheets will be placed around each antenna well above the vapor barrier and mechanically connected to the tower base plates. The towers and base plates will be electrically grounded by an array of six 4-foot long, 0.5-inch diameter copper coated grounding rods driven into the ground and connected to the base plate by 2-0 bare copper wire. All connections will be by mechanical clamps.
- The KAI RFH subsystem instrumentation will consist of a standing wave ratio meter, an ohmmeter, and a watt meter, each linked to an operation computer (see Section 5). Thermocouples and thermowells will be installed at selected locations to monitor temperatures. These locations will provide temperatures in, around, and beneath the heated volume at three depths (see Section 6).

8.4.2.2 SVE

The SVE system for the KAI demonstrations will consist of a vapor containment barrier, vertical extraction wells, horizontal extraction wells, a collection and transfer manifold, and regenerative blowers.

- Vapor containment will be accomplished by the primary barrier used in the construction of the insulated vapor barrier. The barrier must extend at least 12 feet beyond the outside edge of the heated zone. The outer edges will be secured to prevent air infiltration through gaps between the barrier and soil surface. All RF power conduits, extraction piping and miscellaneous hardware will be located below the ground surface to simplify barrier construction and adjustment. Required perforations and connections will be overlapped and/or sealed with heat-resistant tape or silicone chalk.
- The extraction wells will be cased with 2-inch ID temperature resistant fiberglass epoxy pipe developed with sand pack and a minimum 12-inch bentonite seal at the top. For Site S-1, every other well will be vented from 10 to 20 feet below ground and will alternate with wells vented between 2 feet and 10 feet below the ground. The space between the casing and boring walls will be filled with sand for support.

- Horizontal vapor extraction wells will be constructed from the same fiberglass epoxy pipe as the extraction wells and covered by a 1.5 foot layer of drill cuttings. Two 10-foot vented sections of pipe will be placed within the antenna array and piped into the manifold. The pipe will be vented with 0.25-inch diameter holes drilled at rate of one every 1.5 inches over the length of the ground electrode. See Section 6 for design details.
- The vertical and horizontal extraction wells will be joined in a collection and transfer piping manifold. The manifold will be constructed from the same fiberglass epoxy pipe as the extraction wells and valved and ported to allow for flow adjustment and vapor stream property measurement.
- Electric regenerative blowers will be used for extractive force to provide a soil vacuum. The blowers will be explosion proof and corrosion resistant. The blowers will be capable of providing 5 to 50 inches of H_2O vacuum at the extraction well head and a flow rate of between 100 and 300 scfm.

8.5 RF/SVE FIELD OPERATIONS

8.5.1 General

System construction and operation are key factors in RFH/SVE efficiency, effectiveness, and cost. All aspects of operation will be dominated by personnel health and safety concerns and the possibility of equipment damage and breakdown. Operational procedure and personnel will be selected and organized to effect safe efficient operations with minimal manpower. During RF system operation two site personnel will be present 24 hours per day, 7 days per week for the IITRI method and 12 hours per day 6 days, per week for the KAI. The site will be maintained in an neat and orderly fashion during operations. Field activities will include:

- site preparation, system construction and set-up,
- system operations, and
- system dismantling and site restoration.

In order to limit access, the site will be completely surrounded by an 8-foot high chainlink security fence. Site access will be limited by the site manager (SM) and/or the site safety officer (SSO). All individuals that entry or leave the site boundaries will sign in and out at the site office. During all site operations, an area encompassing the RFH/SVE system will be regarded as the exclusion zone.

This zone will be controlled by traffic cones, warning tape, and physical barriers, as appropriate. Only authorized personnel will be permitted in the exclusion zone during operations. A contamination reduction zone will be located adjacent to the exclusion zone for the decontamination of personnel and equipment. An emergency eye wash and overhead shower will be located within this zone. A support zone will be located at the clean side of the contamination reduction zone. The support zone will be readily accessed by motorized vehicles.

Personnel and subcontractors that enter the exclusion zone will have completed 40-hour Health and Safety Training (OSHA 29 CFR 1910.120). The site manager and the SSO will have completed the 8-hour Site Supervisors Training (OSHA 29 CFR 1910.120). A site safety briefing to include all subcontractors and site workers will be held just prior to the start of all site activities. In addition, the start of each work week, the SSO shall conduct a short health and safety meeting. All meetings will be documented in the Site Manager's or the Site Safety Officer's Project Logbook. Authorized personnel will include only those with OSHA training certificates, respirator fit test certificates, and medical clearances on file in the site office.

The SSO will exercise the authority to upgrade or downgrade levels of personnel protection as necessary during site preparation and RFH system operation. The level of personnel protection equipment (PPE) will be based in part on the readings of air monitoring equipment and existing weather conditions, particularly wind velocity and direction. Field activities will be performed beginning in Level D. Hard hats, safety glasses, and steel toe work shoes are required at a minimum. When handling any equipment, soil, or debris, chemical resistant gloves will be worn. If required by air monitoring, PPE may be upgraded to level C by the addition of Tyvex overalls and OSHA approved disposable dust respirators (3M-9970 or equal).

The following four real-time monitoring instruments will be used during operation.

1. Photo Ionization Detector (PID) (i.e., HNu)
2. Flame Ionization Detector (FID) (i.e., OVA)
3. Combustible gas/explosimeter (i.e., LEL/O_2)
4. Electric and magnetic field monitor

An initial site surveillance will be conducted using instruments 1, 2, and 3 prior to any site activities. During pre-test sampling and drilling, monitoring will be conducted using instruments 1, 2, and 3. During RF system operation, all listed instruments will be used for monitoring. All instruments will be in good working order and calibrated as required by regulation and manufacturer's recommendations.

8.5.2 Site Preparation and System Construction

Site preparation and system construction will include activities to ready the site for system set-up, placement and set-up of system components, and operation. Tasks will include activities associated with the operation of the RF, SVE, and VT subsystems and consist of fencing, drainage control grading, concrete transformer pad, electrical lines, placement of trailers, installation of the natural gas line, soil boring, sample collection, well development, piping fabrication, etc. Contaminated materials (e.g., soil and debris from trenching, grading, soil boring, soil sampling, and PPE) will be encountered and/or generated during site preparation.

8.5.3 System Operations

The (RFH) demonstration is expected to be conducted under moderate climate conditions, so no heat/cold stress monitoring will occur. However, heat stress monitoring may become necessary if ambient temperature is at 70°F or above. This is due to the normal hazards of hot weather, enhanced by the RF heating of the soils. The site safety officer will monitor all crew members for signs and symptoms of heat stress. Possible emissions and materials encountered and/or generated during operations include gas from vapor extraction, liquid from vapor extraction, emissions from vapor treatment, and radio frequency radiation. Electrical consumption, RF power, gas and liquid flows, pressures, and temperatures must be monitored during operations.

VT activities will be performed in Level D PPE with chemical resistant gloves. In the event of a vapor barrier leak, SVE and VT operations will be discontinued and an upgrade to Level C PPE will be made before repair. During sampling and analysis activities, the possibility of contact with contaminated gases and liquids increases. During operation vapor stream sampling and analysis will be required on a regular basis. VOCs, SVOCs, and TPHs will be analyzed weekly. This data will be used as a screening tool to monitor performance. A trained engineer will collect and analysis all samples. Samples will be collected before the vapor treatment subsystem to evaluate process status. Samples from the vapor treatment unit's discharge stack will be collected to evaluate and document vapor treatment effectiveness.

Operation at an authorized industrial, scientific, and medical (ISM) designated frequency minimizes the FCC requirements. Site workers must be protected from dangerous levels of radiation and system operation must not interfere with communication or security operations. Since radio frequency heating will operate at frequencies of 6.78 MHz for IITRI and 27.13 MHz for KAI, monitoring will be performed for electric and magnetic fields to insure that all site activities are in compliance with American National Standard ANSI C95.1-1982 . In addition, Department of the Air Force AFOSH Standard 161-9 for exposure to RF radiation shall apply. Careful attention to the following items will preclude most problems:

- Major changes in operation must be made or supervised by a skilled, experienced operator. Emergency shutdowns are the only exceptions.
- Operating plans must be approved by Base communications and security personnel.
- The RFH system must be designed to reduce spurious radiation.
- The applicator array must be adequately shielded and grounded to protect site workers and prevent interference with other electronic systems.

A principal physical hazard during the actual RF heating process is the potential for electrocution. As the system utilizes a 480-volt feed and operates at a maximum of 300 amps, all electrical power must be grounded appropriately with the necessary circuit interrupters. All applicable OSHA standards for electrical safety shall apply (29 CFR 19710.500).

8.5.4 System Dismantling And Site Restoration

System dismantling will include teardown, decontamination, pack-up, and shipping of system components. Rented or leased equipment will be dismantled, disconnected, decontaminated, and packed for return or pick-up as appropriate. The site will be restored to pre-existing conditions. Site S-1 will be graded and grassed or graveled.

8.6 COST ESTIMATES

Cost estimates are based on data generated during the Preplanning and Phase I. While dominated by actual experiences during the Phase I design, procurement, and field activities, the estimates also reflect logistical and capital cost knowledge gained during the Preplanning Phase. Estimates are conceptual in nature. Table 8-1 and 8-2 present summaries of estimated costs for the implementation of Phase II at Site S-1. These estimates assume purchase of all hardware by the USAF and do not reflected commercial costs. Table 8-3 and 8-4 present summaries for implementation of Phase II under a commercialized scenario with capital equipment amortization, long term maintenance, and salvage value. See Appendices A.12 and B.7 for details.

TABLE 8 - 1
IITRI COST SUMMARY - PHASE II
RF SOIL DECONTAMINATION DEMONSTRATION

ITEM	UNIT COST ($)	SUBTOTALS
RF SOURCE		**$883,852**
RF TRANSMITTERS	242,000	
RF CONTROL UNIT	600,000	
ELECTRICITY	41,852	
RF APPLICATION		**$25,244**
EXCITOR ELECTRODES	11,280	
COAXIAL TRANSMISSION LINE	2,300	
GROUND ELECTRODES	11,664	
RF SHIELD		**$7,217**
DOGHOUSE	6,664	
MESH SCREEN	553	
MEASUREMENT/CONTROL		**$21,670**
THERMAL MEASUREMENT WELLS (TMW)	66	
VACUUM MEASUREMENT WELLS (VMW)	29	
THERMOCOUPLES (TCs) AND WIRE	3,437	
VACUUM/PRESSURE GAUGES	138	
GAS CHROMATOGRAPH	18,000	
VAPOR COLLECTION/TRANSFER PIPING		**$3,541**
VAPOR BARRIER	1,492	
GROUND ELECTRODE PIPING	1,188	
HORIZONTAL EXTRACTION PIPING	363	
EXTRACTION MANIFOLD	497	
VAPOR EXTRACTION/TREATMENT		**$251,700**
REGENERATIVE BLOWER	1,700	
CATOX TREATMENT UNIT	250,000	
SITE SUPPORT		**$80,050**
UTILITY TRUCK	35,000	
CELLULAR TELEPHONE	4,875	
MISCELLANEOUS ODCS	47,560	
FENCING	9,200	
GRAVEL	2,500	
CONCRETE	7,108	
WASTE DISPOSAL	7,108	
LIGHTS	1,700	
SUBCONTRACTOR SUPPORT		**$190,954**
DRILLING FOR SYSTEM INSTALL	24,664	
IN GROUND SYSTEM ABANDONMENT	23,390	
RF CONSULTANTS	100,000	
ANALYTICAL	42,900	
LABOR		**$477,389**
SITE PREPARATION/SET-UP	55,688	
TREATMENT	403,139	
SITE RESTORATION/DEMOBILIZATION	18,563	
	SUBTOTAL	**$1,941,617**
ODC MARKUP	10.60%	**$155,208**
ENGINEERING, PROCUREMENT, & PROJECT MANAGEMENT	15%	**$219,634**
CONTENGENCY	15%	**$219,634**
	TOTAL	**$2,536,093**

TABLE 8 - 2
KAI COST SUMMARY - PHASE II
RF SOIL DECONTAMINATION DEMONSTRATION

ITEM	UNIT COST ($)	SUBTOTALS
RF SOURCE		**$884,578**
RF TRANSMITTERS	242,000	
RF CONTROL UNIT	600,000	
ELECTRICITY	42,578	
RF APPLICATION		**$208,000**
ANTENNA	132,000	
ANTENNAE CASING	27,200	
COAXIAL TRANSMISSION LINE	21,600	
ANTENNA TOWERS & BASE PLATES	27,200	
RF SHIELDING & GROUNDING		**$1,104**
MESH SCREEN	256	
GROUNDING	848	
MEASUREMENT/CONTROL		**$20,173**
FIELD MEASUREMENT WELLS (TMW)	377	
PRESSURE MEASUREMENT WELLS (VMW)	254	
THERMOCOUPLES ASSEMBLIES	1,405	
VACUUM/PRESSURE GAUGES	138	
GAS CHROMATOGRAPH	18,000	
VAPOR COLLECTION/TRANSFER PIPING		**$2,102**
VAPOR BARRIER	835	
HORIZONTAL EXTRACTION PIPING	114	
EXTRACTION MANIFOLD	1,153	
VAPOR EXTRACTION/TREATMENT		**$251,700**
REGENERATIVE BLOWER	1,700	
CATOX TREATMENT UNIT	250,000	
SITE SUPPORT		**$68,597**
UTILITY TRUCK	35,000	
CELLULAR TELEPHONE	4,875	
MISCELLANEOUS ODCS	41,815	
FENCING	9,200	
GRAVEL	2,500	
CONCRETE	1,400	
WASTE DISPOSAL	7,108	
LIGHTS	1,700	
SUBCONTRACTOR SUPPORT		**$140,802**
DRILLING FOR SYSTEM INSTALL	8,610	
IN GROUND SYSTEM ABANDONMENT	9,493	
RF CONSULTANTS	80,000	
ANALYTICAL	42,700	
LABOR		**$259,875**
SITE PREPARATION/SET-UP	37,125	
TREATMENT	204,188	
SITE RESTORATION/DEMOBILIZATION	18,563	
▨	**SUBTOTAL**	**$1,836,931**
ODC MARKUP	10.60%	**$167,168**
ENGINEERING, PROCUREMENT, & PROJECT MANAGEMENT	15%	**$236,558**
CONTENGENCY	15%	**$236,558**
▨	**TOTAL**	**$2,477,216**

TABLE 8-3
IITRI COMMERCIAL COST DETAILS
RF SOIL DECONTAMINATION DEMONSTRATION

ITEM	%	COST
LABOR		$477,389
ODC's		$221,526
CAPITAL		$375,704
SUBTOTAL		$1,074,619
ODC MARKUP	10.60%	$63,306
ENGINEERING	15%	$161,193
CONTINGENCY	15%	$161,193
TOTAL		**$1,460,312**

*INCLUDES 10.6%MARKUP

TABLE 8-4
KAI COMMERICAL COST DETAILS
RF SOIL DECONTAMINATION DEMONSTRATION

ITEM	%	COST
LABOR		$259,875
ODC's		$184,752
CAPITAL		$435,644
SUBTOTAL		$880,271
ODC MARKUP	10.60%	$65,762
ENGINEERING	15%	$132,041
CONTENGENCY	15%	$132,041
TOTAL		**$1,210,115**

9.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations are based on lessons learned during the Preplanning Phase and the Phase I demonstrations. The primary objectives of the project were meet. The secondary objectives were addressed during the project with varying success.

9.1 CONCLUSIONS

9.1.1 Primary Objective Number One

Primary objective number one, to broaden the proven range of the RF technology applicability in low permeability soil, was met. This objective is evaluated with CERCLA guidelines for process option screening for effectiveness. The guidelines are modified due to the research and development nature of this project. Applicability is based on meeting five criteria; (1) the potential for handling the estimated areas or volumes of media; (2) the potential impacts to human health and the environment during the construction and operation; (3) the potential for the reduction of contaminant toxicity, mobility, and volume; (4) the permanence of the process, and (5) the reliability of the process with respect to the contaminants and conditions at the site.

The Potential for Handling the Estimated Areas or Volumes of Media

Radio frequency energy can be effectively applied to heat low permeability soils in situ. Available RF generator capacity creates a trade-off between system size and the time required for operation. Any size area or volume could be heated with adequate RF generating capacity (see Section 5 for detailed discussion).

The Potential Impacts to Human Health and the Environment During the Construction and Operation

Impacts to human health and the environment are possible during construction and operation of an RFH system. Except for RF radiation, these impacts are fairly standard for remedial projects with some special concerns for heat. RF shielding and site monitoring are required to eliminate radiation hazards (see Section 5 for detailed discussion).

The Potential for the Reduction of Contaminant Mobility, Toxicity, and Volume

Contaminants were removed and destroyed during the demonstrations at Site S-1, so a direct reduction in contaminant volume occurred with a corresponding reduction in contaminant mobility and potential toxicity. Although possible, RFH has not been used to destroy contaminants in place. During system operations vapor monitoring identified contaminant removal. Contaminant mobility enhancement and removal was also suggested in the comparison of pre- and post soil analyses.

The Permanence of the Process

The contaminants removed during operation were removed permanently and the resulting vapors were burned in a flare. Residual vapors were discharged to the atmosphere after flaring.

The Reliability of the Process with Respect to the Contaminants and Conditions at the Site

In light of information from the Site S-1 RI (HNUS, 1994) and the completed tests, operational concepts should be modified to address the remediation of the contaminated groundwater sourcing from the sump area. No problems from corrosion, acidity, flammability, explosibility, or ignitability were encountered. Site conditions presented no difficulty beyond the normal expected for a research and development effort.

9.1.2 Primary Objective Number Two

Primary objective number two, to more accurately assess the implementation requirements of commercial-scale systems, was met. Implemetability is based on meeting four criteria; (1) technical feasibility; (2) availability of vendors, equipment and waste disposal facilities and services; (3) administrative feasibility, and (4) special long-term maintenance and operational requirements.

Technical Feasibility

The demonstration of the IITRI and KAI RFH techniques at Site S-1 further documented the ability of the developers to design and implement in situ RFH of soil. As with all developing technologies technical feasibility is a problem. Even the patent holders have limited experience and knowledge due to site specifics of soil type, moisture, contaminants, geology, etc. Both developers made major improvements during the Phase I demonstrations. Some examples follow:

1. IITRI

- Aluminum ground electrodes were used to replace copper for material cost reduction and increased durability .

- A simplified RF shield structure was demonstrated, reducing materials and construction costs. Previous shields were completely custom fabricated. The new design incorporates off-the-shelf aluminum culvert sections.

- The excitor electrodes were deliberately pushed to failure. Several important concepts were documented. First, after the removal of moisture from around the electrodes arcing becomes exaggerated, causing high temperatures and failure, a situation to be avoided in the future. Second, the proximity of groundwater close to the bottom tips of the excitor electrodes also causes exaggerated arcing. System design and operation must take these conditions into consideration.

- Passive surface SVE is not efficient in deep, low permeability soils. SVE must be designed and operated to minimize extracted air volumes for vapor treatment cost reduction.

2. KAI

- During operation, the standard (by code) electrical hook-up was not adequate for full automated RF source operation. To assure uninterrupted power delivery, an uninterruptable power source is required when connected to a local power grid (as at Site S-1).

- The use of relatively inexpensive rigid coaxial transmission lines require major system shutdown for antenna movement. Flexible coaxial transmission lines should be used for system flexibility and efficiency.

- Antenna guide casing or sleeves require temperature-resistant materials which are invisible to RF energy. Although a relatively cheap fiberglass epoxy pipe normally made for use in petroleum refineries exists, the depressed state of the petroleum industry has caused a void in the availability of this product. Manufacturers are unwilling to run large batches (12,000 linear feet) for a small order (three 24 foot sections). Therefore, the antenna sleeves had to be custom made for Phase I.

- Materials limitations for antenna sleeves and vapor extraction were evaluated during the demonstration. Antenna Sleeve No. 1 was heated to 232.4°C before deforming during an antenna malfunction. Antenna Sleeve No. 2 withstood temperatures of 150°C (the design temperature) for extended periods with no apparent effect on operations. The standard fiberglass epoxy pipes used for vapor extraction withstood temperatures in excess of 90°C (vapor temperature) for extended periods with no apparent effect on operations. A visual inspection after pipe removal revealed no deformation.

Availability of Vendors, Equipment, and Waste Disposal Facilities and Services

Only two vendors (e.g., IITRI and KAI) are actively engaged in RFH/SVE and the majority of design methods for RFH systems are proprietary to IITRI and KAI. IITRI is an R&D organization not in position to commercialize the triplate method. Non-exclusive licenses now in place with two large US companies should help. An investment in developing the method is required for increased automation and simplification.

Waste disposal facilities and services are location- and contaminant-specific. These services were adequately available during the Phase I demonstrations.

Administrative Feasibility

The USAF has specific regulations for the use of electromagnetic (RF) energy on or around USAF bases. Regulations require that permits be issued by the command headquarters at Wright-Patterson AFB. TNRCC regulators have followed the Phase I progress and have voiced no concerns about the technology. The FCC has also been well informed of the demonstration activities and view the use of RF energy in this way as covered by the ISM Band regulations. Although no FCC permits were required for the Phase I demonstrations, the FCC should be notified before the start of field activities. Community acceptance could be a problem due to the mystique of electromagnetic energy.

A standardized system with pre-approved frequencies would ease implementation and allow rapid mobilization for implementation. The need for frequency approval at USAF sites slows design and mobilization. Past tests and demonstrations have required studies to define dielectric soil properties for choosing optimal heating frequencies. For optimal operation, frequency should be variable with soil moisture. Since electrical consumption is only 17% of the cost of the process, optimization is a relatively minor factor in overall process efficiency. This fact enables system standardization (equipment, materials, operating frequencies).

Special Long-Term Maintenance and Operational Requirements

Due to the developing nature of RFH/SVE, little is now known concerning long-term O&M requirements. Although RF transmission is a well established technology, in situ RFH of soil is relatively new. Long-term data will be slow to accrue for the following reasons:

- The process requires substantial capital investment. Due to unknown market potential, private industry will be cautious and slow to commit development resources.
- Due to conservative planning, design, and operation inherent in R&D activities, demonstrations and tests take considerable time.
- Site conditions and contaminants are so numerous that many demonstrations will be needed to refine system planning, design, and operation.

9.1.3 Secondary Objectives

Secondary objectives for the demonstration included validation of scale-up parameters, the use of electrodes as vapor recovery vents, evaluation of vertical and horizontal transport of contaminants through soil, and the removal of semi-volatile organic compounds (such as phthalates) from soil.

Validation of Scale-Up Parameters

As presented in the preceding sections and within the appendices, substantial cost and operational data was gathered during the Preplanning Phase and Phase I. Section 8 presents a conceptual design and operation model based on the data generated during these Phases with detailed cost estimations for Phase II operations. The costs presented reflect actual experience and incorporate few potential cost reductions concepts developed during field activities. These concepts should be further studied and tested and may provide substantial cost reductions for Phase II.

The Use of Excitor Electrodes or Antenna Wells as Vapor Recovery Vents

Recent demonstrations by IITRI and KAI, prior to the Phase I demonstrations, revealed problems with the use of excitor electrodes or antenna wells as vapor recovery vents. Therefore, due to budget limitations, no attempt was made to extract vapors from excitor electrodes or antenna wells .

Evaluation of Vertical and Horizontal Transport of Contaminants through Soil

Contaminant mobilization factors for SVE design were evaluated during the demonstrations by the IITRI tracer test and the measurement of ground pressure during the KAI demonstration. The actual measurement of a permeability increase (with moisture removal) was accomplished for the first time. SVE operational data collected is also valuable for controlling the zone of SVE influence during RFH/SVE operation. Contaminants and moisture can be effectively transported through low permeability soils at depths to 18 feet.

The Removal of Semi-Volatile Organic Compounds (such as Phthalates) from Soil

RFH appears to mobilize heavy SVOCs, but unknown phenomenan are at work. Pyrene and bis(2-ethylhexyl)phthalate appear to have been mobilized and/or removed during operation above 20 feet. Pyrene is a solid at ambient soil temperatures and unaffected by SVE.

9.1.4 General Conclusions

Although IITRI and KAI each experienced equipment, material, and operational problems, each system was basically installed and operated as planned. With minor exceptions, schedules were met and costs remained within budget.

The S-1 demonstration was effectively a hot spot treatment. The sump is a source area for a groundwater plume contaminated by benzene and chlorobenzene. Vapor analysis for the two demonstrations documented the removal of both contaminants. During the KAI demonstration, approximately 17 and 1.5 pounds of chlorobenzene and benzene were extracted, respectively. Theses removals are estimated to be 26.5 percent and 37.5 percent of the total chlorobenzene and benzene at Site S-1 (these percentages do not include removals during the IITRI demonstration). Since the concentrations of these chemicals were actually rising when the system was shut down, additional SVE operation would have removed more.

Limited data from a small number of field (pilot) tests now exist. Criteria for selecting technologies for remedial and corrective actions must be well defined, and that is not the case for RFH/SVE. Often innovative technologies are used only after all other options are rejected.

RFH/SVE is a technology with the potential, through cost reduction, to be a preferred technology. Costs can be decreased to levels competitive with other high technology options (surfactants, steam injection, other in situ heating methods) for enhancing contaminant removal. Costs will decrease significantly as RF heating is further developed. Future commercial applications should require less labor. Technology improvements and increased field experience will result in more efficient operations. The process will become more automated, permitting operation from a remote location.

9.2 RECOMMENDATIONS

1. Further demonstrations (pilot tests) for operational and removal data collection should be performed to define the range of RFH/SVE operating criteria.

2. Future projects should not proceed without competitive bidding. Sites should be selected to allow use of either method. IITRI cannot bid competitively, but the companies licensed to use the triplate method can with IITRI assistance.

3. Sites should be located where conventional SVE has not worked well or has left residuals of heavier contaminants. This situation could provide a valuable comparison of RFH/SVE and conventional SVE.

4. Site S-1 should be monitored in the future to assess the effect on benzene and chlorobenzene concentrations in the groundwater plume, due to the removal accomplished during the demonstrations.

5. Other promising avenues for RFH use should be investigated, for example; existing system enhancement (SVE, bio, pump & treat), deep DNAPL and solids removal and/or mobility enhancement, reduction in toxicity by heat destruction (bond breaking), and fuel spill recovery for recycling.

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APPENDIX A

IITRI DEMONSTRATION

APPENDIX A
IITRI Demonstration

Section

APPENDIX A.1.

IITRI Project Nos. C06770 through C06776,
C06778,C06779, C06781, C06782, C06784, C06786
HALLIBURTON NUS Sub-contract No. GCKF-92-3688-002
September 16, 1994

RADIO FREQUENCY SOIL DECONTAMINATION DEMONSTRATION PROJECT, SITE S-1 KELLY AFB, TX.

Draft Final Report
Volume I of II

Submitted to:

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FOREWORD

This is Volume I of a Draft Final Report for IITRI Project entitled "Radio Frequency Soil Decontamination Demonstration Project, Site S-1 Kelly AFB, Texas." Volume II contains Appendices A through C. The work reported herein was conducted in the period November 2, 1992 to August 1994. The in situ heating portion of the field demonstration experiment was performed from April 3, 1993 to June 3, 1993.

Respectfully submitted,

Harsh Dev
Science Advisor
Energy and Environmental Sciences

Approved:

Guggilam C. Sresty
Manager
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Table of Contents

List of Figures

List of Figures

List of Tables

I. INTRODUCTION

The purpose of this document is to present the results of the in situ radio frequency heating soil decontamination experiment performed at Kelly Air Force Base, Site S-1, San Antonio, Texas. The heating portion of the experiment was performed from April 3, 1993 to June 3, 1993.

A number of different organizations were involved in this project. These were:

- HALLIBURTON NUS: USAF's prime contractor in charge of the demonstration project.
- IIT Research Institute: Subcontractor to HALLIBURTON NUS; technology developer and operator of the in situ heating system; analysis of soil for diesel range petroleum hydrocarbons.
- USEPA SITE Program Office: Technology evaluation and assessment including the analysis of soil samples for contaminant concentration.
- SAIC: USEPA's contractor for SITE program.

A. BACKGROUND

IIT Research Institute (IITRI) has been working with HQ AFCESA/RAVW, Tyndall Air Force Base for many years to develop the RF technology for in situ soil decontamination. The RF technology was originally conceived and developed for uniform heating of large volumes of earth formations for in situ fuel recovery. The technology was modified for soil decontamination purposes. IITRI had a number of contracts over the past years from U.S. Air Force, U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE) to develop various aspects of the technology.

The radio frequency (RF) soil decontamination technology is based on in situ heating of soil through dissipation of electromagnetic energy in the RF band to volatilize the contaminants followed by collection and treatment of the effluent. The RF technology requires two major subsystems: the RF heating system and the effluent containment collection, and treatment (ECCT) system. The RF heating system includes the electrode array and the RF shield, RF power source, and matching network; the ECCT system includes the vapor barrier, vapor collection system, blower, and the vapor treatment system (VTS).

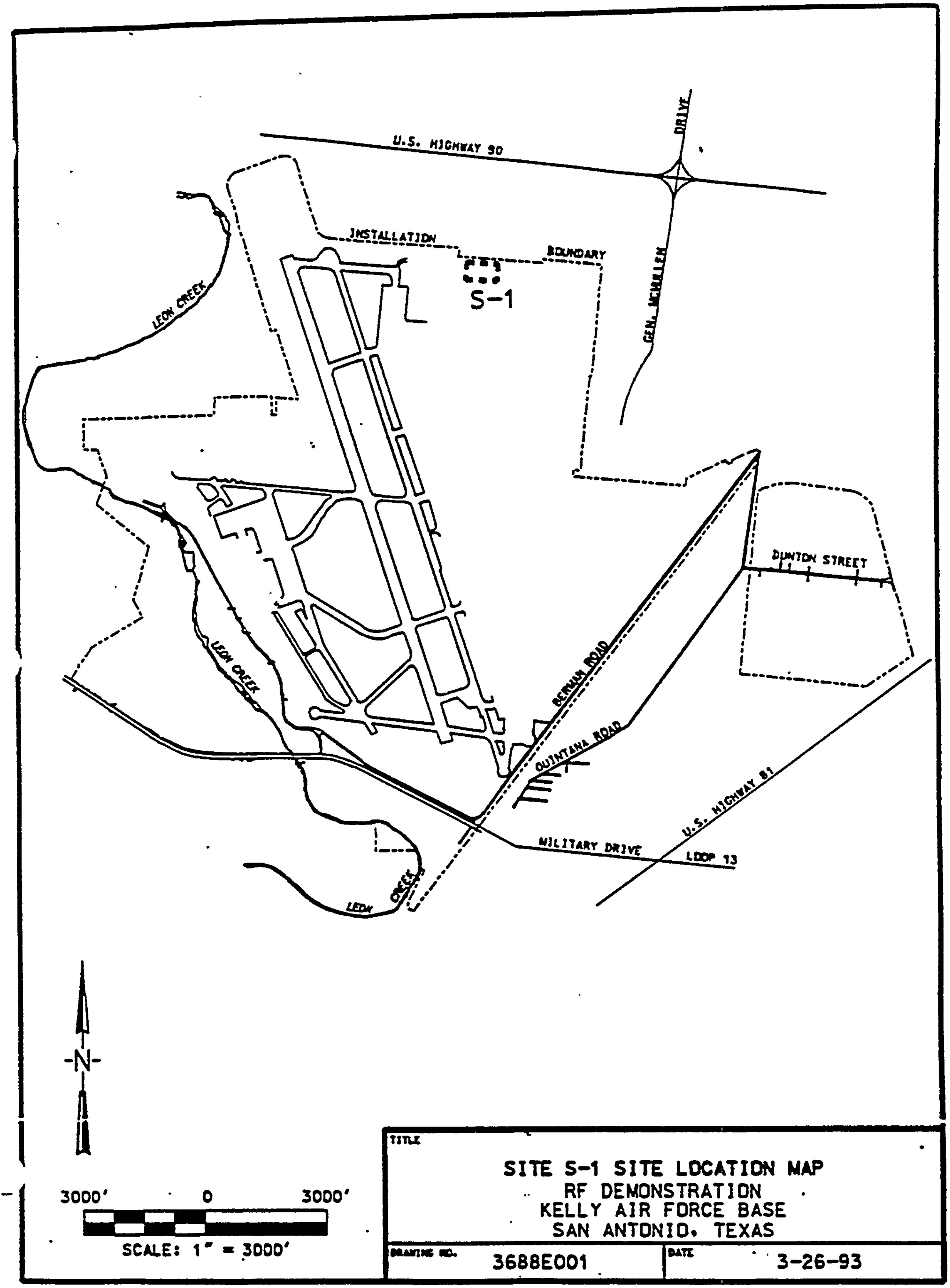
Energy is applied to the soil by energizing an array of electrodes placed in bore holes drilled through the contaminated soil. The electrodes are fabricated from copper and aluminum tubing or pipe. Selected electrodes are perforated and also connected to a vacuum system for the collection of the vaporized contaminants, water vapor and air. A vapor barrier and a RF shield is placed on top of the electrode array. The vapor barrier is needed to prevent emissions of the vaporized contaminants from the heated surface of the soil. The RF shield is needed to reduce RF emissions to low levels so that to avoid RF interference with other electronic systems and also to reduce RF emissions to safe levels.

B. SITE HISTORY

The demonstration experiment was conducted at Site S-1, located near the northern boundary of Kelly Air Force Base (AFB), Texas. This site was used as an intermediate storage area for wastes to be reclaimed off-base. The waste liquids were stored in storage tanks. Mixed solvents, carbon cleaning compounds, petroleum oils and lubricants (POL) were handled at the storage area. The soil is contaminated due to waste spills that occurred during waste transfer and storage tank overflow. The spilled material accumulated in a sump at the bottom of a nearby depression in the ground. The site was used from 1960 to 1973. It is reported that the depression was back filled with fill material after site operations were terminated. Figure 1 illustrates the general location of the site on Kelly AFB.

C. PROJECT BACKGROUND

Work was initiated by IITRI on this project on November 2, 1992. Prior to this, IITRI had completed a bench scale treatability study (Reference 2a) to determine the feasibility of the removal of diesel range TPH from Site S-1 soil. In the same project (Reference 2b), the design of a demonstration system based on 120 kW of input RF power was made. Subsequently, the design was revised in this project for an input power level of 40 kW in order to allow the demonstration to be done with IITRI's RF power source.



TITLE

SITE S-1 SITE LOCATION MAP
RF DEMONSTRATION
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

DRAWING NO. 3688E001

DATE 3-26-93

Figure 1. Location Map for Site S-1.

II. DEMONSTRATION OBJECTIVES

The main objectives of the field demonstration test were the following:

- Obtain a greater than 90 percent removal efficiency from the soil for the following four semi-volatile organic compounds: 2-methynaphthalene, naphthalene, 2,4,6-trichlorophenol, and 2-methylphenol
- Obtain greater than 95 percent removal efficiency from the soil for the following four volatile organic compounds: benzene, toluene, ethylbenzene, and chlorobenzene
- Obtain greater than 90 percent removal of the diesel range total petroleum hydrocarbons (TPH).
- Measure the removal of three ring PAHs, bis(2-ethylhexyl)phthlate and other semi-volatiles found at the site.

It was planned to heat the soil to an average temperature of 150° C. This treatment temperature was selected based on the results of a laboratory treatability study in which the removal of diesel range organics from samples of site S-1 soil was studied.

The RF in situ soil decontamination process was tested by heating a soil volume of dimensions: 17.5 ft long, 10 ft wide and 20 ft deep. In the original design the depth of the heated zone was 24 ft, but this was changed during system installation. The change was necessary because ground water table was shallower than expected.

This project was accomplished by performing the following 13 tasks:

Task 1:	Scale Down Design and Document	(C06770)
Task 2:	Revise Work Plan and Schedule	(C06773)
Task 3:	Review Health and Safety Plan	(C06774)
Task 4:	Review of Sampling and Analysis Plan	(C06775)
Task 5:	Assist in Obtaining Permits	(C06771)
Task 6:	Procurement and Equipment Fabrication	(C06772)
Task 7:	System Installation	(C06776)
Task 8:	Start up and Shakedown of System	(C06778)
Task 9:	Perform Demonstration and Cool Down	(C06779)
Task 10:	Decontamination and Demobilization	(C06786)

Task 11: Review Data, Cost Analysis and Write Final Report (C06781)
Task 12: Attend Meetings (C06782)
Task 13: Analyze Pre-Demonstration Soil Samples (C06784)

III. SITE DESCRIPTION[1]

A. REGIONAL SETTING

1. Geography

Kelly AFB lies in the western portion of the Gulf Coastal Plain, a gently undulating prairie with elevations ranging from 450 feet to approximately 700 feet above the National Geodetic Vertical Datum (NGVD). The plain slopes to the Southeast toward the Gulf of Mexico. Elevations at Kelly AFB vary from 730 to 620 feet above NGVD. Lower elevations lie along Leon Creek at the southern boundary of the base.

The San Antonio area lies within two distinct physiographic regions, the Edwards Plateau section of the Great Plains Province and the western Gulf Coastal Plain. The southwest-northeast trending Balcones Escarpment divides the two regions. The plateau serves as a recharge area for surface waters flowing to aquifers and streams extending through the San Antonio area.

2. Geology

The region surrounding Kelly AFB is underlain by Quaternary alluvium over a thick stratigraphic sequence of Cretaceous sediments. The alluvium consists of mixtures of clay, silt, and gravel. These deposits are typically 10 to 35 feet thick. The Cretaceous unit is the Navarro Group clay. The Navarro Group clay and other limestone and shale units form a thick sequence between the alluvium and the underlying Edwards Group limestone.

3. Hydrology

Surface Drainage

Surface runoff at Site S-1 drains eastward to Apache Creek, approximately 2.5 miles away. Apache Creek flows into San Pedro Creek, which in turn flows into the San Antonio River.

Groundwater

Kelly AFB lies above two groundwater aquifers. The uppermost aquifer lies within the lower strata of the Quaternary alluvium. Although this aquifer is capable of providing potable

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[1] Material in this Section is taken from Preplanning Report for the Demonstration of Radio Frequency Soil Decontamination -- Site S-1, HALLIBURTON NUS, USAF Contract No. F33615-90-D-4011, Delivery Order No. 0007, November 1993.

water, the quality and quantity are variable and questionable. The second aquifer is contained within the Edwards Group and is separated from the first aquifer by the Navarro Clay. The Texas Legislature established the Edwards Aquifer Underground Water District in 1959 to provide for the systematic planning and protection of groundwater in this aquifer. The EPA designated the Edwards a sole source aquifer in 1975 (40 CFR 149).

B. SITE S-1

1. Location

Site S-1 lies in the northern part of Kelly AFB, immediately south of Growdon Drive, north of West Thompson Drive, and west of a railroad spur near Building 1592.

2. Site History

Site S-1 served as an interim storage area for wastes to be reclaimed off base from the early 1960s to 1973. The western two-thirds of the site served as a temporary storage for electrical transformers and scrap metal. Liquid wastes, including mixed solvents and POLs were stored in above-ground tanks. Any spillage that occurred during storage, loading, and unloading flowed into a low area near the tanks. The site was later regraded after the abandonment and removal of the tanks.

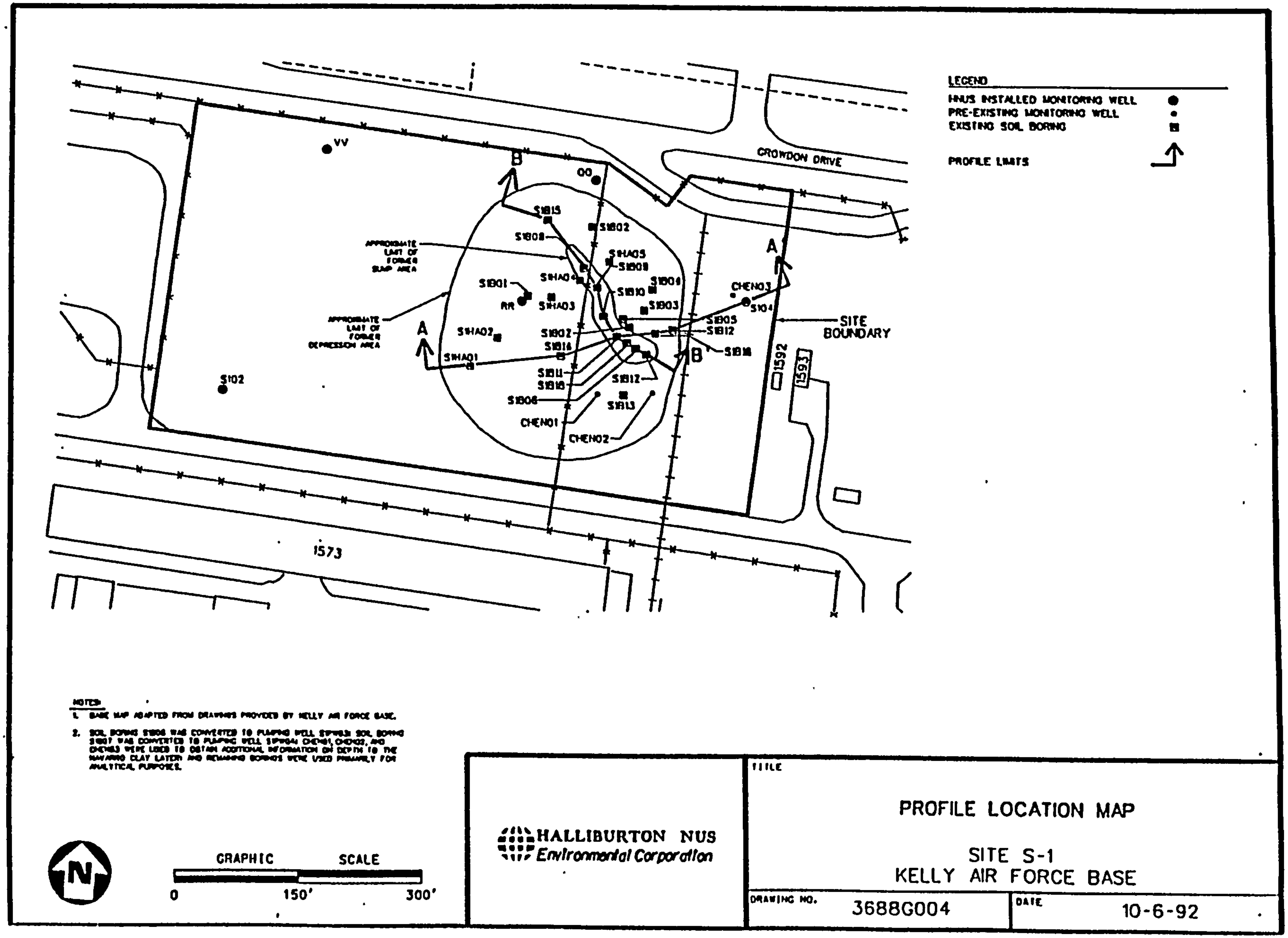
Investigators observed a circular depression on old aerial photographs and investigated it as a possible dump site. No landfill material was found, and the depression area and a sump located within the depression were leveled with fill material. This waste oil sump is shown Figure 2 as a northwest - southeast trending region covering an area of approximately 40 by 150 feet. Further drilling has revealed a northwest-southeast-trending extension of the sump on the northeast side of the site.

3. Topography and Drainage

Site S-1 is generally flat, with surface elevations ranging from 690 to 691 feet above NGVD. Gravel covers the area over the former sump, but grass covers most of the remainder of the site. Rainfall at the site is likely to pool on the surface because of the slight topographic relief and low infiltration rates.

4. Geology

The alluvial material at Site S-1 consists of an upper layer of dark brown to black clay typically 7 feet thick overlying either a reddish brown silty clay or a clayey gravel, sand/gravel unit. The reddish brown silty clay lies in the southeast corner of the



NOTES:
1. BASE MAP ADAPTED FROM DRAWINGS PROVIDED BY KELLY AIR FORCE BASE.
2. SOIL BORING S1B06 WAS CONVERTED TO PUMPING WELL S1PW03. SOIL BORING S1B07 WAS CONVERTED TO PUMPING WELL S1PW04. CHEN01, CHEN02, AND CHEN03 WERE USED TO OBTAIN ADDITIONAL INFORMATION ON DEPTH TO THE NAVARRO CLAY LAYER AND REMAINING BORINGS WERE USED PRIMARILY FOR ANALYTICAL PURPOSES.

HALLIBURTON NUS
Environmental Corporation

TITLE
PROFILE LOCATION MAP

SITE S-1
KELLY AIR FORCE BASE

DRAWING NO. 3688G004
DATE 10-6-92

Figure 2. Site S-1.

site and is usually 7 to 10 feet thick. The coarse-grained unit underlying the remainder of the site consists of surrounded to subangular limestone and chert.

Results from two grain size analyses of the sand and gravel unit collected from a boring adjacent to Site S-1 (APO2) show that the alluvial aquifer is approximately 40% sand, 40% gravel, and 20% fine-grained material. These results as well as other geotechnical samples collected at Kelly AFB demonstrate a significant variability in the porosity and permeability of the alluvium.

Much of the alluvium was removed and replaced by fill material in the former depression area. The fill material is dark brown to black gravely clay with occasional zones of sand and silt covering an area approximately 150 by 300 feet. The depth ranges from 0 feet at the edge of the sump to 25 feet at its center. Large limestone and chert gravels up to 3 inches in diameter inhibited recovery during drilling throughout most of the unit.

The regional aquitard, the Navarro Group clay, lies 28 to 33 feet below the former depression area. Under Site S-1, the Navarro clay is a mottled, orange-brown to gray, stiff, plastic clay with crude laminae. A few borings have revealed silty horizons within the clay.

5. Hydrology

Water level measurements recorded between mid-1989 and late-1990 indicate that the direction of groundwater flow is towards the northeast. The water table beneath the site ranged from 25 to 30 feet below the surface, with a saturated aquifer thickness of 3 to 6 ft. The maximum water level fluctuation observed in the vicinity of Site S-1 was 3.25 ft. Northeast of the site,water level measurements made on April 30, 1992 indicated that groundwater gradient was 0.016 ft/ft, much higher than the 0.003 ft/ft gradient found immediately downgradient of the site. A local high are in the Navarro clay in combination with a groundwater mound effect appears to be the cause for the steep gradient across the sump.

6. Levels and Extent of Contamination

Soils

Site S-1 analytical results show significant contamination in the location of the former sump. The contamination consists of polychlorinated biphenyls (PCBs) in surface soils (9,000 μg/kg) and volatile organic compounds (VOCs) and semivolatile organics in the subsurface. The compound groups most prevalent in the subsurface are halogenated benzenes, methyl phenols, phthalates, and polynuclear aromatic hydrocarbons (PAHs).

Compounds with the highest concentrations in the soil are 1,2-dichlorobenzene (1,200,000 µg/kg) and 1,4-dichlorobenzene (720,000 µg/kg). Table 1 shows the maximum concentration of each VOC and semivolatile compound detected by fixed-base or field laboratory analysis.

Horizontally, the contamination at Site S-1 is largely confined to a 110 by 120-foot area surrounding the sump. Vertically, most of the organic contamination in the soil lies in a 10 to 15-foot thick horizon 17 to 33 feet below the surface in boring S1B10 and S1B11. Although surface staining is evident in aerial photographs, little contamination is found above a depth of 10 feet. Another zone of contamination, isolated from the lower unit, was detected in boring S1B08 at a depth of approximately 12 feet. The lower extent of the contamination in this isolated area could not be determined because of poor sample recovery.

Table 1. Organic Compounds Detected in Soils, Site S-1, Kelly AFB, Texas

Volatile Organics	Chemical Formula	Molecular Weight	Boiling Point at 1 atm., (°C)	Specific Gravity	Temperature at which Vapor Pressure is 1 mm Hg (°C)	Vapor Pressure at 20°C (mm Hg)	Maximum Concentration (µg/kg)
1,2-Dichlorobenzene	$C_6H_4Cl_2$	147.01	180	1.3048	20	1	5,100
1,4-Dichlorobenzene	$C_6H_4Cl_2$	147.01	174	1.2475	<50	0.6	5,100
1,3-Dichlorobenzene	$C_6H_4Cl_2$	147.01	173	1.2884	12.1	2 (25 deg)	1,800
Styrene	C_8H_8	104.2	145	0.9060	-7	5	1,100
Ethylbenzene	C_8H_{10}	106.2	136	0.8670	-9.8	7.1	2,700
Chlorobenzene	C_6H_5Cl	112.6	132	1.1058	-13	9	3,200
2-Hexanone	$C_6H_{12}O$	100.2	128	0.8113	7.7	2	32
Tetrachloroethene	C_2Cl_4	165.8	121	1.6227	-20.6	14	4
Toluene	C_7H_8	92.2	111	0.8669	-26.7	22	6,800
Trichloroethene	C_2HCl_3	131.4	87	1.4642	-43.8	57.8	12
Benzene	C_6H_6	78.1	80	0.8787	-36.7	76	1,200
2-Butanone	C_4H_8O	72.1	80	0.8054	-48.3	77.5	53
1,1,1-Trichloroethane	$C_2H_3Cl_3$	133.4	74	1.3390	-52	100	24
Vinyl Acetate	$C_4H_6O_2$	86.1	72	0.9317	-48	83	4
Chloroform	$CHCl_3$	119.4	62	1.4832	-58	160	17
Trans-1,2-Dichloroethene	$C_2H_2Cl_2$	96.9	48	1.2565	-65.4	265	200
Methylene Chloride	CH_2Cl_2	84.9	40	1.3266	-70	348.9	130

Table 1. Organic Compounds Detected in Soils, Site S-1, Kelly AFB, Texas (Continued)

Semi-Volatile Organics/PCBs	Chemical Formula	Molecular Weight	Boiling Point at 1 atm., (°C)	Specific Gravity	Temperature at which Vapor Pressure is 1 mm Hg (°C)	Vapor Pressure at 20°C (mm Hg)	Maximum Concentration (µg/kg)
Aroclor-1260	Varies	≈370	385 - 420	1.5660		6E-5 (25 deg)	6,700
Benzoperylene	$C_{22}H_{12}$	276.3	>500			1.0E-10 (25 deg)	230
Indeno-(1,2,3)-Pyrene	$C_{22}H_{12}$	276.3	536			1.0E-10 (25 deg)	190
Dibenzo Anthracene	$C_{22}H_{14}$	278.4	524	1.2820		1.00E-10	160
Benzo Pyrene	$C_{20}H_{12}$	252.3	495	1.3510		5.00E-07	390
Benzo Fluoranthene	$C_{20}H_{12}$	252.3	480			5.00E-07	700
Chrysene	$C_{18}H_{12}$	228.3	448	1.2740		6.30E-07	580
Benzo Anthracene	$C_{18}H_{12}$	282.3	439	1.2740		2.00E-09	520
Pyrene	$C_{16}H_{10}$	202.3	393	1.2710		2.5E-6 (25 deg)	940
Fluoranthene	$C_{16}H_{10}$	202.3	375	1.2520		5.00E-06	9,000
Anthracene	$C_{14}H_{10}$	178.2	340	1.2830	145	2.00E-04	130
Pentanthrene	$C_{14}O_{10}$	178.2	340	0.9800	118.2	2.10E-04	920
Acena Phthylene	$C_{12}H_{12}$	152.2	265	0.8988		2.90E-02	20
2,4,6-Trichlorophenol	$C_6H_3Cl_3O$	197.5	246	1.4900	76.5	1.7E-2 (25 deg)	100,000
2-Methlynaohthalene	$C_{11}H_{10}$	142	241	1.0058			12,000
Di-n-Octyl Phthalate	$C_{24}H_{38}O_4$	390.6	220	0.9900		1.4E-4 (25 deg)	2,800
Naphthalene	$C_{10}H_8$	128.2	218	1.0253	52.6	5.40E-02	10,000
Bis(2-Ethylhexyl)-Phthalate	$C_{24}H_{38}O_4$	390.6	218	0.9843		2.00E-07	57,000
2,4-Dimethylphenol	$C_8H_{10}O$	122.2	212	0.9650	51.8	6.20E-02	2,400
2,6-Dimethylphenol	$C_8H_{10}O$	122.2	203	0.8600	58		2,200
2-Methyphenol	C_7H_8O	108.1	191	1.0273	38.2	0.3 (25 deg)	8,100
Phenol	C_6H_6O	94.11	182	1.0722	40.1	0.2	3,200

IV TECHNOLOGY DESCRIPTION

A. PROCESS DESCRIPTION

In situ radio frequency (RF) heating and soil decontamination is a two-step process. These steps are: heating of soil to the treatment temperature, and recovery and treatment of the volatilized contaminants. Once the soil temperature is elevated above 40° to 50° C, these two steps work simultaneously.

In situ heating is accomplished by energizing an array of electrodes emplaced in bore holes drilled through the soil. The electrode array is supplied with electromagnetic (EM) energy in the RF band, typically between 2 and 13 MHz. The actual operating frequency is selected from the available ISM band frequencies in the above range. Typically three rows of electrodes are utilized. The two outer rows are called the guard electrodes and they serve to confine the energy to a well defined volume of the soil. The center row is called the excitor row. Figure 3 is an illustration of the in situ RF heating process depicting the electrode rows and the vapor collection system.

In RF heating, mechanism of heat generation is similar to that of the microwave oven. Electrical energy is dissipated volumetrically and converted to thermal energy due the absorption of EM energy by moisture and soil. The primary mechanism of energy absorption is the rotational and vibrational displacement and physical distortion of dipoles induced in polar molecules. The dielectric properties of soil determine the amount of RF power that can be dissipated in the soil. These properties are the relative dielectric constant (ϵ_r) and the loss tangent. The loss tangent, $\tan(\delta)$ is defined as $\sigma/(\omega\epsilon_o\epsilon_r)$ where σ is the apparent conductivity, ω is the frequency of the applied electric field, radians/sec, and ϵ_o is the permittivity of free space, and it equals 8.85×10^{-12} farads/meter. All the dielectric properties are a function of soil temperature, the frequency of the applied field and the composition of the major components. The amount of RF power dissipated in the soil is directly related to the frequency of the applied electric field, square of the amplitude, the relative dielectric constant and the loss tangent.

Due to its volumetric nature, the process does not depend upon conductive transport of thermal energy, even though thermal conduction does occur. With an appropriate array design and operating strategy, it is theoretically possible to obtain uniform heating of the soil volume enclosed within the two outer rows of the excitor array.

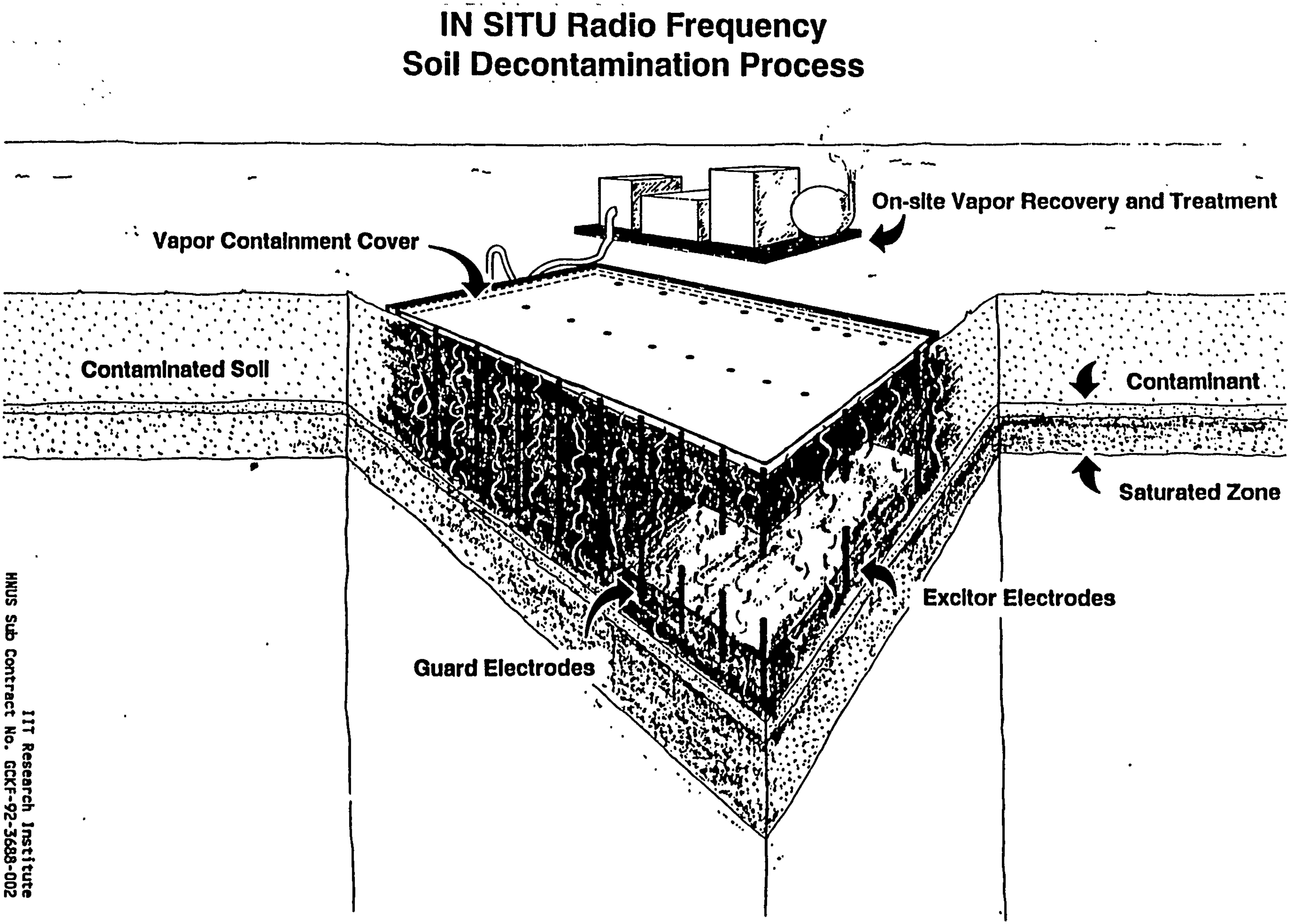

IN SITU Radio Frequency
Soil Decontamination Process

Figure 3. Artist's Illustration of the RF Process.

As the soil heats up, the soil moisture and the organic contaminants begin to vaporize and they will eventually boil depending upon the final temperature and their boiling points. The vaporized and boiled materials are removed from the soil matrix by applying a vacuum to gas collection points. These points are vented electrodes placed in the array used to heat the soil. The preferred location of the gas collection electrodes is in the middle of the electrode array. This is the best location because the temperature rises first and reaches a higher level in the central row of electrodes. Collection of hot vapors from the central electrode row at high operating temperatures is however, technically challenging, because collection piping must be non-metallic and poses suitable dielectric insulating properties so as to prevent arcing and radiation of RF energy.

Vapors may also be collected from the surface of the heated zone as well as from the two outer rows of the electrode array. Collection from the two outer rows poses less electrical design challenges because metallic piping may be used here. Gases and vapors produced in the soil volume will also rise directly to the surface due to diffusion, and buoyancy. These may be collected at the surface by means of horizontal perforated gas collection lines placed on the surface of the soil. Depending upon their positioning these lines may be made from metal.

A vapor containment barrier is needed to prevent emissions from the heated soil surface. Typically this barrier must possess high temperature operating characteristics, be impermeable to organic vapors, and must be a suitable dielectric insulator. An elastomeric material like silicon rubber sheets can be used.

Figure 4 is a conceptual block diagram depicting the RF process. Electrical energy from the utility grid is converted to the high frequency electromagnetic energy by a RF power source. This source can be a modified radio transmitter, an amplifier or an oscillator. RF power sources can be trailer mounted for easy transportation to the waste sites. The output of the RF power source is conveyed to a matching network which optimizes the transfer of power between the source and the load. The load comprises of the electrode array along with the soil.

The recovered gas stream may need treatment prior to discharge to the environment. The type of treatment and clean-up required depends on the nature, concentration and total amount of contaminants present in the gas stream. Any proven technology for the clean up of the vent gas stream may be used, provided it can be built in transportable trailer mounted modules. Several options for gas treatment are available:

- Open release of dilute streams of hydrocarbons

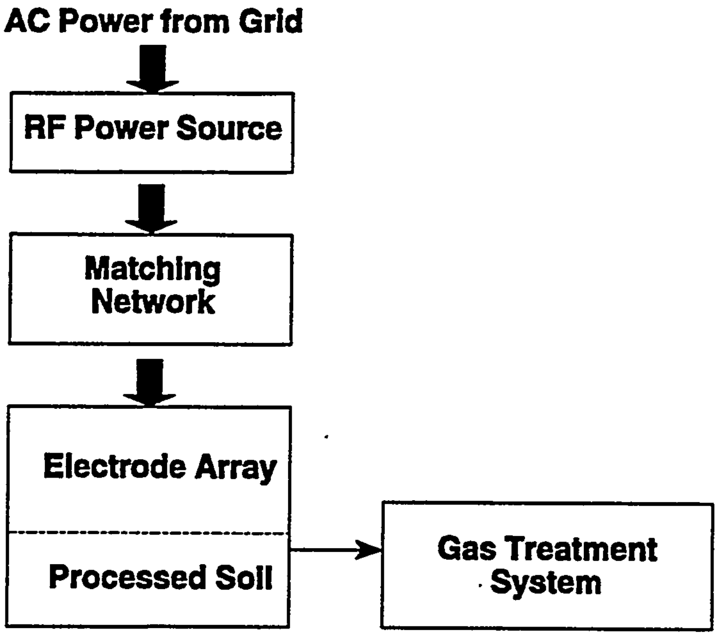


Figure 4. Conceptual Block Diagram of the RF Process

- Cooling, condensation, carbon treatment
- Incineration
- Catalytic incineration
- Appropriate combination of above

During the in situ heating of soil several different phenomena occur which help in the vaporization and recovery of the contaminants. First, there is the development of effective permeability to gas flow in the soil matrix. Second there is the increased sweep of air and steam through the treatment zone and third, there is the possibility of steam distillation reducing the boiling point of a multi-phase mixture of organic and aqueous phases.

The effective permeability to air flow increases as the soil water is removed by evaporation and boiling, the vacated pore space becomes available for the flow of steam, vapors and air.

As the permeability to gas flow increases, a sweep of air or steam can be easily established in the soil to help facilitate the removal of organic vapors which are in the soil pore space. The air flow is induced in the soil by the application of vacuum. The steam flow is created by the applied vacuum and boiling of native soil moisture present in the heated volume and of any new water entering the heated zone from the surrounding soil. For some combinations of soil types and contaminants the effect of steam flow may be more beneficial in the removal of the contaminants from the soil matrix than an equivalent flow rate of air.

Figure 5 is a graph depicting the increased permeability to the flow of nitrogen gas in a small sample of clayey soil packed inside a cylindrical device for measuring permeability. The figure illustrates that as the pore saturation of water is reduced, the permeability to air flow increases. It does not matter how the water is removed from the soil pores. Data for two operating modes is presented. In the first, the soil moisture is removed at elevated temperature by heating the core. In the second operating mode, the soil moisture was removed by a nitrogen sweep through the core which was maintained at room temperature. The first operating mode is of course faster in obtaining the permeability change.

Steam distillation of organic liquids such as benzene, xylene, etc. occurs when a mixture of the organic liquid and water is brought to a boil under condition where two or more liquid phases co-exits. Under these conditions, the mixture boils at a lower temperature than that of either of the two phases when present alone. The mixture boils when the partial pressure of all the vapor phase components above the mixture equals 760mm Hg or the prevailing atmospheric pressure. In a multi-liquid-phase mixture, each liquid phase exerts its own vapor pressure, which contributes

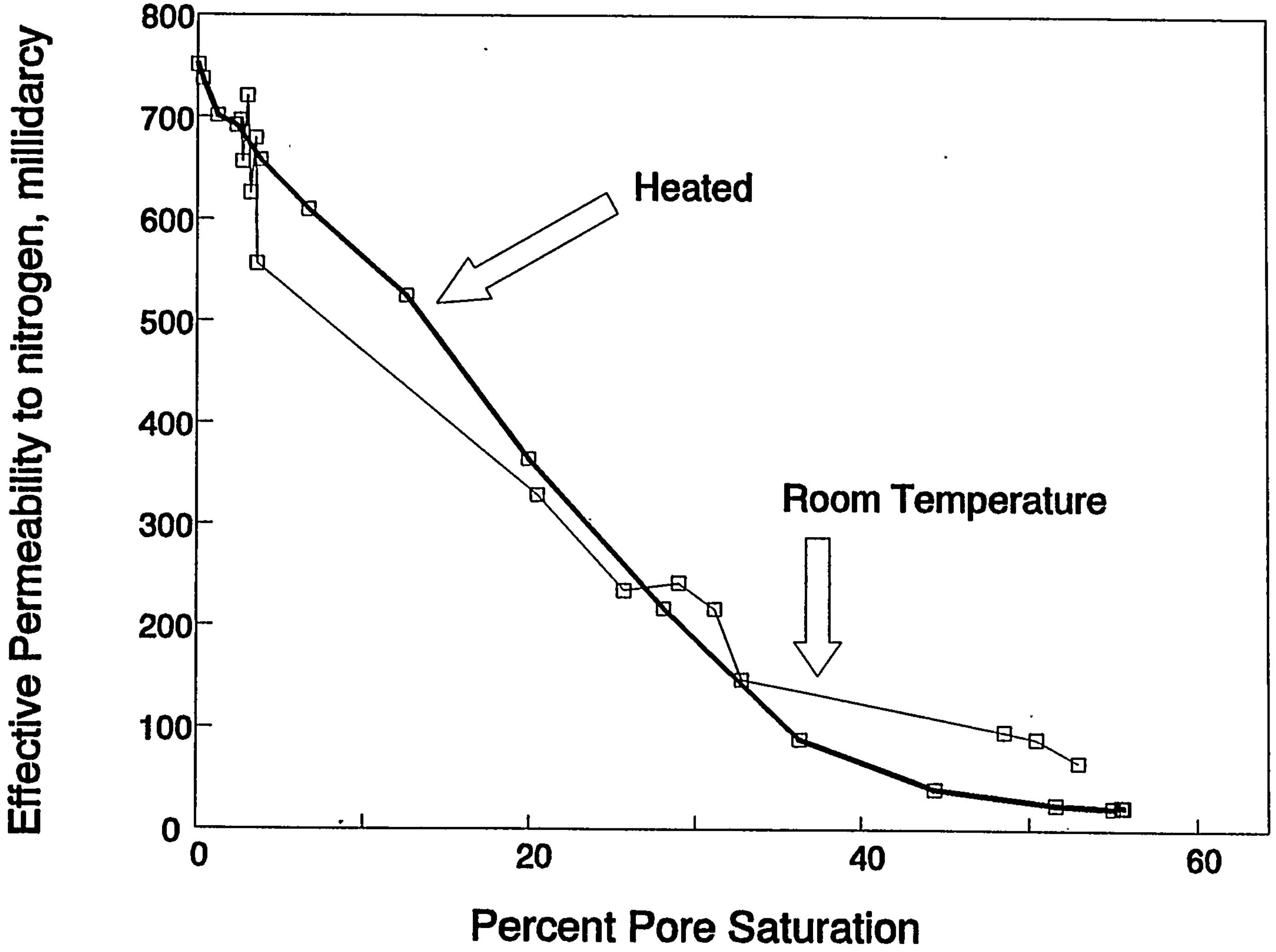


Figure 5. Soil Permeability as a Function of Pore Saturation

TABLE 2. BOILING POINT REDUCTION
(Steam Distillation Conditions)

Contaminant	Normal B.P., °C	Mixture B.P., °C	Steam/ Contaminant lb/lb
1,1,1 Tricholoroethane	74.1	64.4	0.04
Benzene	80.1	68.3	0.09
Toluene	110.6	83.9	0.24
Tetrachloroethylene	120.8	87.7	0.19
Bromoform	150.0	94.3	0.31
Hexachloroethane	186.0	98.7	1.57
Pentadecane	270.5	99.95	30.10

each liquid phase exerts its own vapor pressure, which contributes to the total pressure above the liquid surface. Due to this reason the mixture boils at a temperature less than that of either of the liquid phases present. Table 2 lists the pure component and the mixture boiling points when several common environmental contaminants are subjected to steam distillation conditions.

B. ENERGY REQUIREMENTS

The theoretical amount of thermal energy required to heat soil depends upon the following factors:

- Initial soil temperature
- Final treatment temperature
- Initial Soil moisture content
- Initial hydrocarbon content
- Thermal properties of moist and dry soil

The actual amount of thermal energy needed for the heating of soil depends upon the factors listed above and heat loss. Heat loss from the heated volume can occur in the following ways:

- conduction from the heated soil surface
- conduction from the sides and bottom of the heated block of soil
- heating of any air flowing through the hot zone
- convection and radiation from the heated surface

system and gets converted to steam represents an additional heat load, the economic penalty may be off set by the beneficial aspects of steam sweep on the removal of the contaminants from the soil. In any event, the rate of water intrusion has to be limited to reasonable level such that the power source can provide the necessary extra energy, otherwise the entire volume will not reach the desired temperature or else experience a temperature drop.

In a prior study (Reference 1) the heat loss from the first three mechanism listed above was estimated for heating of large blocks of soil to a depth of 20 ft. In this study approximately 1 acre of soil was heated at the same time using a large RF power source with heating time ranging from 0.25 to 0.5 year. Under such conditions it was estimated that the actual energy required can be 25 percent higher due to heat loss, than the theoretical amount needed.

The additional energy required due to water intrusion was not considered because it is a site specific variable and water intrusion may be controlled by other means. On the other hand it is almost impractical to reduce heat losses due to conduction while operating under in situ conditions.

Table 3 gives an estimate of the theoretical amount of thermal energy needed for heating up one ton of soil to a temperature of 150° C. The following assumptions were made: the soil contains 10 to 20 percent initial moisture, initial contaminant concentration of 1%, average contaminant latent heat of vaporization of 200 Btu/lb; and no water intrusion. Table 3 shows that when the soil contains 10 percent water, 60 percent of the theoretical energy is required to boil the water. When the soil contains 20 percent initial water, 75 percent of the theoretical energy is required to boil the water. The energy needed to heat the soil after accounting for the conductive heat losses may be estimated from Table 3 by adding 25 percent to the amounts shown. Thus the thermal energy needed is in the range of 120 to 190 kWh/ton of soil heated. The amount of RF energy required to heat the soil is also equal to the above estimate due to extremely low losses for RF transmission and 100 percent conversion from RF to thermal energy.

The amount of AC power needed from the utility to heat the soil is a function of the RF power requirements and the AC to RF conversion efficiency of the RF power source. The conversion efficiency ranges from 45 to 65 percent depending upon the type and design of the RF power source. Older, tube-based RF transmitters like IITRI's 40 kW unit, have a conversion efficiency of about 45 percent. Modern tube units have an efficiency ranging from 60 to

TABLE 3. THEORETICAL ENERGY REQUIRED TO HEAT SOIL TO 150° C

	Soil Moisture, %			
	10%		20%	
	Btu/ton	kWh/ton	Btu/ton	kWh/ton
Sensible heat required to reach 100° C	88,200	25.84	88,200	25.84
Heat Required to boil water	194,000	56.84	388,000	113.68
Heat required to boil contaminants	4,000	1.17	4,000	1.17
Heat required to raise temperature from 100° to 150° C	40,050	11.73	35,550	10.42
Total Heat Required	326,250	95.58	515,750	151.11

design of the RF power source. Older, tube-based RF transmitters like IITRI's 40 kW unit, have a conversion efficiency of about 45 percent. Modern tube units have an efficiency ranging from 60 to 65 percent. Future solid state units are projected to have conversion efficiency in the range of 70 to 75 percent.

The above discussion does not allow for the AC power requirements of the vapor treatment system. These requirements are estimated to be low, of the order of 10 percent of that needed for heating soil.

V. SYSTEM DESIGN AND INSTALLATION

The system as designed and implemented in the field at Site S-1 is described in this section. The purpose of this design was to heat soil to an average temperature of 150°C in order to meet the objectives listed in Section 2. The temperature of 150°C was selected based on the removal of diesel range organics observed during the soil treatability study done by IITRI in a prior project (Reference 2). The results of the treatability study are also summarized below.

A. TREATABILITY OF S-1 SOIL FOR THE REMOVAL OF DIESEL RANGE ORGANICS

1. SOIL SAMPLE DESCRIPTION

Three new bore holes were made by HALLIBURTON NUS on October 19, 1991, at the southeastern corner of site S-1. Two of these bore holes were on the center line of the pit while one was outside. Continuous coring was done during the drilling of these bore holes by means of a hollow stem auger drill. Table 4 summarizes the core recoveries, field OVA readings, HALLIBURTON NUS' analysis for TPH from selected core intervals, etc. Soil needed for the treatability study was selected from the samples sent to IITRI. In Table 4 the core sample used for each of the five experiments is also indicated by means of the experiment number.

Table 5 provides a list of other contaminants found in the new borings. As the data in Tables 4 and 5 show, TPH with a concentration of up to 980 ppm is by far the most abundant contaminant present in the soil samples analyzed for this study. Other contaminants listed in Table 5 are present at levels which are approximately one thousandth the concentration of TPH. The results from the samples obtained from SB-16 show that the concentrations are considerably lower 5 to 6 ft outside the original estimated location of the sump boundary. Thus SB-16 may indeed be outside the original boundary and also outside the zone of current contamination. The field demonstration should be performed in the southern edge of the sump, near the location of borings SB-17 and SB-18.

2. Treatability Study Objectives and Approach

Soil treatability experiments were performed to determine the required treatment conditions for the removal of petroleum hydrocarbons found in soils obtained from borings made in Site S-1, Kelly AFB. The main focus of the study was to determine the

TABLE 4. FIELD SCREENING AND LAB. ANALYSIS OF CORE SAMPLES OBTAINED ON 10/19/91, SITE S-1, KELLY AFB
(All results in ppm)

Depth Interval	SB-17				SB-18				SB-16			
	TPH ppm	Moist %	OVA ppm	Reco very ft	TPH ppm	Moist %	OVA ppm	Reco very ft	TPH ppm	Moist %	OVA ppm	Reco very ft
2-7	400	20.3	40-700	4.5	<20	19.5	300-700	4 Exp5	<20	12.2	30-80	1.9
7-12	NA	NA	20	1	<20	24.7	100-1000+	4.6 Exp4	<20	9.2	5-80	4.5
12-17	NA	NA	10-40	1.0	<20	26.7	300-1000+	5 Exp2	NA	NA	0	0.8
17-22	980	8.5	200-300	2.0 Exp1	NA	NA	200-300	1.5 Exp3	NA	NA	15	0.4
22-27	NA	NA	40	0.8	110	15.7	500-700	2.5	-	-	-	0.0
27-32	-	-	-	0.0	NA	NA	700	2	NA	NA	0-2	0.8
32-37	-	-	-	0.0	<20	22.1	10-100	3	-	-	-	0.0

TPH: Total petroleum hydrocarbons as analyzed by HALLIBURTON NUS.
OVA: Field measurement for hydrocarbons
NA: Not Analyzed
-: No Sample Recovery

TABLE 5. CONCENTRATION (μg/kg) OF SEMI-VOLATILES IN BORINGS SB-16 TO SB-18

Chemical Name	SB-16	SB-17	SB-18		
	2-7′	2-7′	2-7′	22-27′	32-37′
1,2,4-trichlorobenzene				190	
1,2-dichlorobenzene				3600	230
1,3-dichlorobenzene		200		1600	
1,4-dichlorobenzene		1100		9300	
2-methylnaphthalene		2300		4400	
Benzo(a)anthracene	170				
Benzo(b)fluoranthene	260				
bis(2-ethylhexyl)phthalate		13000	640	1800	
Di-n-butylphthalate		200	250		
Fluoranthene	430	300			
Naphthalene		140			
Phenanthrene		200			
Pyrene	350				
Solids, wt %	87.8	79.7	80.5	84.3	77.7

Blank cells indicate the contaminant was below its quantitation limit

In SB-16, 7-12 ft all were below quantitation limit

In SB-17, 17-22 ft all were below quantitation limit

In SB-18, 7-12, and 12-17 all were below quantitation limit temperature and time conditions necessary to remove at least 90 percent of the total petroleum hydrocarbons (TPH) as analyzed by the California DHS method (Reference 3) for TPH.

The analytical method allows for determination of TPH as gasoline or as diesel. In this study the TPH was reported as diesel to determine the condition necessary for the removal of higher boiling components represented by diesel. Most of the hydrocarbons in diesel contain nine to 21 carbon atoms. They are primarily straight and branched chain alkanes, alkyl benzenes and PAH. The boiling point range of the straight chain alkanes is in the range of 150°-376°C; the lowest boiling branched chain alkane in diesel boils at 306°C; the alkyl benzenes boil in the range of 80° to 255°C, and the PAHs boil in the range of 218°C to greater than 500°C. Thus most of the diesel components can be classified as semi-volatiles. Based on previous treatability studies performed by IITRI on clayey soils it is anticipated that lower boiling volatile organics would have even better removal efficiency under the same conditions that give greater than 90 percent removal for diesel range TPH.

The laboratory approach to the treatability study attempts to simulate the temperature and gas flow conditions that occur in situ. This approach was developed at IITRI over the last five years and was used to develop conditions for the successful field experiment at Volk ANGB (Reference 4). The treatability experiments were performed by packing the clayey soils of Site S-1 into a 1.5-in. diameter pipe. The soil column was heated with externally wrapped heating tapes. Gas flow was simulated by injecting at a controlled rate either nitrogen or superheated steam at the base of the soil column.

Under in situ conditions, as soil is heated and the native moisture is removed from the soil pores, the effective permeability to gas flow increases. Thus a gas and steam sweeping action is established in the heated zone due to the vacuum imposed for the collection of the contaminant gases, vapors and steam. The gas and steam sweep thus established helps to increase the rate of contaminant removal from the soil matrix. In the laboratory this sweeping action is simulated by injection of nitrogen, air or steam at the base of the soil column.

3. Experimental Apparatus

The treatability experiments were performed by heating a column of soil packed into a 1.5-in. diameter stainless steel pipe. The soil inside the pipe was heated by means of heating tapes wound around the pipe. Thermocouples were used to measure the temperature of the soil inside the pipe. The experimental set up is illustrated in Figure 6. The hot gases and vapors formed upon

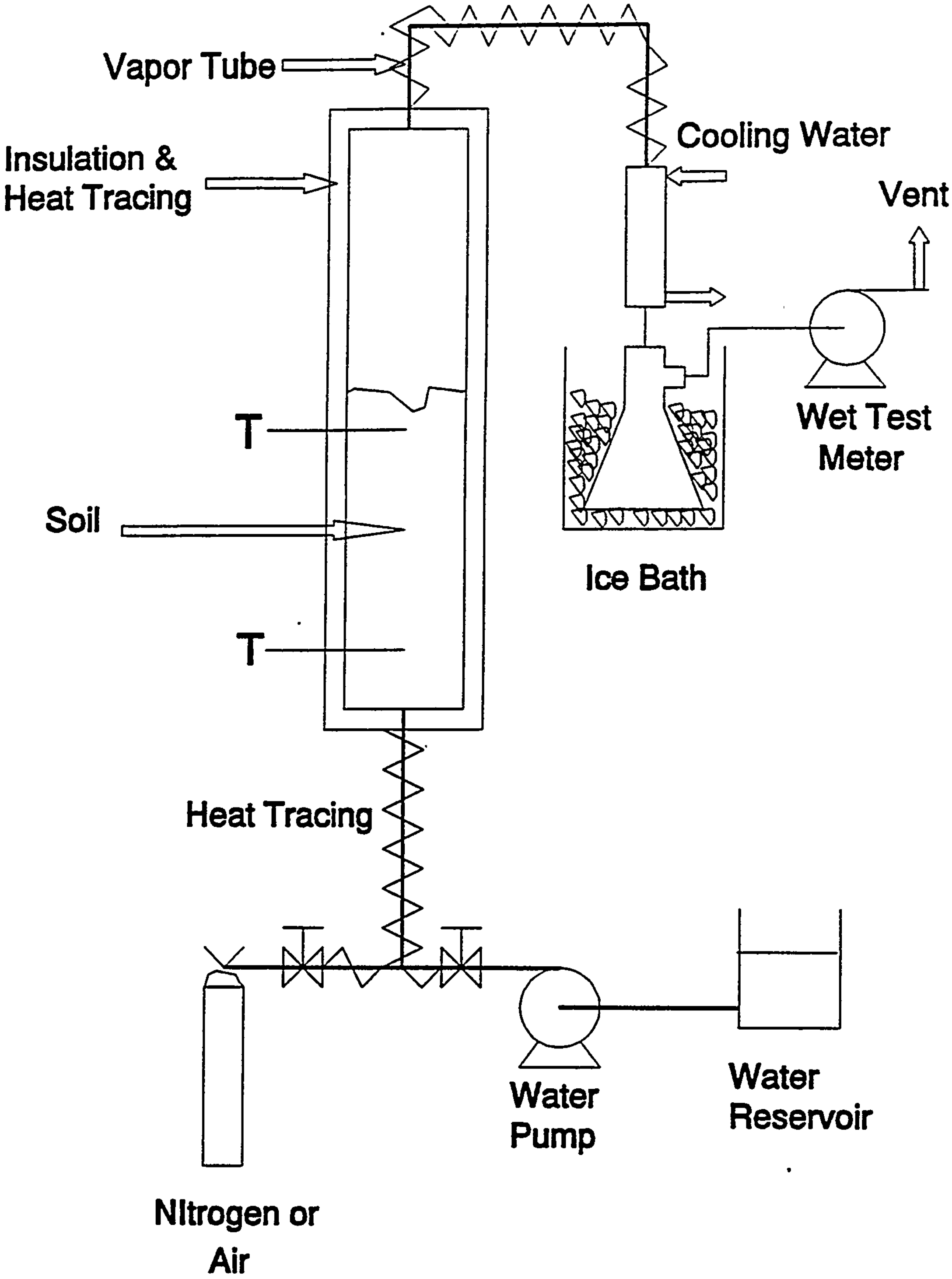


Figure 6. Soil Treatability Experimental Set Up

heating the soil pass through a heated vapor tube into a water cooled condenser. The outlet of the condenser is connected to a chilled condensate receiver wherein all the liquids formed in the condenser are collected. The uncondensed gases leaving the condensate receiver were passed through a wet test meter.

The soil column was equipped with an injection port at the bottom through which a selected gas (air or nitrogen) or superheated steam was introduced into the soil column to simulate the gas sweep established in the soil upon in situ heating and collection of the produced gases and vapors. The volume of uncondensed gas leaving the chilled condensate receiver was measured by means of a wet test meter as shown in Figure 2. When nitrogen or air was injected at the base of the column it was assumed that the uncondensed gas leaving the receiver was 100% v/v air or nitrogen. Superheated steam was made by pumping deionized water at a controlled rate through a heat traced tubing. The amount of water pumped through the soil column was determined by weighing the water reservoir.

4. Experimental Procedure

The cleaned stainless steel reactor was packed with soil core samples sent to IITRI by HALLIBURTON NUS. Only core samples obtained from the two bore holes made inside the pit were used in the treatability study. In all experiments soil obtained from a single core interval (5 ft length of core) was packed into the reactor. As the reactor was being packed, soil samples were taken for TPH analysis and transferred to a clean glass jar. In some cases, the collected soil sample was split into two portions, one of which was spiked with a solution of known concentration of diesel in carbon disulfide. The jar was sealed with a teflon lined cap and refrigerated pending analysis.

After packing the reactor with soil, the column was connected to the vapor condenser, the wet test meter and the gas injection system as shown in Figure 6. The experiment was begun by heating the column of soil while passing nitrogen or air through the column. During this phase of the experiment native water present in the soil was recovered along with the condensed contaminant vapors in the chilled receiver. Once the recovery of the native soil moisture had ceased (determined by visual observation in the glass condenser) then the nitrogen or air flow was stopped, and the condensate receiver was replaced with a new one. Steam injection was now begun. The temperature of steam entering the base of the soil column was measured and adjusted to match the average temperature of the soil in the column.

Once the final soil temperature was attained, the soil was maintained at the temperature for a period of 100 to 380 hours (the soak period). During the soaking period the flow of sweep gas was maintained at a constant rate.

At the end of the soaking period steam injection was terminated and nitrogen was re-injected at the base of the column. The purpose of nitrogen injection was to remove all residual steam from the column. The experiment was then terminated and the soil was allowed to cool down to room temperature. During this period the reactor was kept vented to the condenser and the condensate recovery system.

Once the soil had cooled to room temperature, the reactor was opened and the soil was transferred to a clean 1-gallon glass jar. The jar was sealed and tumbled on a roller table for a period of 20 min. A sample of the treated soil was obtained from the gallon jar and transferred to a sample jar. In some experiments two samples were obtained, one of which was spiked with a solution of known concentration of diesel in carbon disulfide.

5. Experimental Results and Conclusions

Five soil treatability experiments were performed. The experimental conditions and TPH concentration in soil are shown in Table 6. The TPH removal calculation is summarized in Table 7. Detailed information regarding each experiment along with temperature profiles are provided in Reference 2. The data shown in Tables 6 and 7 are based on TPH analysis performed by IITRI.

The data in Table 6 indicate that in 2 of the 5 experiments the soil did not have significant amount of TPH contamination as compared to the other samples from the site. Results from the other three experiments show that TPH can be reduced to the range of 60 to 230 ppm depending upon the treatment condition. Thus increasing treatment temperature from 113° to 150°C has a significant effect on the final concentration of the soil. Due to the long residence time in the field, the actual removal of the TPH under field conditions is expected to be even higher than that seen in the laboratory.

The results of Experiments 1 to 3 indicate that with the specific combination of contaminants and the soil matrix there is no effect of the type of sweep gas (steam/nitrogen versus nitrogen alone) on the residual concentration of the TPH. In Experiment 2 a low percent removal was attained due to the low initial concentration of the TPH in the soil. Table 7 is a summary of the removal calculations which take into account the change in soil moisture upon heating.

The calculations summarized in Table 7 are based on a mass balance for TPH and moisture. The basis for performing the mass

TABLE 6. SOIL TREATABILITY EXPERIMENTAL CONDITIONS AND RESULTS

Expt. No.	Soak Temperature C	Soak Time hr	Nitrogen/ Air Sweep	Water Injection g/min	TPH Concentration ppm	
					Initial	Final
1	113	122	Nitrogen	4.6	3124	227.7
2	150	118	Nitrogen	5.2	198	70
					198	59.1
3	151	102	Nitrogen	0.0	2740	94
4	153	112	Air	0.0	59.9	11.5
5	112	388	Nitrogen	0.5	18.2	13

Expt 1:	soil from boring SB-17, 17-22 ft depth
Expt 2:	soil from boring SB-18, 12-17 ft depth. Three different treated samples were analyzed. First line provides the results of the first sample and the second line gives the average of the other two.
Expt 3:	soil from boring SB-18, 17-22 ft depth
Expt 4:	soil from boring SB-18, 7-12 ft depth
Expt 5:	soil from boring SB-18, 2-7 ft depth

TABLE 7. CALCULATION OF TPH REMOVAL DURING TREATABILITY STUDY
(Basis: 100 gm of Initial Soil)

Expt. No.	IN INITIAL SOIL			IN FINAL SOIL		TPH REMOVED µg	PERCENT REMOVAL %
	TPH Conc. µg/gm	Moisture %		TPH Conc. µg/gm	Moisture %		
1	3124.0	9.1%		227.7	0.1%	291747.8	93.4
2	198.0	26.8%		70.0	0.0%	14677.0	74.1
2	198.0	26.8%		59.1	0.0%	15474.8	78.2
3	2740.0	15.1%		94.0	0.0%	266044.4	97.1
4	59.9	23.4%		11.5	0.0%	5109.2	85.3
5	18.2	16.6%		13.0	2.8%	704.3	38.7

Expt 1. Initial Soil average of two analysis: 3371, and 2877 µg/gm

Expt 2. Three different treated soil samples were analyzed. First line provides the results of the first sample. The second line gives the average results of the other two samples.

Expt 3. Initial Soil analyzed two ways: by dilution for low level calibration: 2270 µg/gm
and by hi level calibration curve and no dilution: 2740 µg/gm.
Use hi level result.

balance was 100 gm of initial soil. Consider, as an example, 100 gm of initial soil used in Experiment 1. The soil contains 312,400 μg of TPH, 9.1 gm of moisture, and 90.59 gm of solids. The 90.59 gm of solids (considered as inert) remain unchanged upon heating, but the moisture content reduces to 0.1% and the TPH concentration reduces to 227.7 μg/gm. Thus, in the final soil, solids represent 99.88% of the total residual mass. The residual mass of final soil is 90.70 gm. Thus the amount of TPH present in 90.7 gm of final soil is 20,652 μg. The amount of TPH removed from the initial soil is (312,400 - 20,652) = 291,748 μg. Therefore, the removal of TPH, expressed as a percentage of initial TPH present in 100 gm of soil is (291,748/312,400) * 100 = 93.4 percent.

B. HEATING SYSTEM DESIGN

1. Design Heated Volume

The volume of the soil heated by the RF process is determined by the dimensions and geometry of the electrode array because the soil between the two outer electrode rows is heated. For this demonstration the size of the heated volume was limited by the size of the available RF power source, which was 40 kW. The soil was heated by installing an array of electrodes in the soil. The electrodes were installed in vertical bore holes drilled in three parallel rows. Figure 7 is a plan view of the electrode array implemented for the demonstration at Site S-1. The length of the two outer rows of electrodes (Rows A and C) is 17.5 ft and length of the Excitor row (Row B) is 7.5 ft. The depth of the two outer rows was 29 ft while the depth of the Excitor row was 20 ft. The heated volume will be determined by the geometry of the electrode array. As discussed above, the two outer rows are both longer and deeper than the central row. This was done to contain the fringing RF fields that emanate from the ends of the excitor row. Thus the volume that is expected to be heated is larger than the length and depth of the excitor row but less than the depth and length of the two outer rows. The width of the heated zone is equal to the separation of the two outer rows, that is 10 ft.

The length expected to be heated is equal to the length of the excitor row plus 66 percent of the row separation at each end. This gives an effective heated length of (7.5+0.66*5*2)≈14.1 ft. Similarly, the expected depth of the heated zone is equal to the depth of the excitor row plus 66 percent of the row separation below the tips of the excitor electrodes. This gives a heated depth of (20+0.66*5)=23.3 ft. This gives a heated zone volume of approximately 3,285 cu. ft or 122 cu. yd.

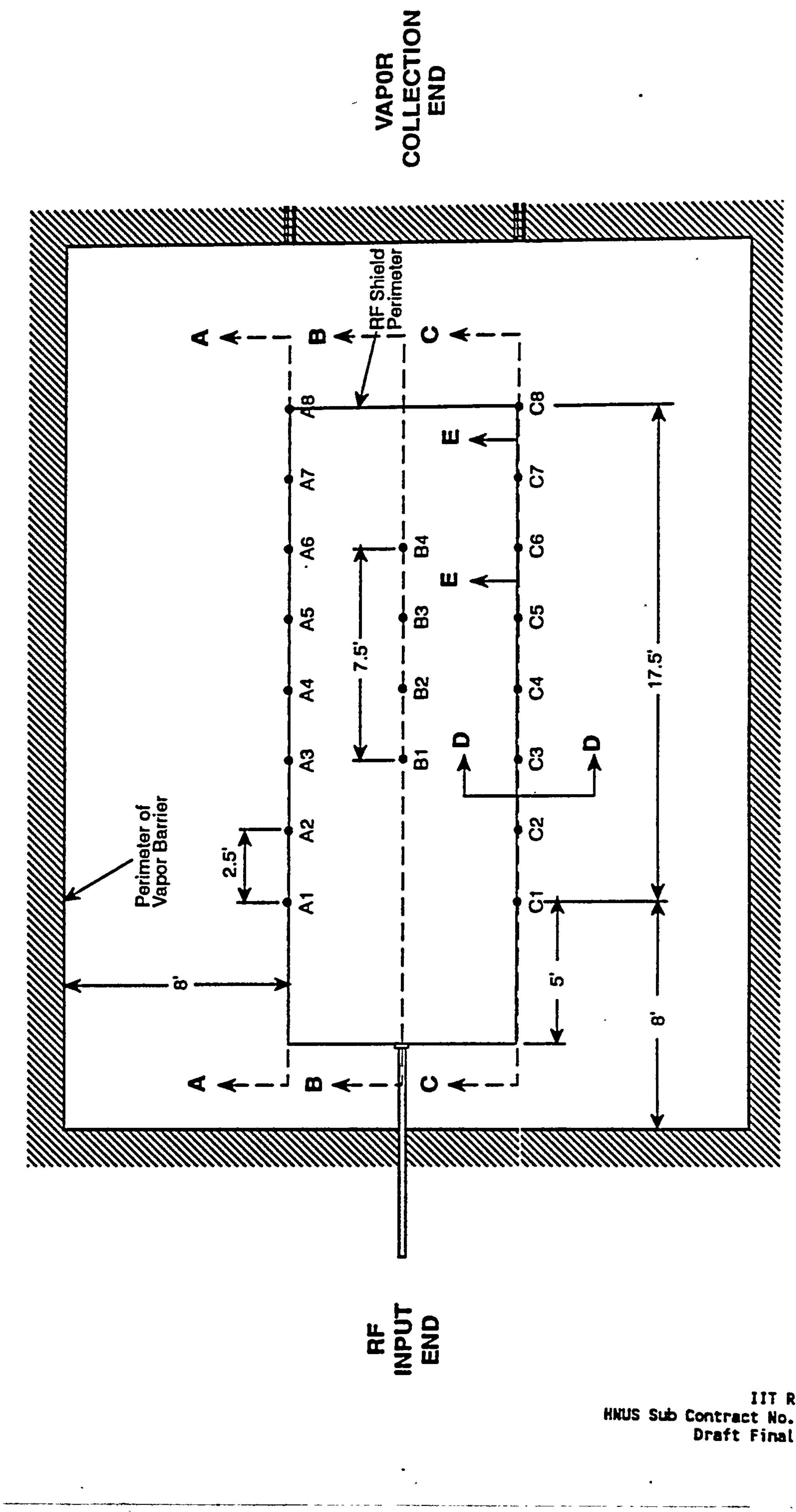


Figure 7. Surface-Level Plan View of the Array (Electrode Locations Shown by •).

Thus the volume that the electrode array was expected to heat has a dimensions of:

Width:	10 ft
Length:	14.1 ft
Depth:	23.3 ft

2. Estimate of Heating Time

Previously, the energy required to heat one ton of soil was estimated as a function of soil moisture content. The RF energy varied between 120 to 190 kW-hr/ton of soil when the soil moisture varied between 10 to 20 percent. The soil moisture content at site S-1 varied between 9 to 26 percent. The heating time for the soil may be estimated by using the higher value for energy requirement corresponding to a moisture content of 20 percent.

The weight of the soil volume which is expected to be heated is approximately 165 tons. Thus the energy required is 31,350 kW-hr. If the RF power source works continuously at the rated output of 40 kW, it will take 33 days to heat the soil to the desired temperature of 150°C. But because the source will not operate at its rated capacity nor will it work continuously, the actual time required will be longer than 33 days.

A practical operating rate of the power source might be in the range of 70 to 80 percent of its rated capacity, or 28 to 32 kW. It was planned to shut down the RF power source three times every 24 hours to take temperature measurements. Each shut down was expected to last 30 to 60 mins. Thus power feed interruptions of 1.5 to 3 hrs in every 24-hr period were planned. Thus the energy output per day from the power source after accounting for planned interruptions and operating rate is 590 to 720 kW-hr/day. Thus a practical heating time for the soil treatment zone would be 44 to 54 days.

3. System Design Overview

Implementation of the RF technology for soil remediation requires two major subsystems; the RF heating system, and the effluent containment, collection, and treatment (ECCT) system. The RF heating system's purpose is to heat the soil to the required temperature range in the most efficient manner possible. The main components of the RF heating system are the RF power source, the coaxial transmission line, the matching network, the electrode array, the RF shield and RF chokes. The purpose of the ECCT system is to collect and treat the effluents generated during decontamination of soil in an environmentally benign and efficient manner.

A conceptual layout of the RF system configuration is shown in Figure 8. This figure shows all the major components of the heating system and how they are configured in the overall system. The electrode array determines the size of the volume heated by the process. The electrode array had three rows of vertically emplaced electrodes. The width of the array was 10 ft, length 17.5 ft and depth of 20 to 29 ft. The depth of the central row of electrodes was 20 ft while that of the outer rows was 29 ft. A RF shield was placed over the electrode array to mitigate RF radiation from the heated zone. The RF power was generated by the RF power source and conveyed over a co-axial cable to the array through two matching networks and a RF choke. The purpose of the matching networks was to optimize power transfer from the source to the array. These networks contain active and/or passive inductive and capacitive components which were adjusted during heating to optimize power transfer.

A vapor barrier is shown in the plan view. The purpose of the vapor barrier is to help control fugitive emissions from the site and to control the infiltration of air into the heated zone from the surface. The upper surface of the vapor barrier was covered with a thermal insulation blanket to minimize heat loss.

Gas collection lines leave the array and convey the hot gases to an on site vapor treatment system. Hot gases comprise of air, steam and vaporized contaminants present in the soil. Gases are collected from four places by means of application of a vacuum: the two outer rows of electrodes and from two horizontal perforated lines placed on the surface below the vapor barrier. A RF choke is used on the gas pipeline leaving the system to prevent the conduction of RF currents along the surface of the pipeline.

The temperature of the soil was measured by means of thermocouples mounted inside the electrodes and by periodically inserting fiber optic temperature measurement probes into thermowells. The thermocouple cables leaving the two outer rows of electrodes were connected to a data logger. The thermocouples in the excitor row and the fiber optic thermometer in the thermowells were read after shutting down the RF power.

The vapor treatment system utilized in this demonstration consisted of a propane flare in which the entire collected gas stream was burnt. The vacuum required for the collection and transport of the gases was provided by means of compressed air ejectors. The motive air used for the operation of the ejectors was mixed with the collected gases.

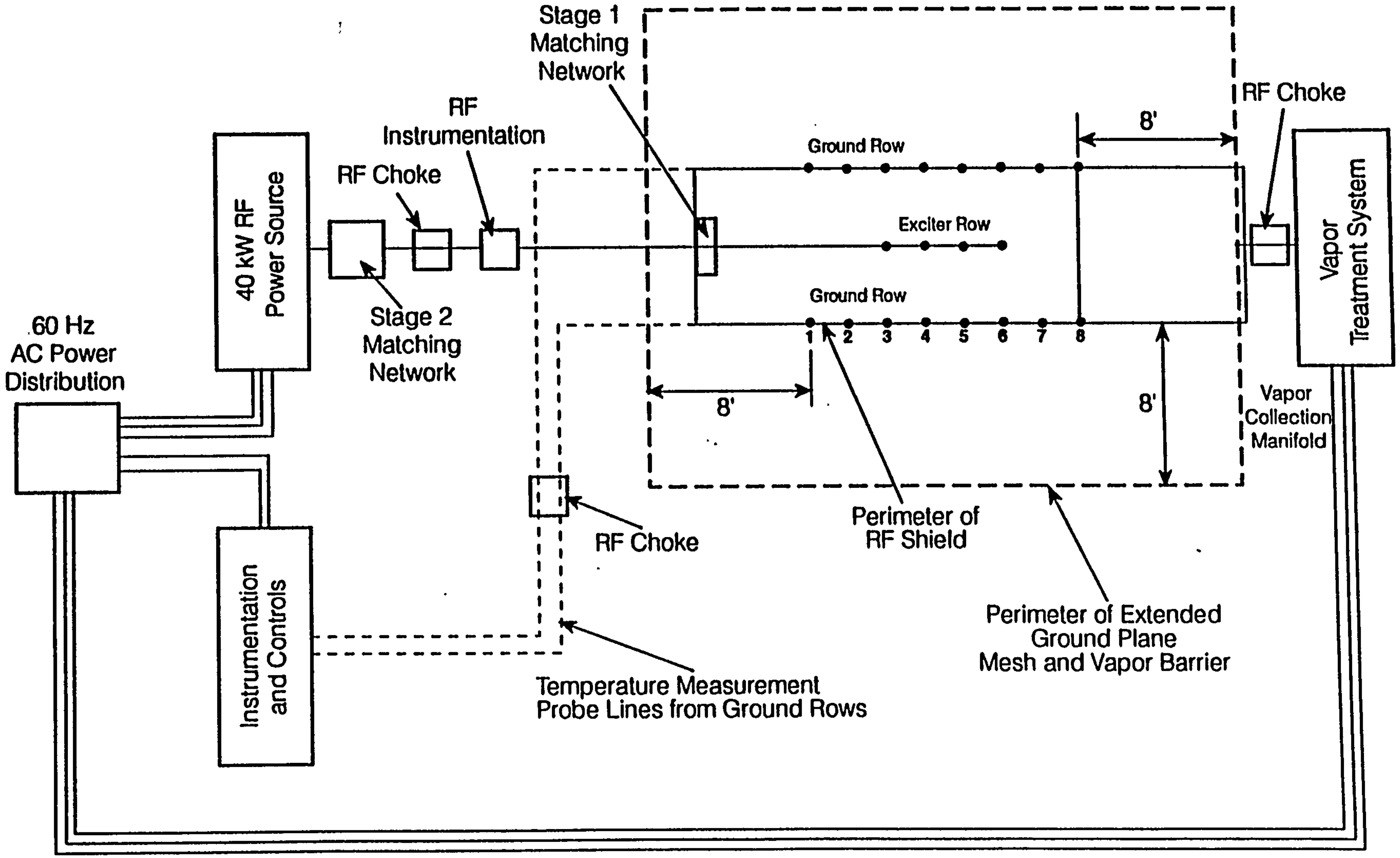


Figure 8. Conceptual Layout of the Demonstration System.

4. Electrode Array Design

Figure 7 (Page 32) is the surface level plan view of the electrode array. It shows the three rows of electrodes and their spacing. The three vertical sections AA, BB and CC of the array are displayed in Figure 9. In this figure the dotted lines show the electrodes in the two ground rows of electrodes, A1,C1,...,A8,C8. The depth of these electrodes was 29 ft. All of these electrodes except the ones at the four corners were perforated and connected to the gas collection system. The bottoms of these electrodes were capped. All the electrodes in the two ground rows were made from 2-in. diameter schedule 40 aluminum pipe. At the top the perforated ground electrodes were connected with each other within a row to form a gas collection manifold. Thermocouples were placed inside selected electrodes to obtain temperature data.

The excitor electrode of Section BB are illustrated by the solid lines in Figure 9. There were four excitor electrodes. The two outer electrodes were 3 in. dia. Type K copper tube and the two inner electrodes were 2 in. diameter type K copper tube. The depth of these electrodes was 20 ft. The tops of these electrodes were connected together by means of copper tube and Tees. A single RF feed line of 3 in. diameter was provided to the excitor electrode manifold. At the bottom of the excitor electrodes a brass sphere was welded to the electrode in order to increase the surface area of the tips of the electrodes in order to reduce the current density concentration at the tips. The sphere at the bottom of electrodes B1 and B4 had a diameter of 5.5 in. The sphere at the bottom of electrodes B2 and B3 had a diameter of 4.5 in. None of these electrodes were used for gas collection.

All the boreholes were drilled by means of hollow stem augers which were required to obtain undisturbed core samples of the soil while drilling for the electrode bore holes. As a result the ID of the bore hole was considerably larger than the OD of the electrodes. The annular gap had to be backfilled with either native material or else another material having similar clay, silt and sand levels. The soil borings obtained from the site contained large pieces of gravel mixed with plastic clay which was difficult to re-insert in the annular space between the electrode and the borehole. So the bore holes were backfilled with a mixture of clay and red "ball park sand". The clay was obtained from a materials yard and the sand was obtained from a local sand pit. The mixture was four volumes of the sand to one volume of the clay.

Figure 9 illustrates the outline of the RF shield which was made from corrugated aluminum sheeting curved to form a semi-circular cylinder of diameter 9 ft. The shield is described in another section later.

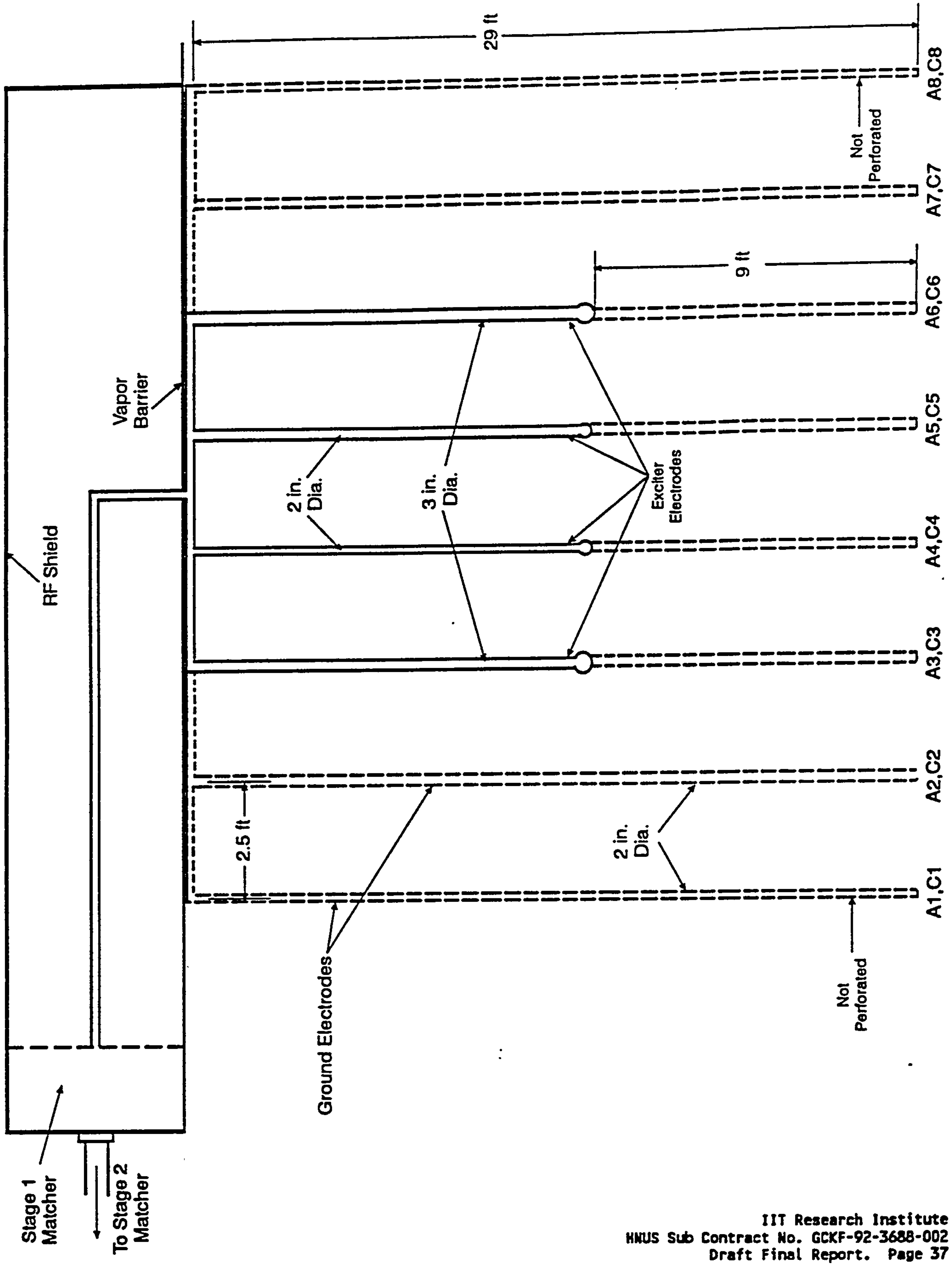


Figure 9. Vertical Sections , BB, CC of Electrode Array.

TABLE 8. ELECTRODE ARRAY DIMENSIONS--DESIGNED VS. IMPLEMENTED

Dimension	Planned	Implemented
Depth of outer rows, ft	29	29
Depth of center row, ft	24	20
Length of the outer rows, ft	17.5	17.5
Length of the center row, ft	7.5	7.5
Separation of two outer rows, ft	10	10

The design of the electrode array was changed in the field after the bore holes were drilled and the water table was discovered to be shallower than anticipated. The original design of the array required the excitor electrodes to be 24 ft deep. But the depth of the electrodes was reduced when the shallow water table was discovered. Table 8 compares the original dimensions of the array to that actually implemented.

Figure 10 illustrates a typical Section DD of the array. This figure shows the construction of the array near the surface. The drawing illustrates the locations of: the horizontal gas collection line place on the surface, the pea gravel fill, the contaminated soil overpack, the aluminum bus bar connecting the outer electrodes, the extended ground plane wire mesh, the vapor barrier, the thermal insulation and the bentonite-filled trench to make a seal between the soil surface and the vapor barrier.

Figure 11 illustrates a typical section EE. This view illustrates the interconnection of any two adjacent gas-collecting electrodes in the two outer rows. The tops of most of the electrodes in the ground row were connected to the branch leg of a Tee. The straight runs of the Tees were interconnected by means of short pieces of flexible silicone rubber hose clamped to pipe nipples threaded into the Tee.

A short piece of aluminum angle was also welded to each Tee. These were welded such that they bent towards the outside of the array. The electric bus bar was bolted to each of these angles to

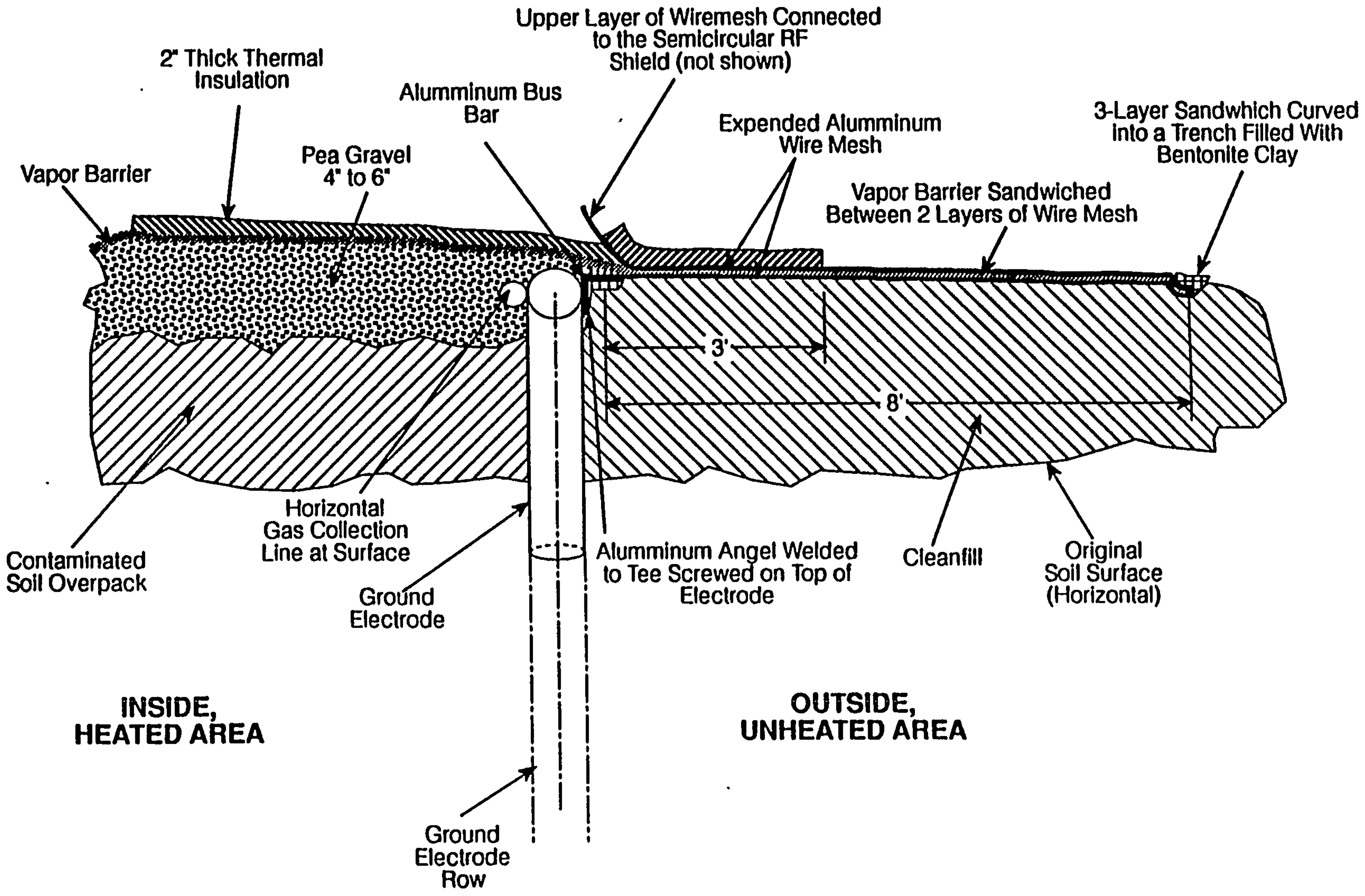


Figure 10. Transverse Section DD of the Array Near Soil Surface.

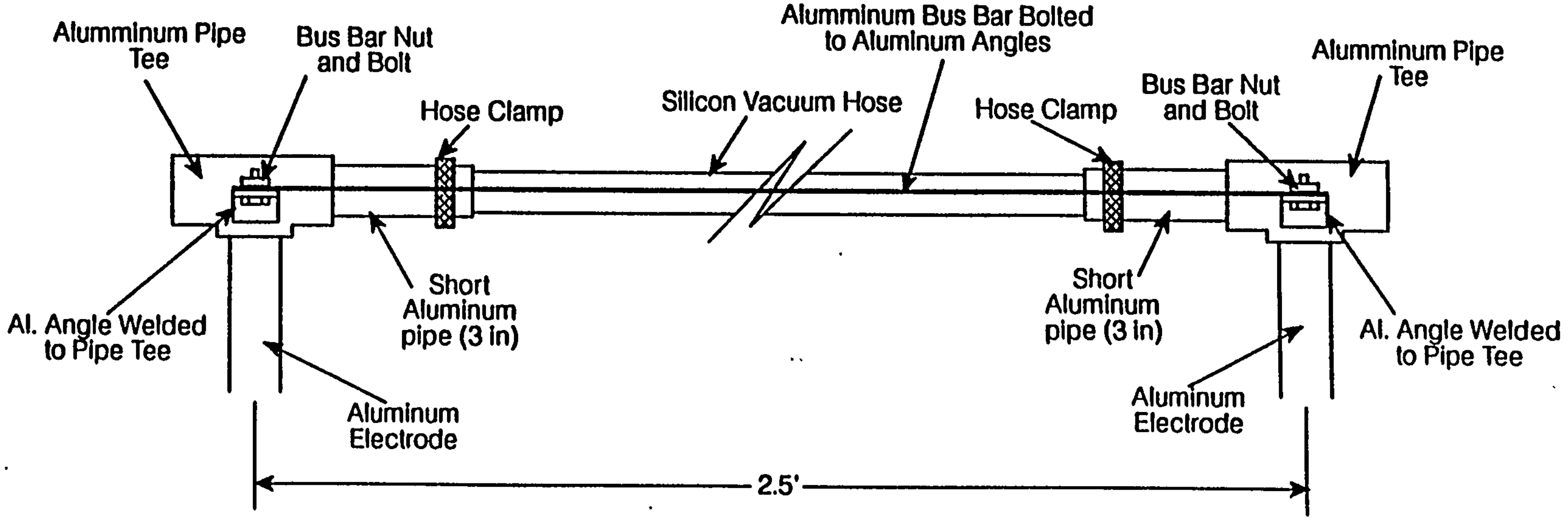


Figure 11. Typical Section EE: Electrode Interconnection in Ground Rows A and C.

provide the current path from electrode to electrode. The bus bar was made from a strip of aluminum sheeting 2.5 ft long, and 3 in. wide.

5. RF Shield

Figure 12 illustrates the RF shield. The RF shield consisted of a semi-circular cylinder lying on its side. It was made by screwing together in the field pre-curved sheets of corrugated aluminum. The finished length of the shield was approximately 22 ft; 9 ft diameter. The ends of the cylinder were made from aluminum sheet. The height of the shield was 4.5 ft. Means of continuously venting the interior of the shield were provided. The vented air was passed through activated carbon drums.

6. Vapor and Gas Collection Lines

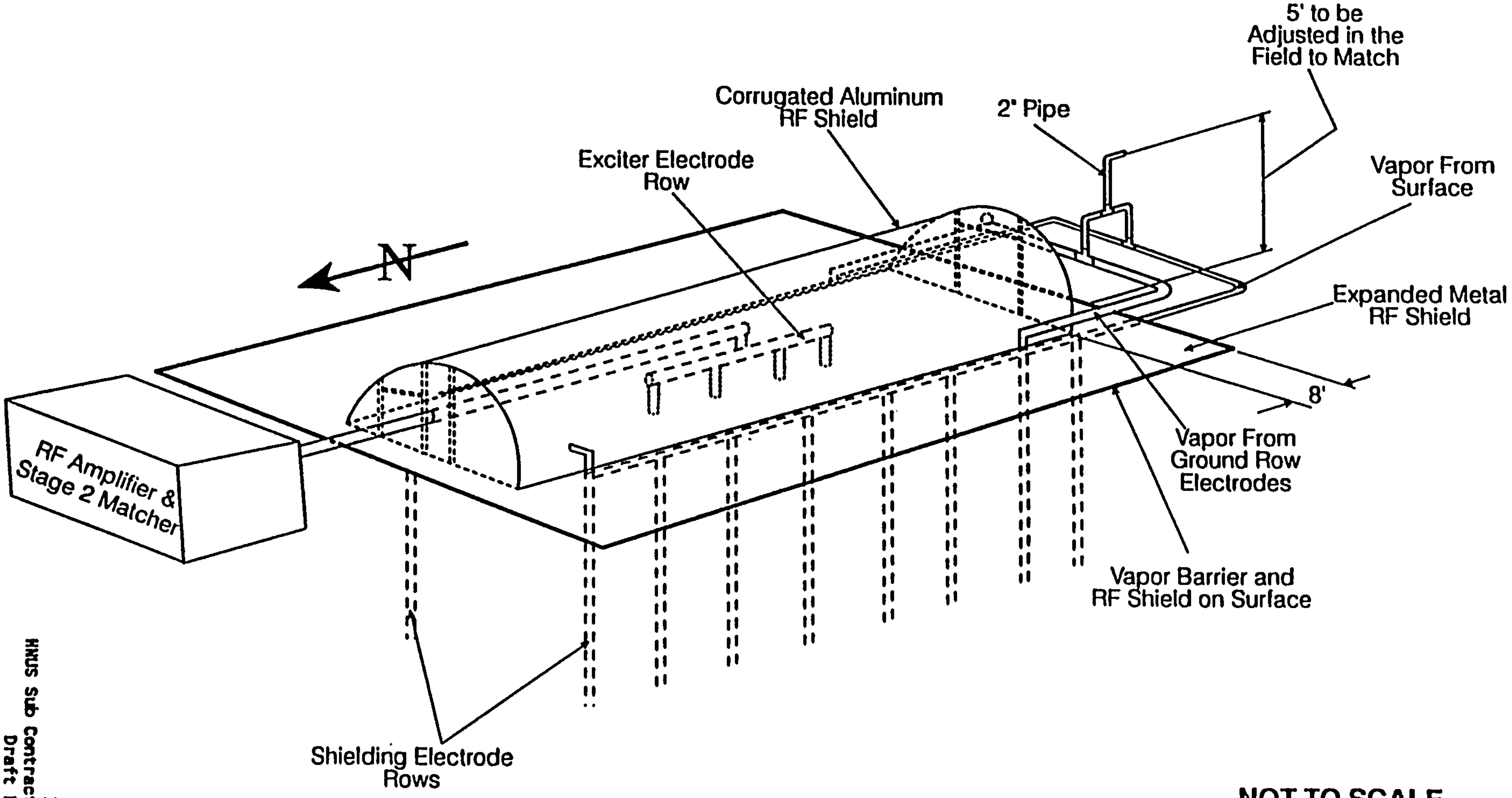
Figure 13 illustrates the network of pipes used to collect hot gases from the soil surface and at depth. The main gas line was split into four legs, each with its own ball valve and a vacuum gauge. The gases were collected from two perforated horizontal surface gas collection lines as well as from each of the two outer electrode rows. The surface gas collection lines were made from aluminum pipe. All lines were heat traced once they left the heated soil area. The ball valves were provided to adjust the vacuum level in each leg of the collection system.

7. Temperature Instrumentation

The soil temperature was measured by means of thermocouples attached to the inner walls of selected thermocouples and by inserting fiber optic thermometers into thermowells installed in bore holes located between the electrode rows.

Table 9 gives the distribution of the electrodes which were installed inside the electrodes. In both the ground row electrodes the thermocouples were installed at a depth of 1, 12, 24, and 29 ft. In the excitor row the thermocouples were installed at a depth of 1, 10, 20 ft.

In the original design the location of the thermocouples was selected to provide temperature data at four horizons of interest below the soil surface. These horizons were: the 1-ft depth, the mid point of the excitor electrodes, the tips of the excitor electrodes and the tips of the ground electrodes. However, during field installation of the electrode array the design of the excitor electrodes had to be changed because a shallow water table was encountered, contrary to expectations. At this time it was not possible to change the location of the thermocouples already



NOT TO SCALE

Figure 12. RF Shield (Stage #1 matcher enclosed under arch)

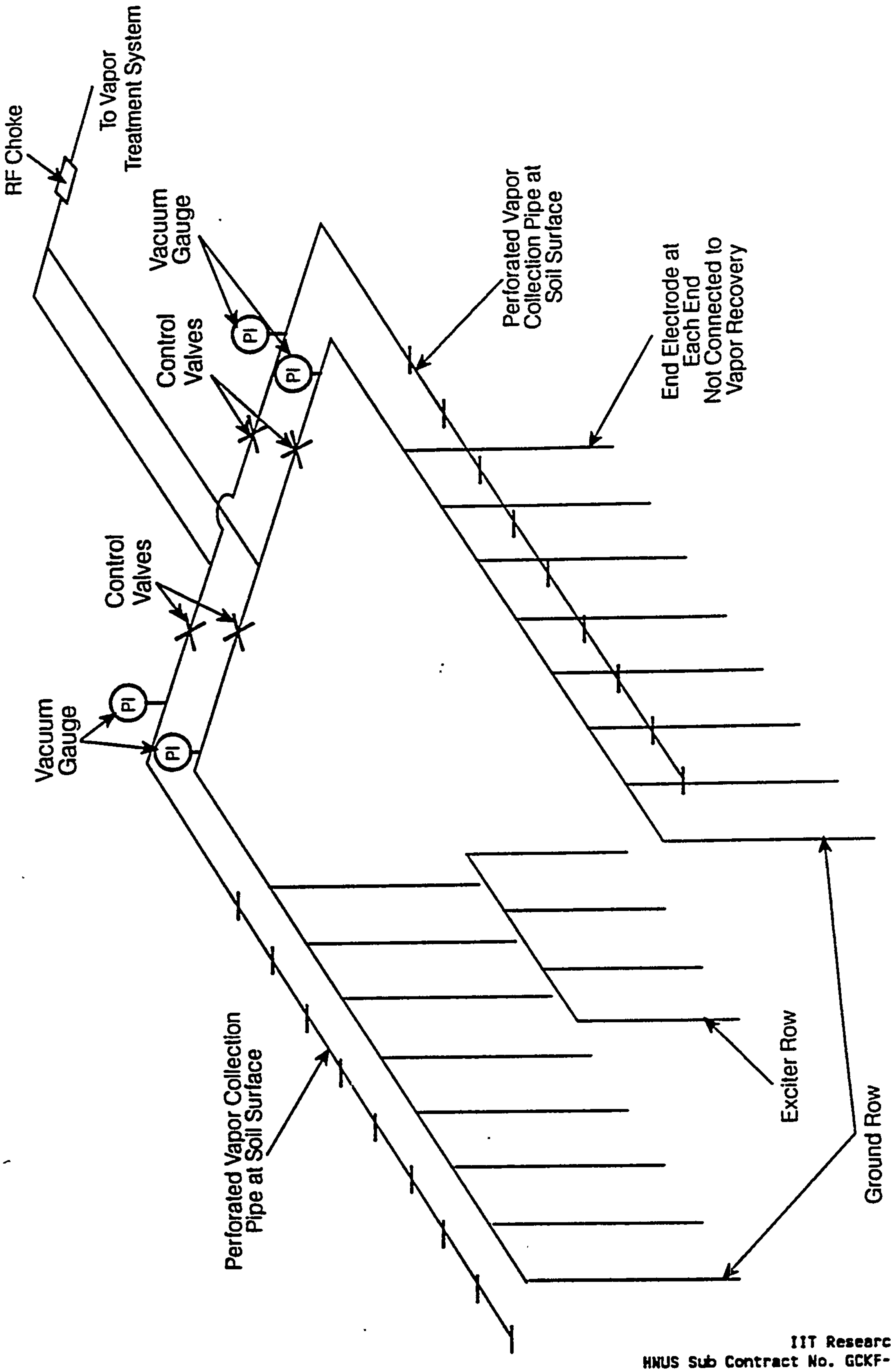


Figure 13. Vapor Collection Manifold.

TABLE 9. THERMOCOUPLE DISTRIBUTION INSIDE ELECTRODES

	Ground Row A	Ground Row B	Excitor Row C
No. of Thermocouples	11	16	12
Electrodes with T/Cs	A2,A3,A4	C1,C2,C3,C4,C6	B1,B2,B3,B4
Total No. of Electrodes	8	8	4
Depths of T/Cs, ft	1, 12, 24, 29	1, 12, 24, 29	1, 10, 20

installed in the ground electrodes. Thus the four temperature measurement horizons are not true horizontal planes as is evident from Table 9.

The location of the thermocouples in the array is presented graphically in Figures 14 through 16. The thermocouple location is marked with a X. Figure 17 illustrates the method of thermocouple attachment to the electrode wall. All thermocouples were Type K with a 1/16 in. SS 304 sheath. The junctions were ungrounded. The sheaths on these thermocouples were long enough so that the transition from sheath to wire occurred above ground. The thermocouple wires were run inside conduit to minimize RF pick up. A separate conduit was not necessary. For the excitor electrodes the thermocouple sheaths were run inside the tubular RF bus supplying power to the center row. For the two ground rows the thermocouples were run inside the vapor collection conduit attached to the tops of the ground electrodes.

All the thermocouples from the ground electrodes were connected at the surface to a data logger through a multiplexer. Data was recorded by the data logger once every 4 hours. The data were available for inspection on a PC screen which was refreshed every 2 min. The measurement of temperature in the excitor row required the RF power to be switched off. Then the thermocouple wires were plugged into a hand held thermometer and the temperature of the 12 measurement points in the excitor electrodes was manually entered into the project log book. These readings were taken once every 8 to 12 hours.

Temperature of the soil in the region between the electrodes was taken by inserting a fiber optic probe into thermowells placed

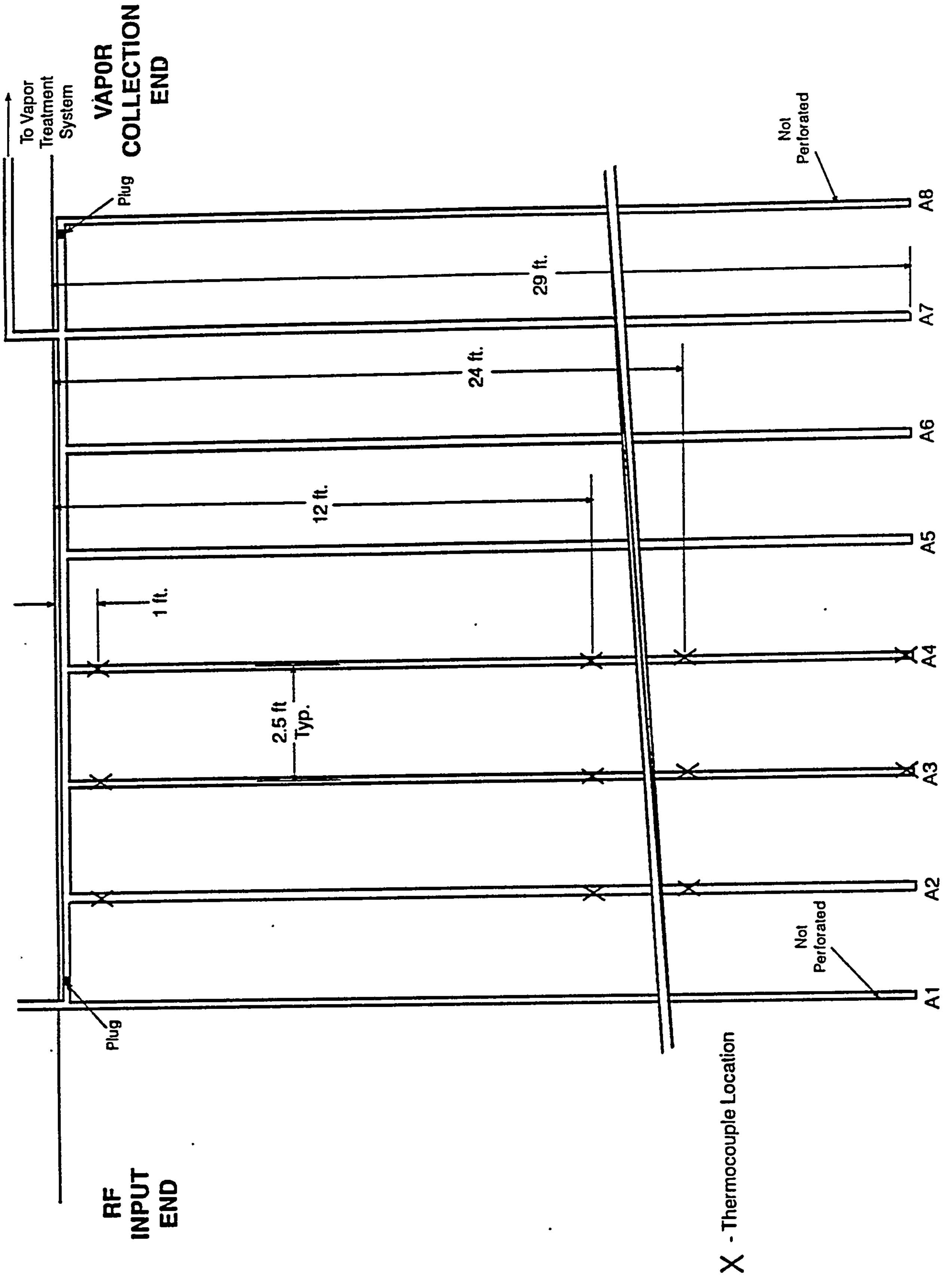


Figure 14. Thermocou[illegible] Locations in Plane AA.

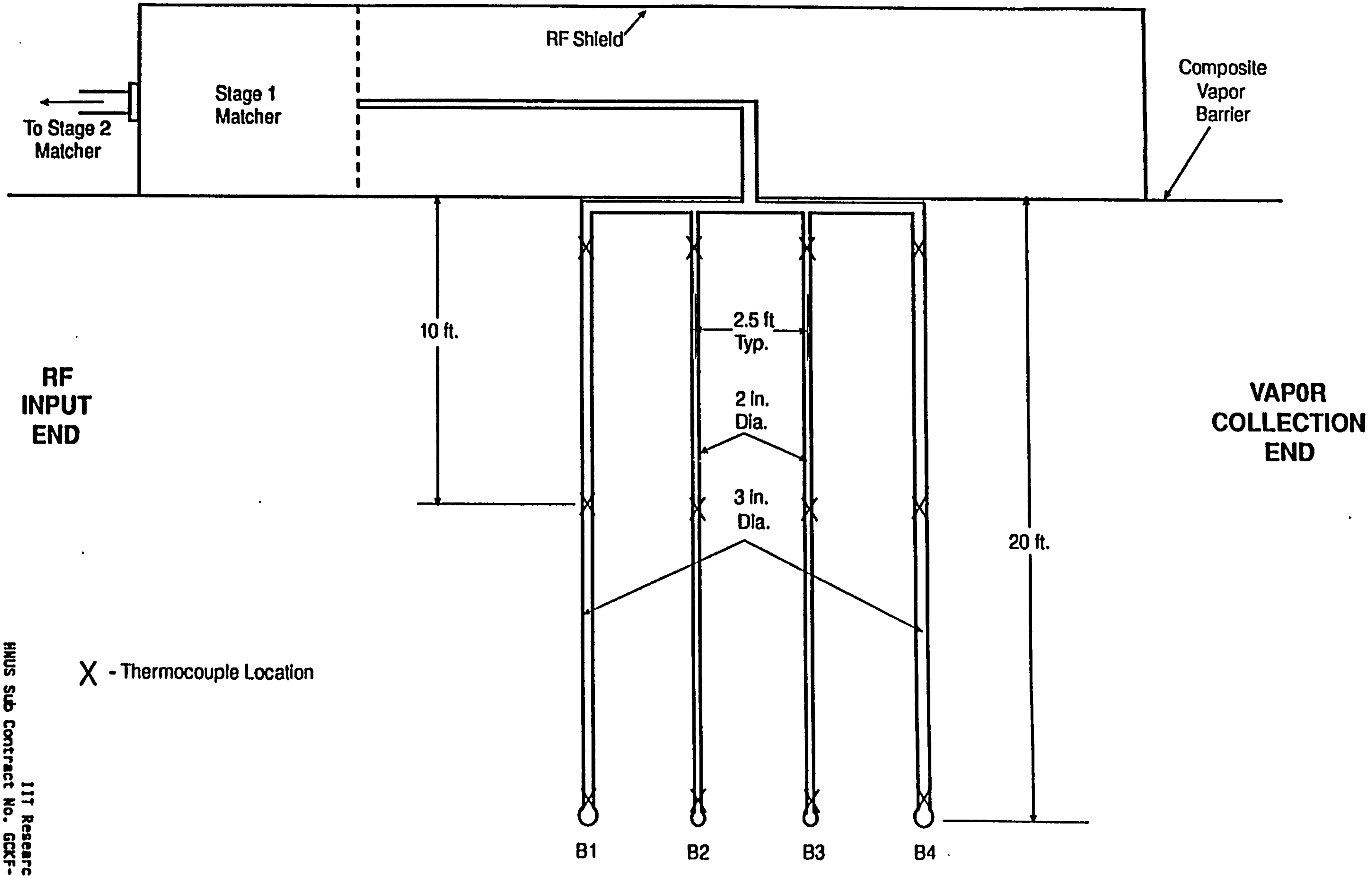


Figure 15. Thermocouple Locations Plane BB.

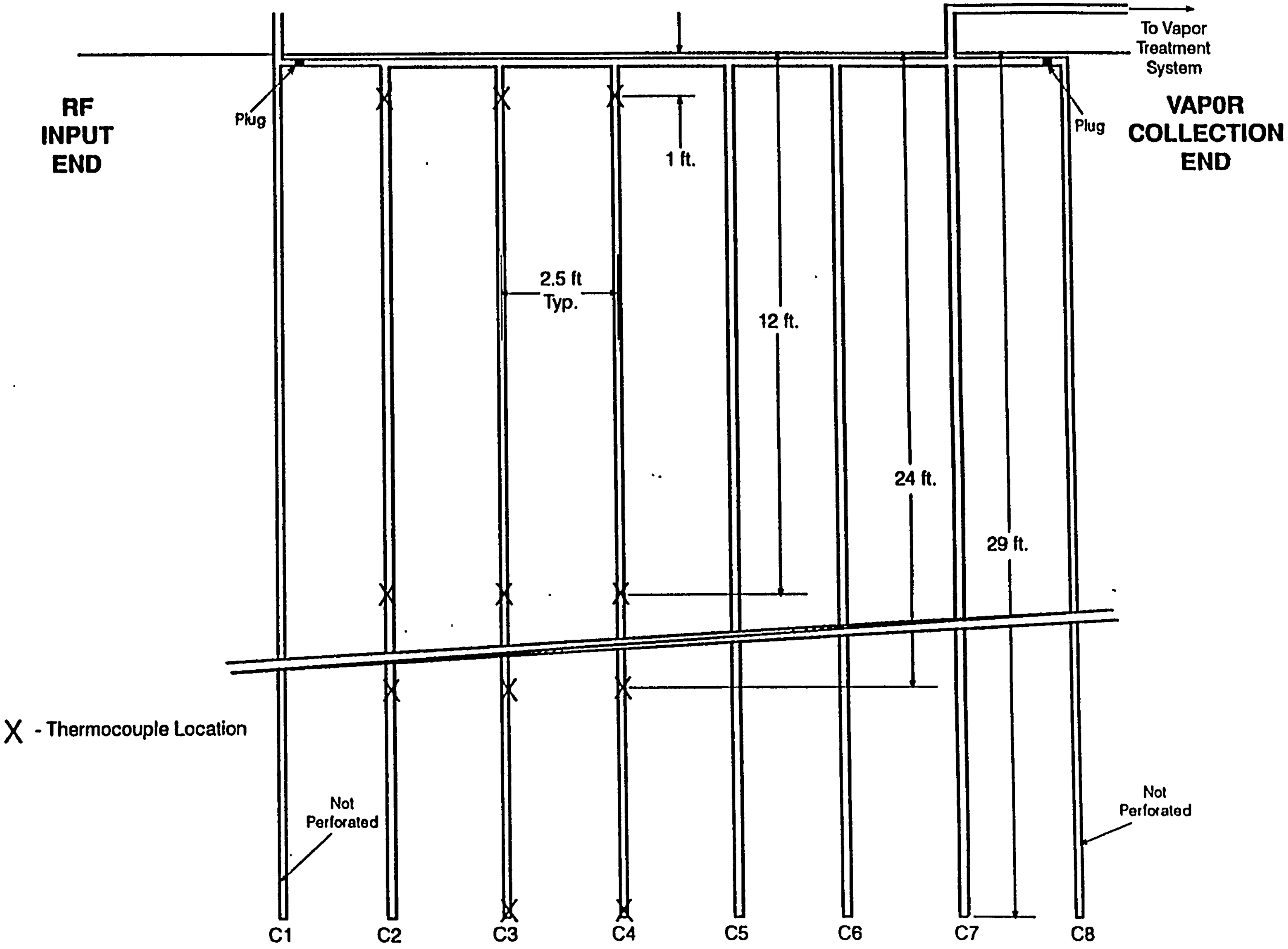


Figure 16. Thermocouple Locations in Plane CC.

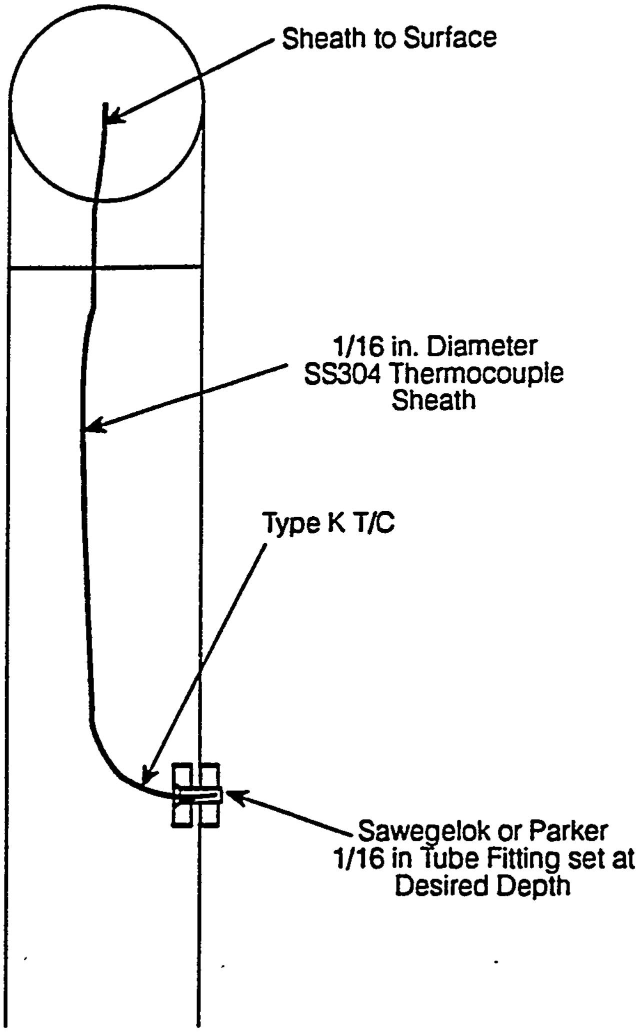


Figure 17. Typical Thermocouple Installation Within Electrode.

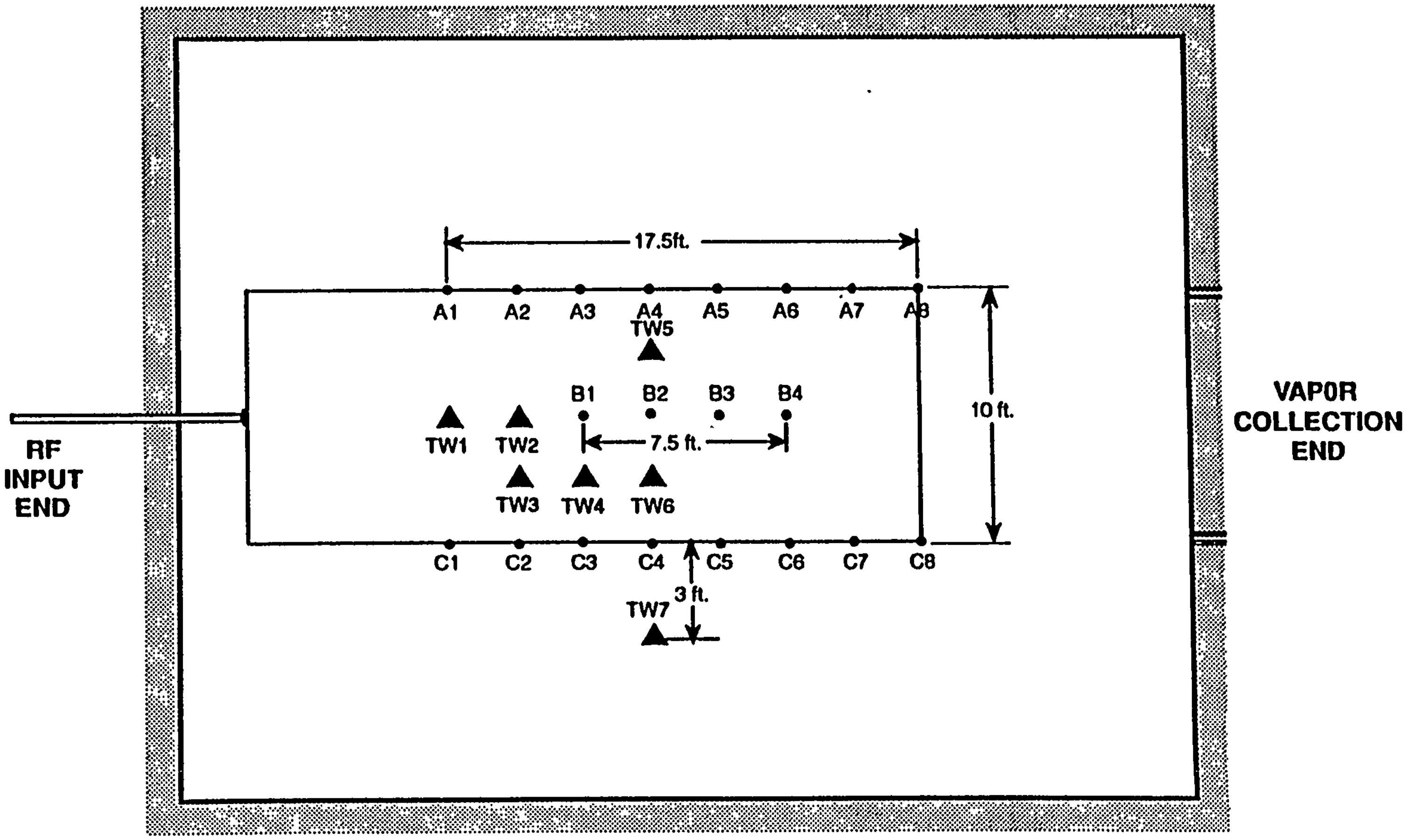


Figure 18. Surface-Level Plan View of the Array. Electrode (•) and Thermowell (▲) Locations.

in bore holes. Figure 18 shows the locations of the seven thermowells marked TW1 through TW7. In each thermowell location a bundle of teflon tubes sealed at the bottom was placed in a borehole. The tubes in the bundle were of different lengths so that the temperature could be measured as a function of depth. In TW1 through TW6 there were six tubes in each bundle. These tubes were installed such that their bottoms terminated at depths of 1, 12, 24, 29, 31 and 34 ft below the heated surface. These depths were selected to correspond to the depths of thermocouples in the electrodes. These thermowells had two additional depths of 31 and 34 ft. to investigate what effect if any there was below the electrode array. Thermowell TW7 had three tubes installed at depths of 12, 24 and 29 ft. Thermowell TW7 was installed approximately 3 ft outside the array directly opposite electrode C4. The temperature at the bottom of each tube was measured by inserting the fiber optic probe in each tube one at a time. The bottoms of each plugged tube was filled with a small amount of silicone oil to help facilitate temperature equilibration between the thermowell and the fiber optic probe. The fiber optic temperature measurements of all the thermowells were made and recorded once every 24 hours. However, four probes were left in selected thermowells and these could be measured whenever desired. Measurements taken by fiber optic probes do not require shutting down of the RF power.

VI. DEMONSTRATION OPERATION

A. SYSTEM START UP

The RF heating system was turned on at Noon on April 3, 1993. Prior to this time, the vapor collection system had been operational for several days, collecting gases and vapors from the soil volume which was at ambient temperature. Initially power to the array was applied at low levels in the range of 0-5 kW. During this time the system was stabilized and measurements of radiated E (electric) and H (magnetic) fields were made in the vicinity of the demonstration system. The purpose of these measurements was to ensure that there were no unsafe levels of radiated fields. Another set of measurements was made at the low input power level for assessing near and far field radio frequency interference (RFI).

The input power was gradually increased over the next two days until on April 5, 55 hours after start up, the input power reached the rated capacity of power source. After attaining the rated power operation, additional measurements were made to assure that there was no radio frequency interference as a result of the demonstration project. RFI measurements were made near the test site, and at distances of 0.5 and 1 mile from the array.

The safety measurements were made at least three times every day during the course of the demonstration.

B. CHRONOLOGY OF EVENTS

Table 10 summarizes the highlights of the demonstration experiment. A detailed summary of events culled from the project log books is presented in Appendix A. The central volume of soil between electrodes (A3,C3,C6,A6) reached an average temperature of 100°C in the period April 22 to April 24, 1993. The average temperature in this zone reached the target temperature of 150°C by May 15, 1993. However, on May 18, 1993, RF power matching difficulties were encountered which were to stay with us for the remaining duration of the experiment. As it will be discussed in Section 7, these were due to extreme hot spots located in the excitor row which caused melting of the copper electrodes. As the temperature data will show, no substantial increase in temperature of the heated zone occurred after the matching difficulties started.

Attempt to continue heating of the soil after May 18 were made in the hope of maximizing the volume of soil inside the array which gets heated to 150°C. The heating experiment was terminated on June 3, at Noon.

Table 10. Chronology of Selected Events

Date	Event
4/3/93	Started Heating
4/6/93	Excitor Row reaches 99° C
4/19/93	Excitor Row reaches 100° C
4/22 to 4/24/93	Central volume defined by (A3,C3,C6,A6) reaches an average temp. of 100° C
5/6 to 5/11/93	Temperature at measurement point B2A started increasing faster than the other points. 253° C on 5/6; 740° C on 5/11
5/15/93	Central volume defined by (A3,C3,C6,A6) reaches an average temp. of 150° C
5/18/93	RF power matching difficulties start
5/30/93	Tracer injection experiment was performed
6/3/93	Heating was terminated

C. DATA RECORDED AND PARAMETERS MONITORED

1. RF Power Delivery System:

During the course of the demonstration project the following measurements were made regarding the operation of the RF system:

- Forward and reflected power at the array (upstream of the Stage 1 matcher)
- Net input power was calculated by difference of the forward and reflected power
- Vector voltmeter reading: V_a, V_b and phase angle
- Forward and reflected power as measured at the output of the RF power source

The above measurements were recorded in the project log book at least once every 2 to 3 hours of operation

The following parameters were monitored by the operators:

- Settings on the RF power amplifier
- Reflected and forward power as measured at the power

source with suitable adjustments to the Stage 2 matching network to maintain zero reflected power
- Monitoring of the vector voltmeter readings

The above parameters were monitored on a semi-continuous basis. All the necessary gauges and controls were arrayed at the operator's work bench.

Once in every 8 hour shift, the operator would survey the RF equipment with a portable E and H field probe to assure that any radiation from the equipment was at safe levels.

2. Soil Temperature Data

The following measurements were made once in 24 hours:

- Measurement of the thermowell temperature by manually inserting fiber optic probes into each thermowell. There were six thermowell locations inside the electrode array each containing 6 thermowells. One thermowell was outside the array and its temperature was monitored by the data logger.

The following measurements were made once every 8 to 12 hours:

- Measurement of the temperature from the 12 thermocouples installed in the excitor electrode row. These measurements were made during shift changes after shutting down the RF power input to the soil.

The following measurements were made once every 4 hours:

- The thermocouples in the two outer row of electrode, the ground rows, were logged automatically by the data logger once every four hours. This included the measurement of thermowell TW7 temperatures also In addition, the operator manually wrote down the temperature readings from the PC display once every 2 to 3 hours.

In addition to the above measurements, the ground row temperatures were monitored on a semi-continuous basis from the PC display where the data was updated every 2 minutes.

3. Vapor Collection and Treatment System

This system was operated and maintained by HALLIBURTON NUS personnel. However, the following data were also recorded by IITRI personnel:

- Vacuum level in each of the four legs of the gas collection system

- Total flow rate exiting the ejectors and entering the flare
- Flow rate and pressure of compressed air supplied to the ejector system
- Vacuum at the inlet of the ejectors
- Temperature of the heat traced vapor collection lines

VII. DEMONSTRATION TEST DATA

A. SOIL TEMPERATURE DATA

1. Summary

As mentioned in Section 6, in situ heating of the soil was begun on April 3, 1993. Power was initially applied to soil at 16:40 hours. The center row of electrodes reached a temperature of 99°C by April 6 and it reached 150°C by April 19. Figure 19 illustrates the electrode array showing the location of the electrodes and thermowells. Thermocouples were attached to the inner walls of many electrodes to measure temperature as explained in detail in Section 5.

Figure 20 illustrates the average soil temperature within two zones of the electrode array. These zones are referred to as Volume I and Volume II. Volume I is the soil contained within the two outer electrode rows and the center row of electrodes, defined by electrodes (A3, C3, C6, A6). As Figure 20 shows, the average soil temperature in Volume I exceeded 150°C for a number of days. In fact the average in this zone peaked at approximately 280°C. The reason for the high average temperature in this volume was the presence of extreme hot spots that developed along the center row of electrodes which melted the copper tube used for the fabrication of the electrodes. Melting point of copper is 1083°C. As will be shown later, there were large temperature non-uniformities in the transverse direction. For example, while the temperature in the center row reached copper's melting point, the temperature in the two ground rows did not exceed 110°C.

It is estimated that the region defined as Volume I is approximately 56 cu. yd. It should be noted that due to the large temperature range within this zone, every temperature measuring point was not at 150°C. It is estimated that 34 cu. yd. of soil was heated such that every measurement point within it achieved and maintained 150°C for long period (>100 hours) of time.

Figure 19 illustrates a second region of soil called Volume II. This area of the array is outside the central row of electrodes and it is bounded by electrodes (A1,C1,C2,A2). It was anticipated that the energy dissipation in this area would be reduced, and, as anticipated, the average temperature of Volume II was less, in the range of 60° to 70°C. It is estimated that Volume II is 18.5 cu. yd. However, due to symmetry considerations, there is another volume of similar size at the opposite end of the array (bounded by electrodes A7,C7,C8,A8) which probably experienced a similar temperature history. There were no temperature measurement points in the opposite end of the array. Thus total volume where

Figure 19. Electrode Hole and Thermowell Layout
(Plan)

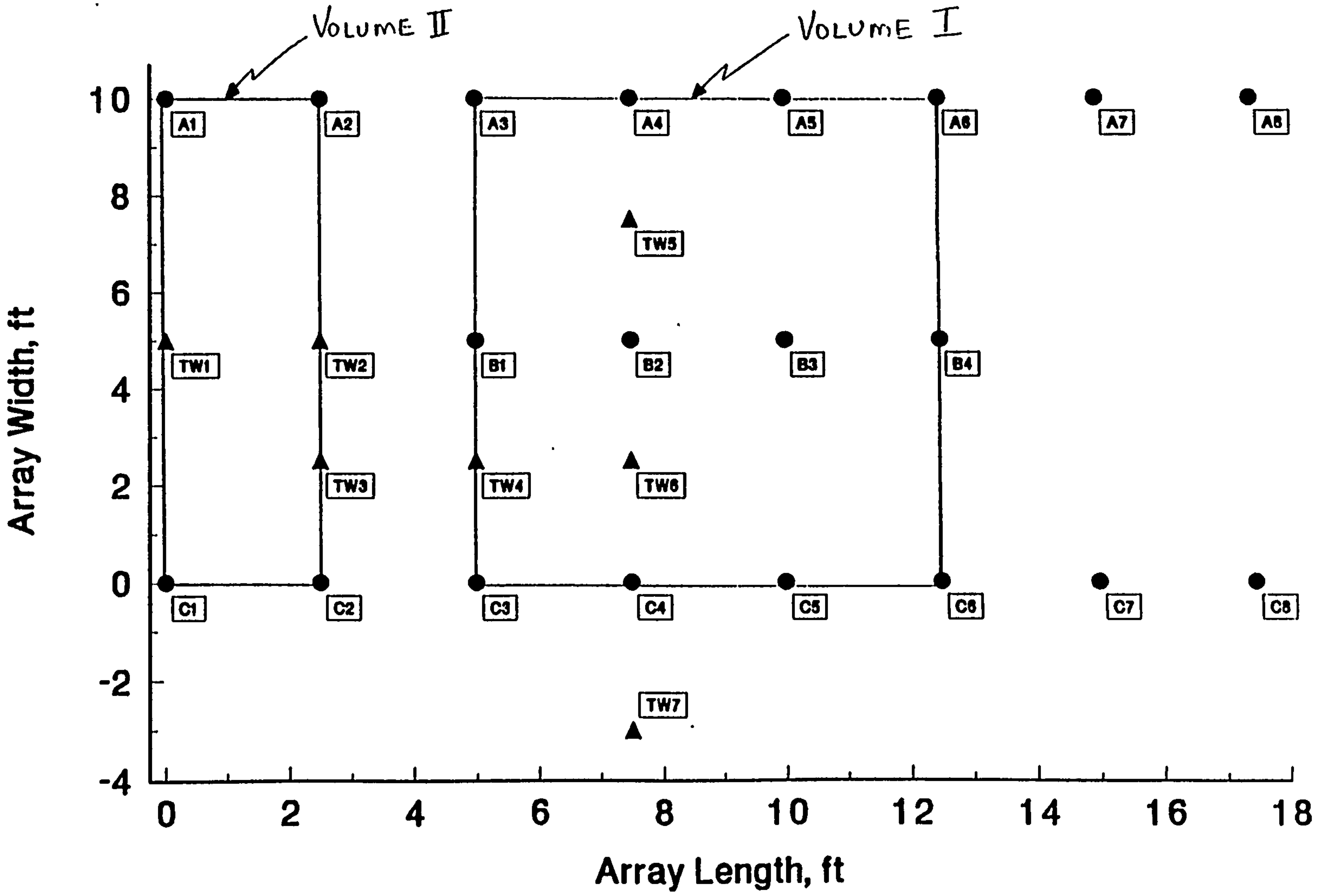
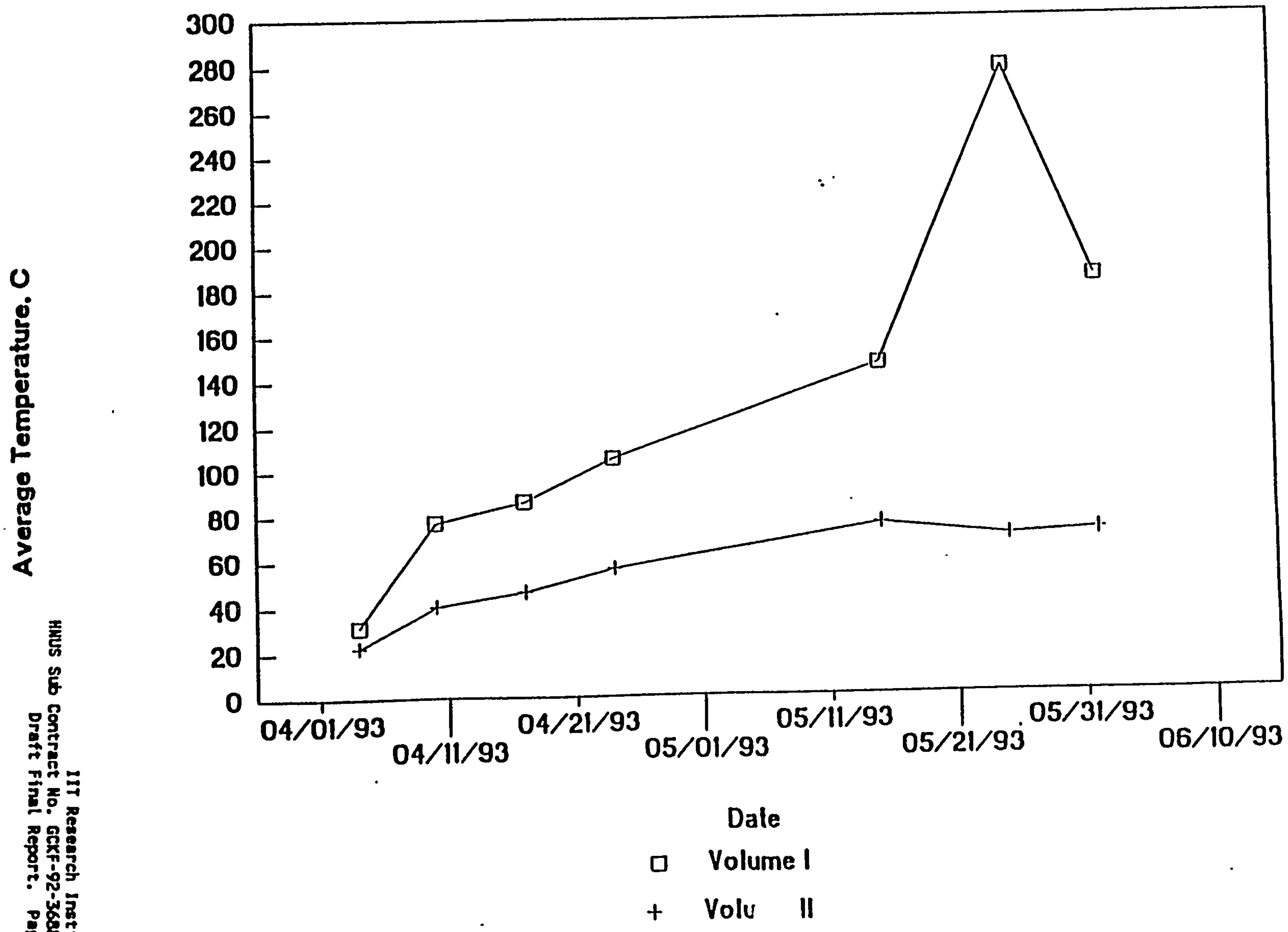


Figure 20

AVERAGE TEMPERATURE IN THE ARRAY, C

(In Volume I and II)



the average temperature was in the range of 60°C to 70°C is estimated to be 37 cu. yd.

There is an intermediate temperature region between Volumes I and II where the average temperature was in the range of 70° to 150°C. It was estimated that the volume of soil where every measurement point equalled or exceeded 100°C is 93 cu. yd. This was estimated by the data presented in the spatial temperature distribution plots presented in a later section herein and in Appendix B.

As mentioned above, there was clear evidence that the copper electrodes in the central row melted due to very high temperatures achieved in this row. Copper melts at 1083°C. Evidence of fused electrodes was recovered during post demonstration demobilization activities from each of the four electrode bore holes B1 to B4. An examination of the complete temperature data presented in Appendix B shows that the melting point of copper was first exceeded at the bottom of electrode B2, as measured by thermocouple B2C. This occurred sometime between May 19 and May 20. The other two measurement points in electrode B2 exceeded the melting point of copper between May 25 and May 26. During the same time, temperature point B3B and B1C also reached or exceeded the melting point of copper. It should be noted that of the 12 temperature measuring points within the center row, only five points reached the melting point of copper and one other fell just short of it by 20°C.

The evidence obtained from the field indicated that every excitor electrode melted. Each of the locations of these electrodes was redrilled with a hollow stem auger. From each hole, electrode pieces were recovered. However, no hole yielded an amount of copper sufficient to account for all the material in an electrode. Due to this it is likely that nearly complete melting of all four electrodes took place. From each hole, nearly intact top section of the electrode was recovered. These varied in length from 6 in. to 24 in.

It is also possible that the thermocouples lost their accuracy once the temperature exceeded 899°C, which is the continuous-duty temperature rating of the thermocouples used in this field experiment. This rating is imposed by the design of the SS 304 sheath used with the Type K, Chromel-Alumel thermocouples used in the field. The chromel alumel thermocouple itself may be used with high temperature sheaths, for measuring temperatures up to 1260°C. SS304 melts in a temperature range of 1400 to 1454°C so it is unlikely that a total failure of the thermocouple sheath occurred.

One possible reason for the overheating of the electrodes in the center row of electrodes was the close proximity of the electrode tips to the water table. This is a possible reason because RF fields will hunt out and concentrate towards water or other polar fluid if present in the vicinity.

The actual depth to water table inside the heated volume during the course of heating is unknown. However, during site preparation activities, four dewatering wells were installed at the four corners of the array area, outside the perimeter of the vapor barrier. There was a water table monitoring point inside the array. One of the electrode bore holes was used for this purpose until it became necessary to remove the piezometer in order to complete the array. The dewatering wells were operated continuously (barring brief shut downs for maintenance and one power failure) in an attempt to keep the water level depressed.

Water level measurements were made in the central piezometer in the period February 2, 1993 to February 11, 1993. Water level was in the range of 22.47 ft to 23.84 ft below ground surface. In the above mentioned time period water table levels decreased by approximately 1 to 1.5 ft. Dewatering wells were operational during this period.

2. Excitor Row Temperatures

Figure 21 illustrates the average temperature in the excitor (Center row) row of electrodes as a function of time and depth. The temperature was measured in each electrode at three depths-- 1 ft, 10 and at the bottom, at approximately 19.5 ft (shown as 20 ft in the Figures). Complete temperature data of the excitor electrodes is presented in Appendix B along with additional graphs.

3. Ground Row Temperatures

Figure 22 illustrates the average temperature of the thermocouples inserted in ground row electrodes. The data is presented as a function of time and depth of insertion. The graph also shows the average of those thermocouples measurement points which were opposite the excitor electrodes B1 to B4. As the graph shows, the average temperature of the ground row measurement points did not exceed 100°C. Although the average was maintained in the temperature range of 85 to 90°C for long period of time. There was one measurement point in electrode A4 which exceeded 100°C. Complete data tables and additional graphs of temperature for the ground electrodes are presented in Appendix B.

4. Thermowell Temperatures

Figure 23 illustrates the average temperature as measured in the six thermowells located inside the array. There was a seventh thermowell located outside the array, opposite electrode C4.

Figure 21

Excitor Row Average Temperature

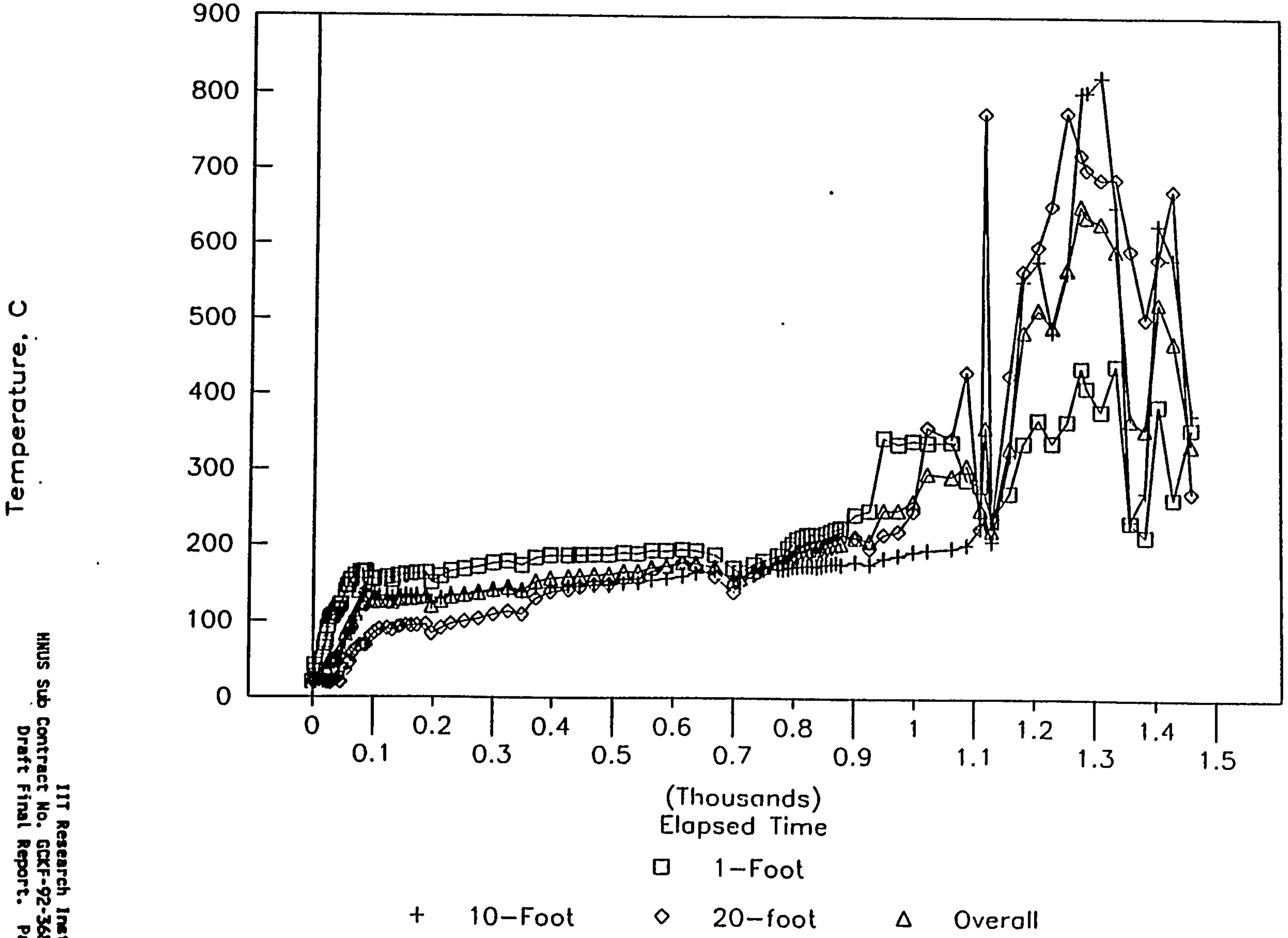


Figure 22

Ground Rows Average Temperature

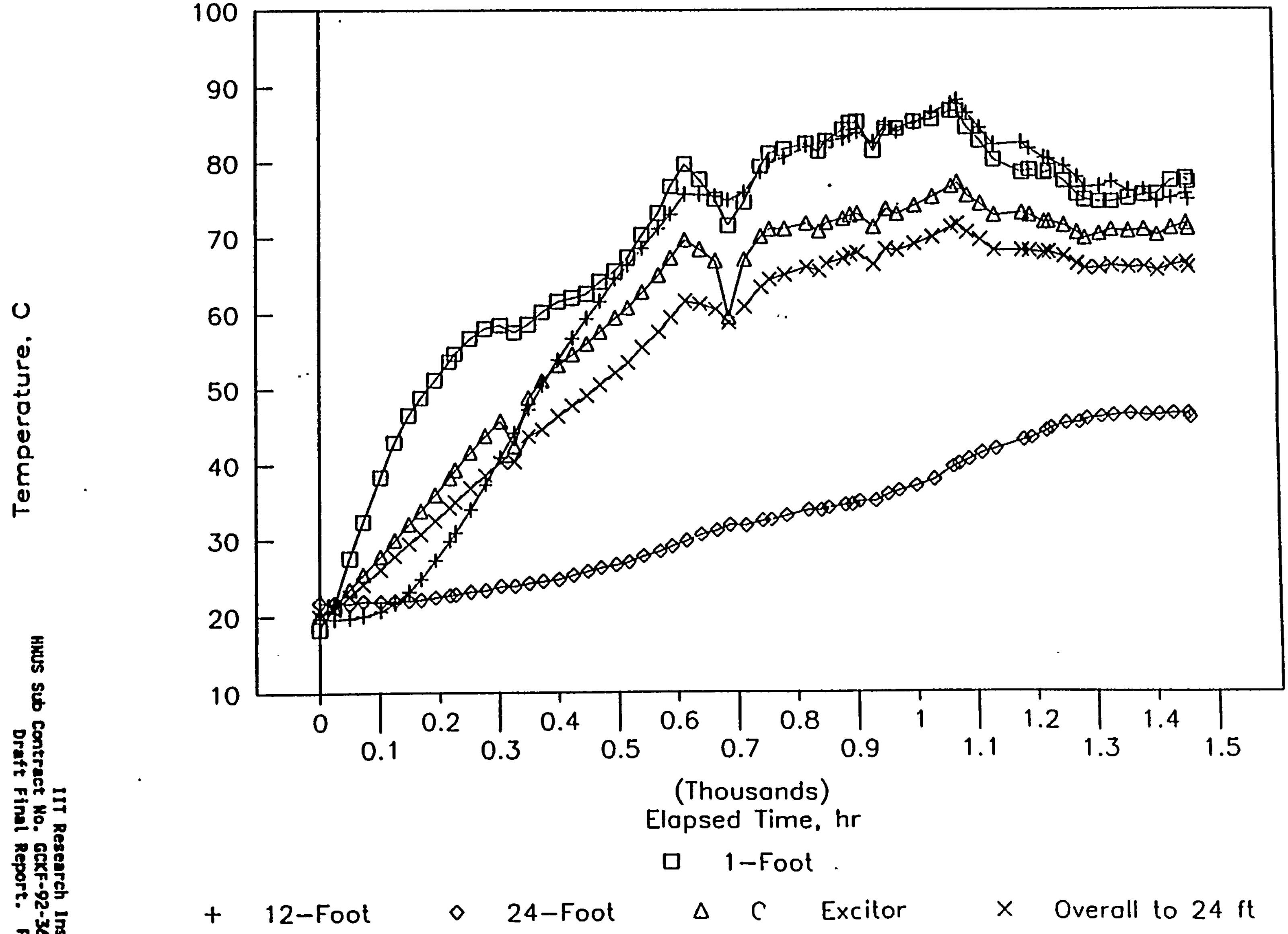


Figure 23

Average Thermowell Temperature vs. Time

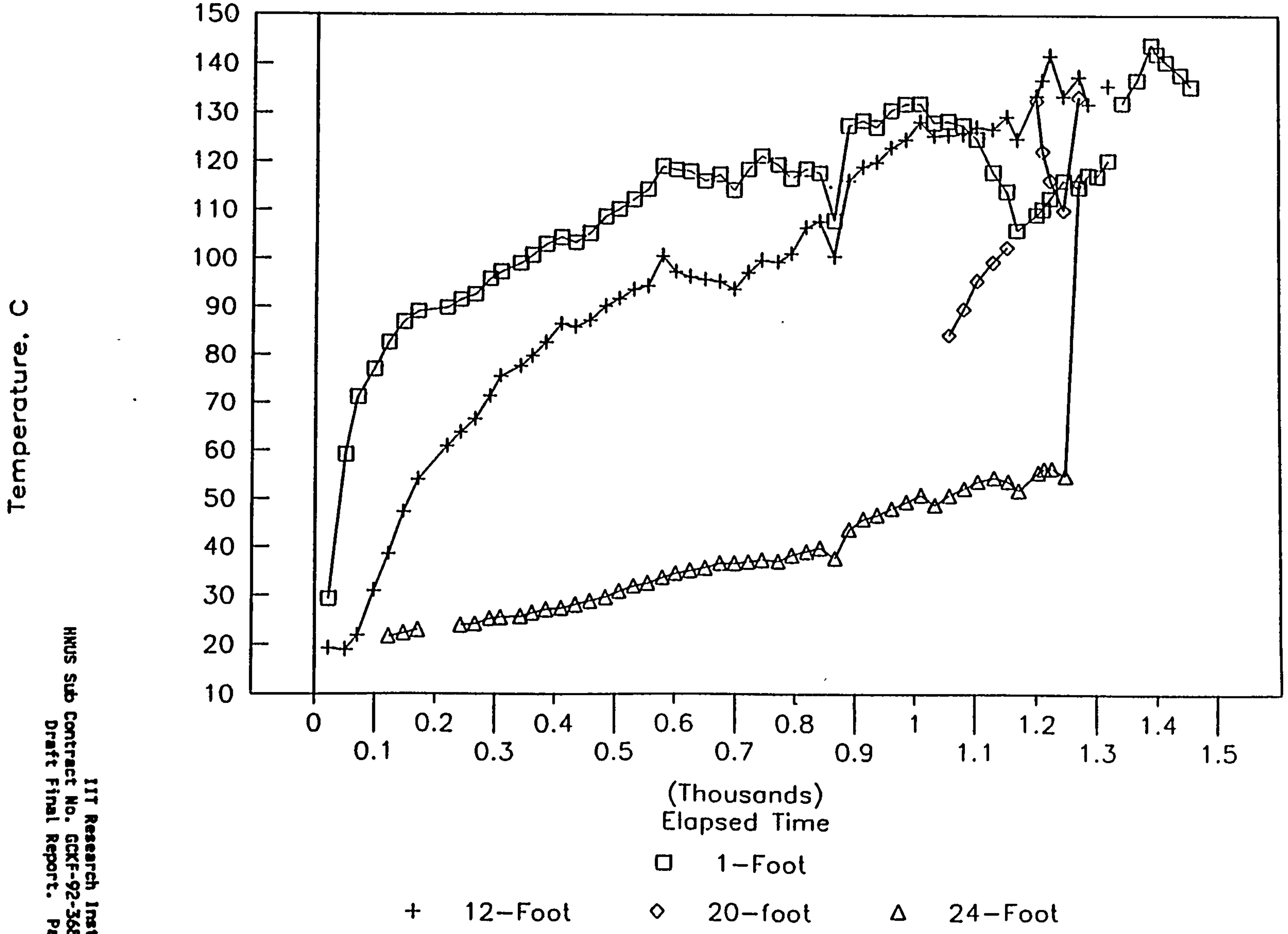


Figure 19 illustrates the thermowell locations. A detail description of the thermowells was presented in Section 5. As the data show, the average thermocouple temperature at a depth of 1-ft reached 140°C towards the end of the demonstration. Similarly the average at the 12 foot level reached 130 to 140°C range. The 24-foot level reached approximately 50°C. During the course of the test, attempts were made to make measurements at a depth of 20 ft in a thermowell which was inserted to a depth of 24 ft. These data show that the average temperature at the 20 ft level reached almost 130°C. It should be noted that these averages include measurements made in TW1 which is on the edge of the array and it consistently showed temperatures much less than the other thermocouples. TW3 was the other thermowell inside the array to exhibit lower temperatures.

Additional temperature data from the thermowells is presented in Appendix B.

5. Temperature Outside the Array

There was one thermowell, TW7, which was placed in a bore hole three feet outside Ground Row C. This hole was located opposite electrode C4. This thermowell had measurement points at depths of 12, 24, and 29 ft. The data is presented as a function of time and depth in Figure 24. At a depth of 12 ft, a maximum temperature of approximately 65°C was achieved. At a depth of 24 ft. the temperature was on the range of 35 to 40°C at the time of shut down. Appendix B illustrates curves in which the temperature in TW7 is compared with the temperature inside the nearest electrode, C4.

6. Temperature During Cool Down

Figure 25 illustrates the average temperature of the two ground rows as a function of depth and time during cool down. As the curves show, the soil cooling rate was quite small despite the continued operation of the vacuum extraction system.

7. Spatial Temperature Distributions

The spatial temperature distribution in five different vertical planes intersecting the electrode array was plotted. Figure 26 defines the locations of the five vertical planes. These were labelled: LONG, LNGU, TRANS, TRNS, and TRNV. The first two are longitudinal vertical planes aligned with the length of the array. The other three are transverse vertical planes, aligned with the width of the array. For illustrative purposes, the spatial distribution as a function of time for plane TRANS is presented here. The remaining distributions are presented in Appendix B.

Figure 24

OUTSIDE THERMOWELL (TW7) TEMPERATURES

(All Depths)

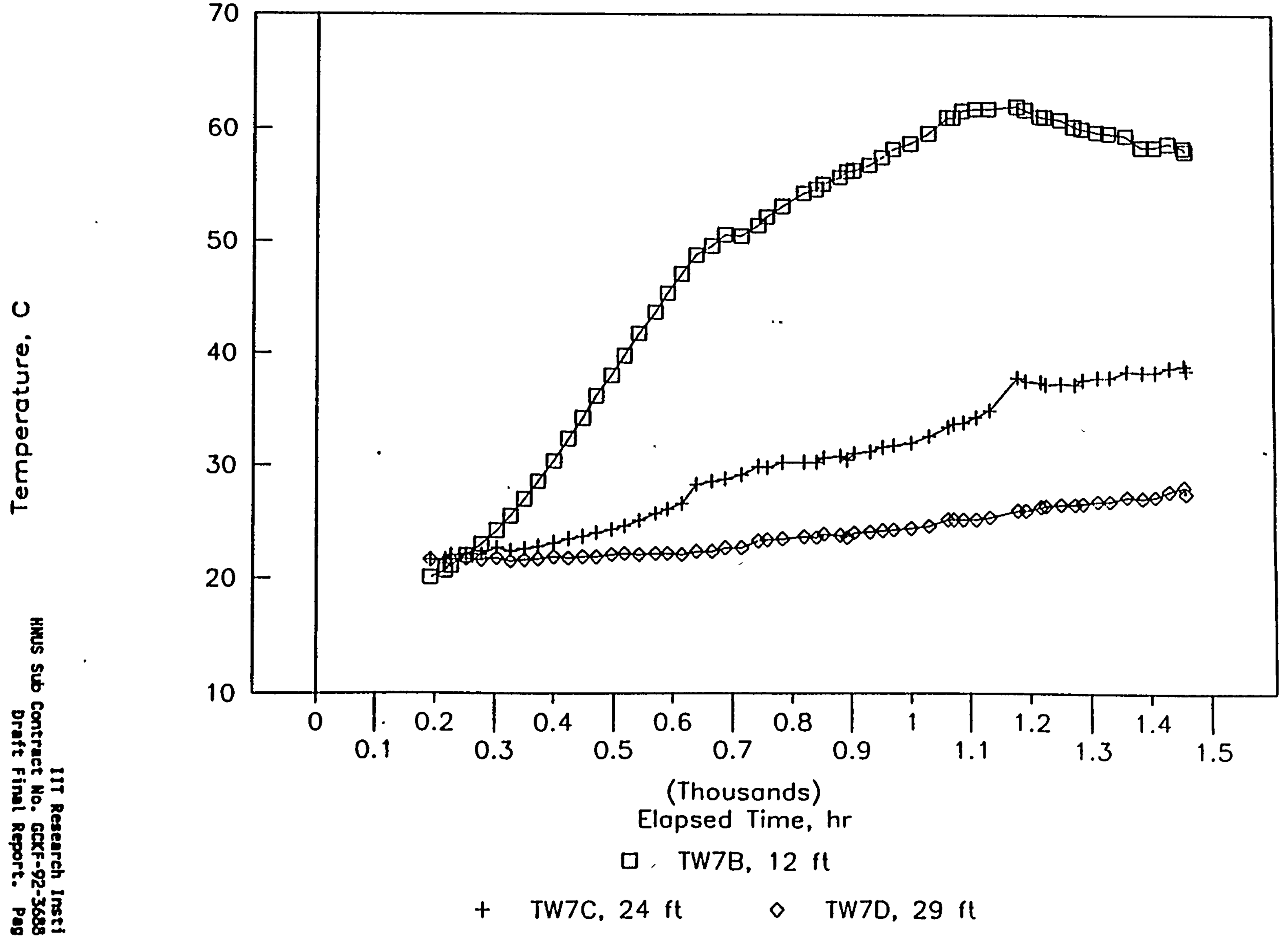


Figure 25

Ground Rows Average Temperature

(Since 12:00hr, June 3, 1993)

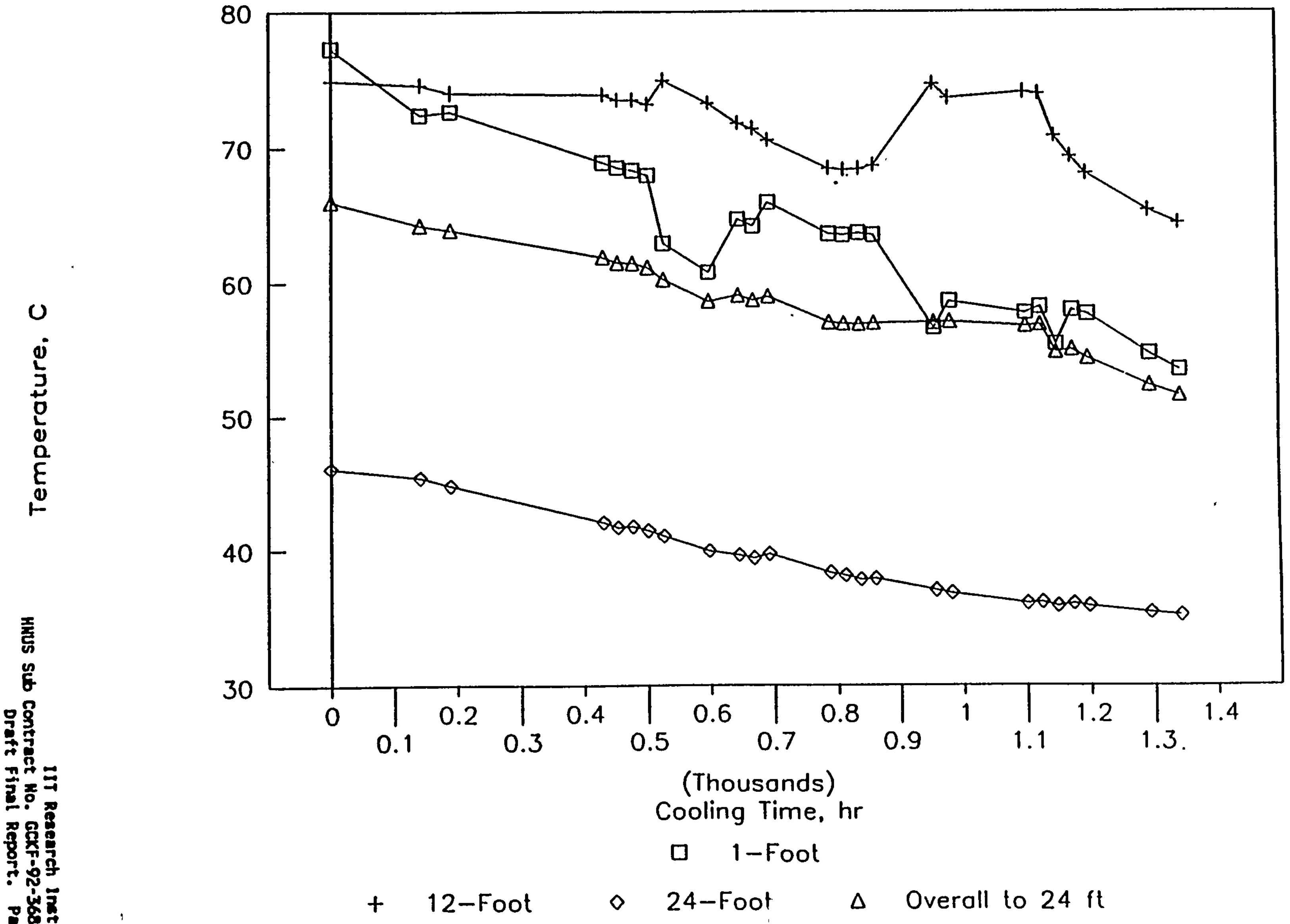


Figure 26. Definition of Vertical Planes for Temperature Distribution
(Plan)

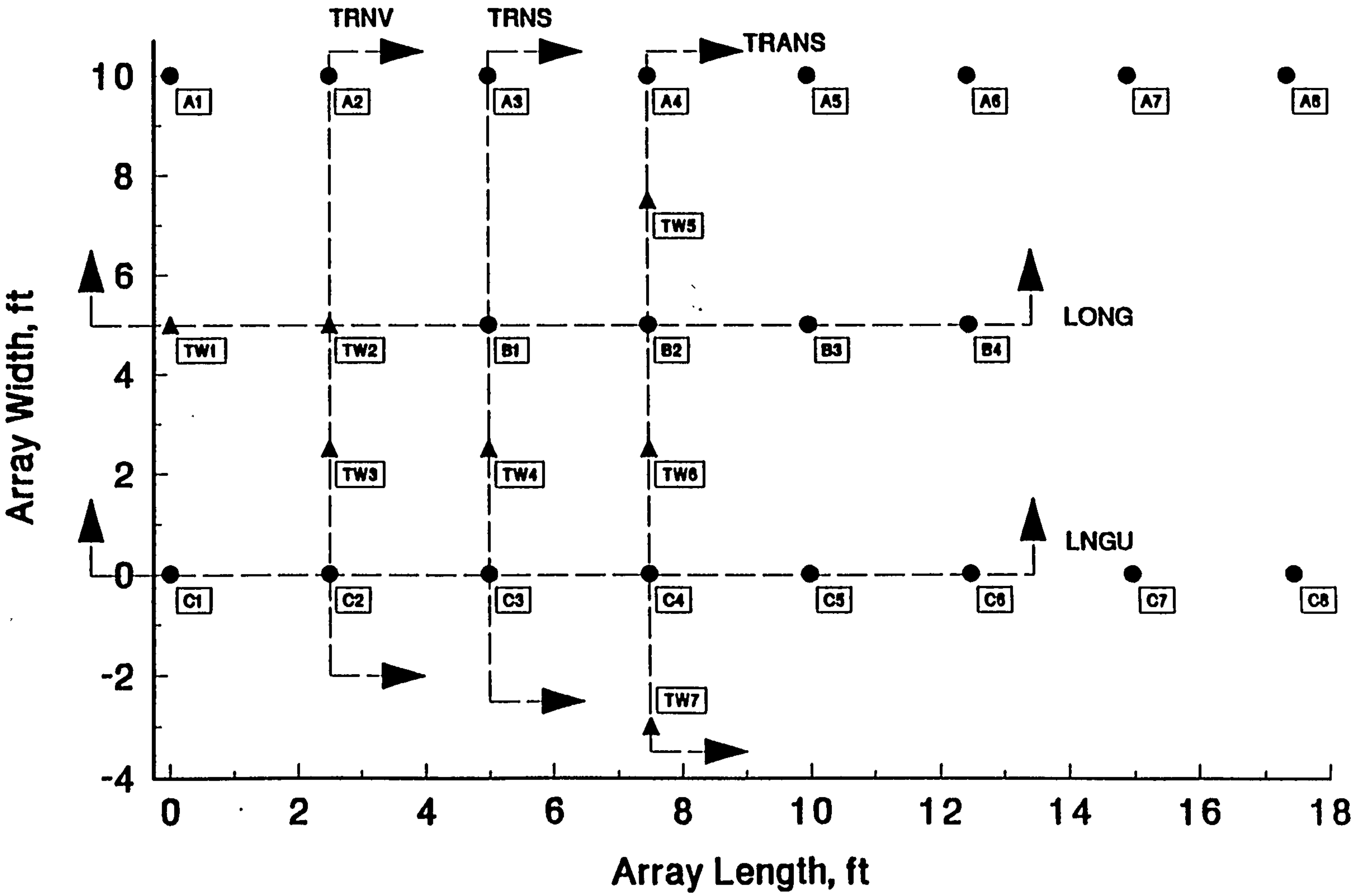


Figure 27. Transverse Temperature Distribution in Plane TRANS

(Depth: 1 ft)

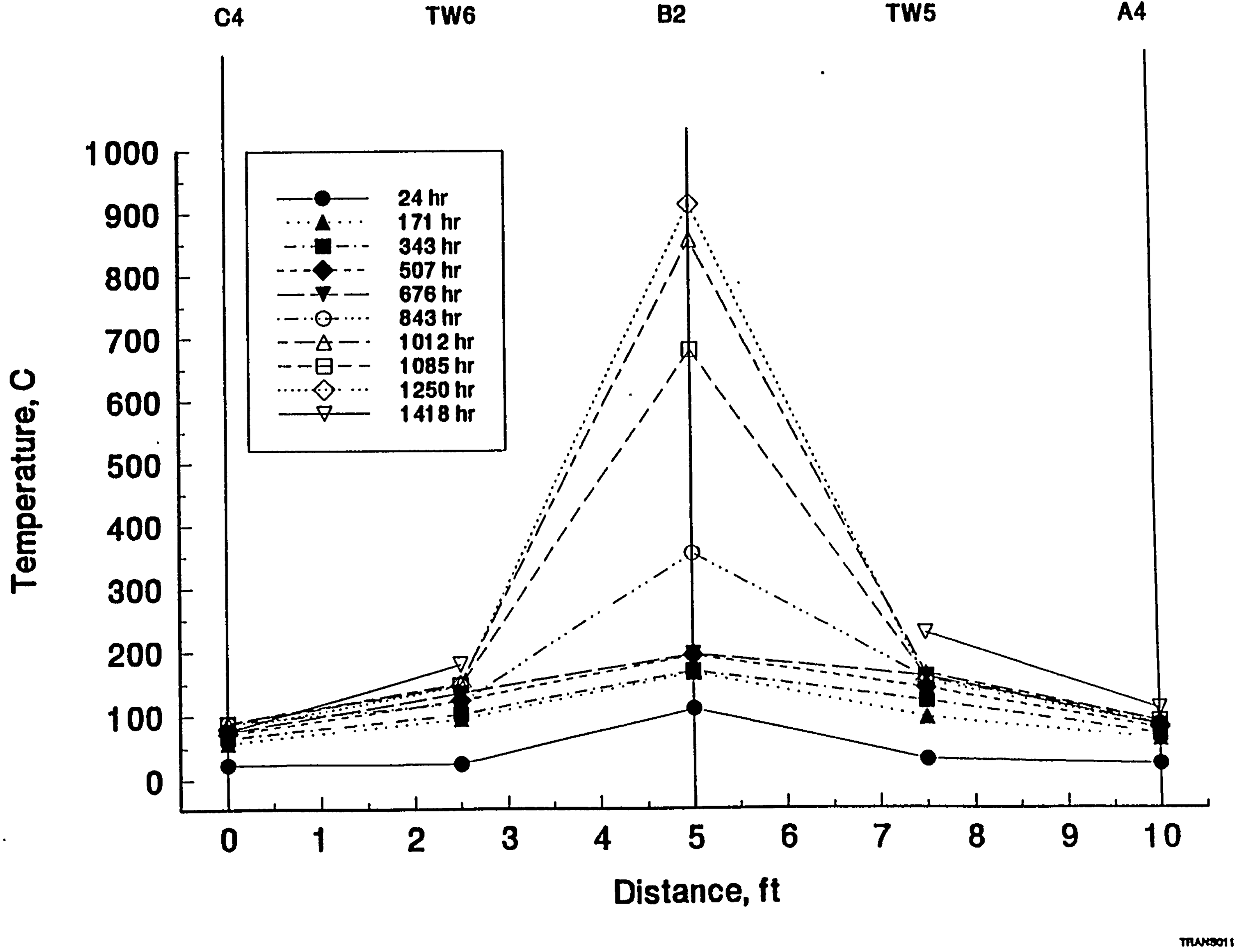


Figure 27 illustrates the spatial temperature distribution in transverse plane labelled TRANS. This is the central plane running perpendicular to the length of the array and it intersects all three rows. Figure 27 shows the temperature profile at a depth of 1 ft. As indicated earlier, ground row temperature at C4 did not exceed 100°C. Temperature at A4 did exceed 100°C towards the end of the experiment. The data shown in this and other spatial distribution figures were selected at approximately one week intervals, after the first day of operation. It should be noted that after 1085 hours, operating difficulties were noted relating to the stability of the electrical match between the load impedance and the impedance of the power source. Temperature at many measurement points decreased after this time, even though attempts were made to continue power input to the soil.

Figure 28 illustrates the transverse temperature distribution at a depth of 10 to 12 ft. B2 was the only measurement point at a depth of 10 ft; all others were at 12 ft. This figure shows the high temperature attained by thermocouple B2B at 1250 hours after start of the demonstration. Figure 29 illustrates the transverse temperature distribution in a depth range of 20 to 24 ft. It should be noted that in this figure, the only measurement point at 20 ft was that in electrode B2, all others were at 24 ft.

B. ANALYSIS OF SOIL FOR TOTAL PETROLEUM HYDROCARBONS

Soil samples obtained from the field by HALLIBURTON NUS were handed over to SAIC, USEPA's contractor for analysis. However, IITRI also performed analysis on the samples using the California DHS method for the analysis of Total Petroleum Hydrocarbons (TPH) expressed as diesel range organics. This was done so that the results may be compared with the results of the Bench scale studies done by IITRI.

The soil samples were shipped to IITRI in coolers after SAIC had finished its analyses of the soil sample. Thus there was a long storage period for these samples, much more than the customary 14 days allowed by many QA/QC procedures. Storage in IITRI was in the original jars which were kept in a refrigerator.

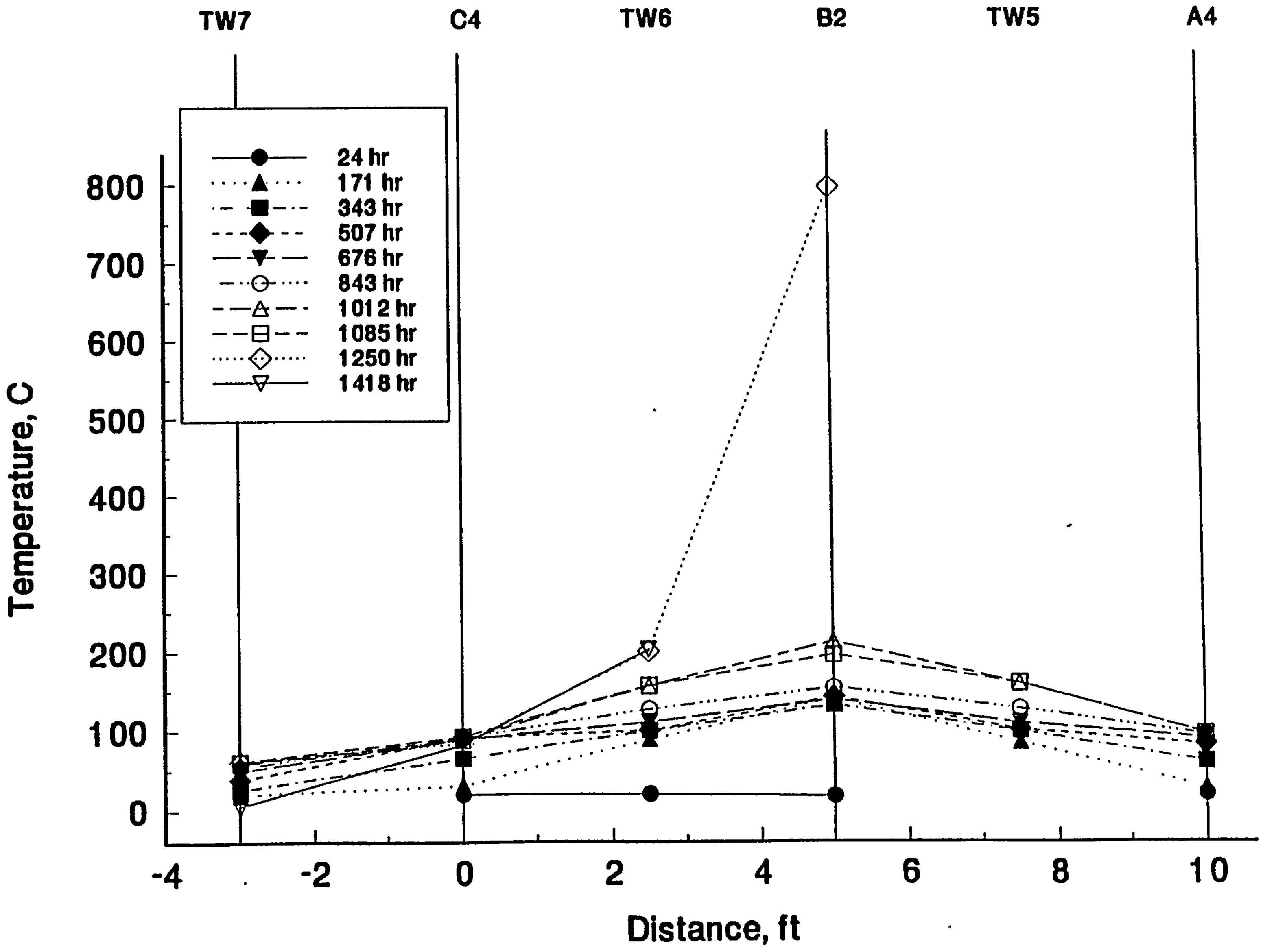
1. Pre-Demonstration Soil Samples

The soil was analyzed by means of methylene chloride extraction followed by extract concentration and analysis of the concentrate by a GC/FID. A solution of diesel in methylene chloride was used to prepare a multi-point calibration curve for the instrument.

Tables 11, 12, and 13 summarize the results of Soil moisture determination, TPH analysis and QA/QC sample analysis,

Figure 28. Transverse Temperature Distribution in Plane TRANS

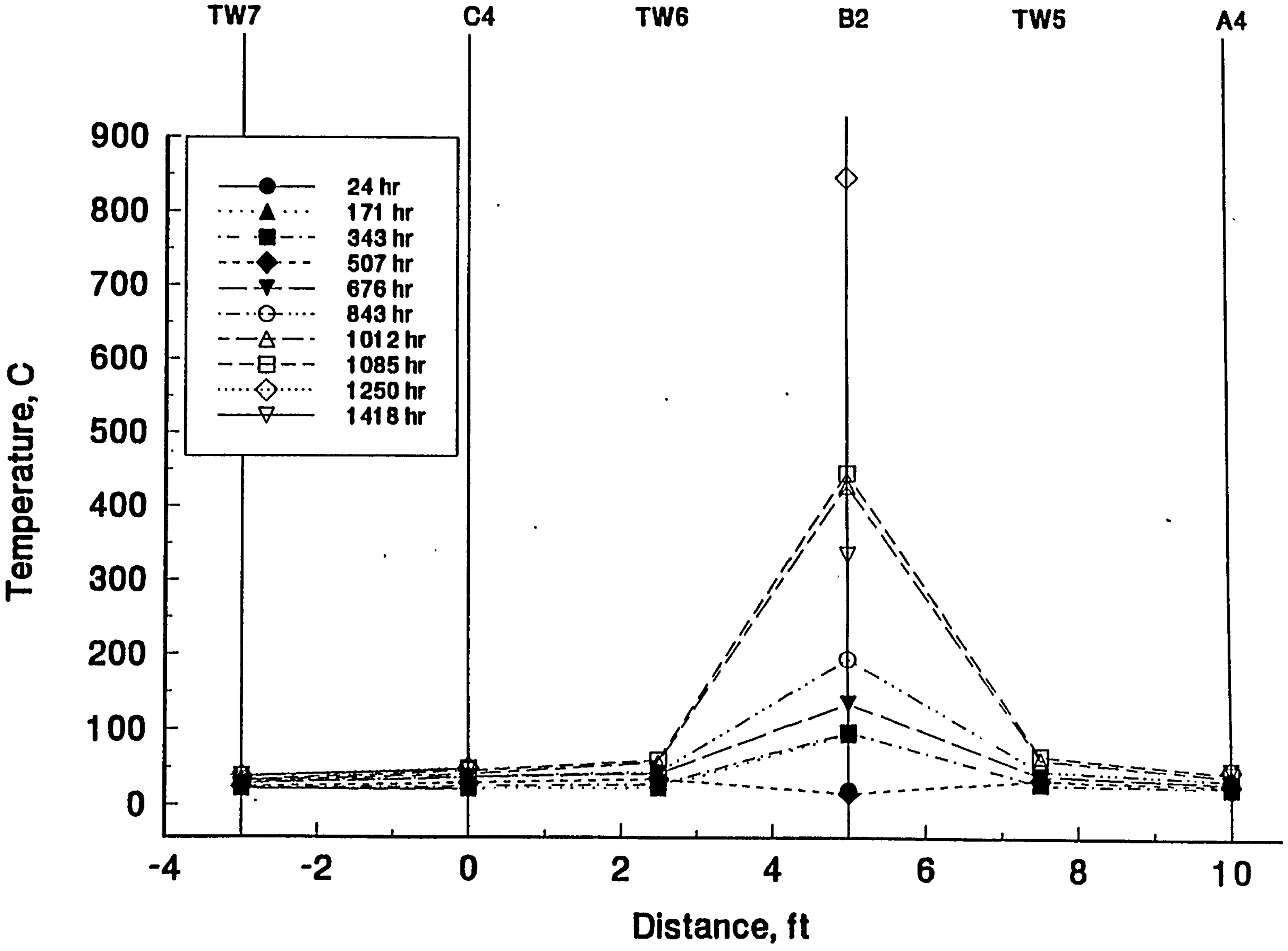
(Depth: 10-12 ft)



TRANS122

Figure 29. Transverse Temperature Distribution in Plane TRANS

(Depth: 20-24 ft)



TRANS8241

TABLE 11. DETERMINATION OF MOISTURE IN PRE-DEMONSTRATION SOIL SAMPLES

Reference No.	Sample Hole Location	Sample Depth Code	Depth Interval ft	Percent Water	Comment
1	EA01	U0406	4-6	22.0%	
2	EA01	U0406	4-6	20.4%	Duplicate of No. 1 above
3	EA02	U1214	12-14	26.5%	
4	EA03	U0204	2-4	19.9%	
5	EA03	U1618	16-18	15.9%	
6	EA04	U0002	0-2	17.2%	
7	EA04	U2022	20-22	11.0%	
8	EA05	U2224	22-24	10.7%	
9	EA07	U0810	8-10	20.7%	
10	EA07	U1214	12-14	26.4%	
11	EA08	U1416	14-16	23.6%	
12	EA08	U2830	28-30	10.1%	
13	EB01	U0002	0-2	21.1%	
14	EB01	U1214	12-14	27.1%	
15	EB02	U0406	4-6	21.5%	
16	EB02	U0810	8-10	20.3%	
17	EB03	U0204	2-4	16.2%	
18	EB03	U0204	2-4	18.9%	Duplicate of No. 17 above
19	EB03	U1012	10-12	19.3%	
20	EB04	U1416	14-16	21.0%	
21	EB04	U2022	20-22	16.8%	
22	EC02	U0608	6-8	22.9%	
23	EC02	U2022	20-22	8.9%	
24	EC03	U0002	0-2	22.0%	
25	EC03	U1820	18-20	24.2%	
26	EC03	U2224	22-24	9.0%	
27	EC03	U2224	22-24	9.9%	Duplicate of No. 26 above
28	EC05	U1012	10-12	11.0%	
29	EC05	U1012	10-12	11.5%	Duplicate of No. 28 above
30	EC06	U0204	2-4	18.2%	
31	EC06	U1820	18-20	20.6%	
32	EC07	U0406	4-6	16.0%	
33	EC07	U0406	4-6	20.0%	Duplicate of No. 32 above
34	EC08	U0406	4-6	20.0%	
35	EC08	U0406	4-6	16.4%	Duplicate of No. 34 above
36	EC08	U1416	14-16	19.7%	
37	EC08	U2224	22-24	9.8%	
38	TW01	U1416	14-16	22.0%	
39	TW02	U0406	4-6	19.6%	
40	TW02	U1416	14-16	25.7%	
41	TW02	U1416	14-16	23.4%	Duplicate of No. 40 above

TABLE 12. DETERMINATION OF TPH IN PRE-DEMONSTRATION SOIL SAMPLES

Reference No.	Sample Hole Location	Sample Depth Code	Depth Interval ft.	Gas Chromatograph Sample No.	Gas Chromatograph Batch No	TPH Conc. in soil ppm as received	TPH Conc. in soil ppm dry basis	No. of Peaks in Diesel Range	Was Extract Diluted? Yes/No	Comments
1	EA01	U0406	4-6	MC-23	6	47	61	31	N	
3	EA02	U1214	12-14	MC-28	7	240	326	43	N	
4	EA03	U0204	2-4	MC-35	8	30	37	37	N	
5	EA03	U1618	16-18	MC-4 spike dil	3	6995	8317	58	Y	MC-4 + Spike of 1 ml of 2.06 mg/ml
5	EA03	U1618	16-18	MC-4dil	3	6835	8128	55	Y	
6	EA04	U0002	0-2	MC-27	7	13	15	39	N	
7	EA04	U2022	20-22	MC-20	6	2443	2746	57	N	
7	EA04	U2022	20-22	MC-20RE	6	2426	2727	60	N	MC-20 reinjected
7	EA04	U2022	20-22	MC-38	8	2318	2605	58	N	Duplicate of MC-20
8	EA05	U2224	22-24	MC-7dil	2	2554	2860	55	Y	
9	EA07	U0810	8-10	MC-31	7	78	98	28	N	
10	EA07	U1214	12-14	MC-14	5	21	29	32	N	
10	EA07	U1214	12-14	MC-14RE	6	12	17	39	N	MC-14 reinjected
10	EA07	U1214	12-14	MC-14RE	7	N.D.	N.D.	32	N	MC-14 reinjected
11	EA08	U1416	14-16	MC-34	8	27	35	40	N	
12	EA08	U2830	28-30	MC-29	7	413	460	52	N	
13	EB01	U0002	0-2	MC-37	8	329	417	36	N	
14	EB01	U1214	12-14	MC-8	3	39	53	58	N	
15	EB02	U0406	4-6	MC-6	1	65	82	67	N	
15	EB02	U0406	4-6	MC39	9	171	218	45	N	MC-6+spike: 1.0 ml of 1.92 mg/ml
16	EB02	U0810	8-10	MC-26	7	187	234	25	N	
17	EB03	U0204	2-4	MC-1	3	N.D.	N.D.	26	N	
19	EB03	U1012	10-12	MC-24	6	3027	3751	42	N	
20	EB04	U1416	14-16	MC-15	5	821	1039	54	N	
21	EB04	U2022	20-22	MC-16	5	1049	1260	49	N	
21	EB04	U2022	20-22	MC-18	6	1049	1261	56	N	
21	EB04	U2022	20-22	MC-40	8	1490	1791	60	N	MC-18 + spike: 5.0 ml of 1.92 mg/ml

N.D.: None Detected

Shaded Results: In these the TPH area response was less than or equal to Average method blank area + three times standard deviation of the blanks

RE: Extract reinjected, Duplicate: duplicate extraction/injection; dil: extract was diluted

TABLE 12. DETERMINATION OF TPH IN PRE-DEMONSTRATION SOIL SAMPLES

Reference No.	Sample Hole Location	Sample Depth Code	Depth Interval ft.	Gas Chromatograph Sample No.	Gas Chromatograph Batch No	TPH Conc. In soil ppm as received	TPH Conc. In soil ppm dry basis	No. of Peaks in Diesel Range	Was Extract Diluted? Yes/No	Comments
22	EC02	U0608	6-8	MC-2	1	351	455	64	N	
22	EC02	U0608	6-8	MC-2RE	2	341	443	61	N	MC-2 reinjected
23	EC02	U2022	20-22	MC-32	8	2597	2852	58	N	
24	EC03	U0002	0-2	MC-12	4	34	44	39	N	
25	EC03	U1820	18-20	MC-21	6	5499	7257	50	N	
25	EC03	U1820	18-20	MC-21 DIL	7	9239	12194	55	Y	
26	EC03	U2224	22-24	MC-5	2	4287	4710	59	Y	
26	EC03	U2224	22-24	MC-5 DUP.	2	3964	4400	56	Y	MC-5 duplicated
26	EC03	U2224	22-24	MC-5 DUP.	2	4003	4443	58	Y	Reinjection of MC-5 duplicate
28	EC05	U1012	10-12	MC-3	3	865	972	50	N	
28	EC05	U1012	10-12	MC-3D2	3	996	1119	61	Y	MC-3 diluted, X 22.2
28	EC05	U1012	10-12	MC-3 dil	3	862	969	62	Y	MC-3 diluted, X 7.41
29	EC05	U1012	10-12	MC-25	6	463	523	38	N	MC-3 duplicate
30	EC06	U0204	2-4	MC-30	7	68	83	36	N	
31	EC06	U1820	18-20	MC-33	8	3126	3938	55	N	
31	EC06	U1820	18-20	MC-33RE	9	3148	3965	57	N	MC-33 reinjected
31	EC06	U1820	18-20	MC-33dil	10	3228	4066	54	Y	MC-33 diluted
32	EC07	U0406	4-6	MC-16	5	26	31	35	N	
34	EC08	U0406	4-6	MC-19	5	20	25	31	N	
36	EC08	U1416	14-16	MC-9	3	N.D.	N.D.	41	N	
36	EC08	U1416	14-16	MC-17	6	52	65	44	N	Duplicate of MC-9
37	EC08	U2224	22-24	MC-10	4	1945	2156	52	N	
38	TW01	U1416	14-16	MC-22	6	504	646	58	N	
39	TW02	U0406	4-6	MC-11	4	31	39	35	N	
40	TW02	U1416	14-16	MC-36	8	426	573	49	N	

N.D.: None Detected

Shaded Results: In these the TPH area response was less than or equal to
Average method blank area + three times standard deviation of the blanks

RE: Extract reinjected, Duplicate: duplicate extraction/injection; dil: extract was diluted

TABLE 13. DETERMINATION OF TPH IN PRE–DEMONSTRATION SOIL SAMPLES QA/QC SAMPLES

Gas Chromatograph		TPH Conc.	TPH Conc.		
Sample No.	Batch No	In sample mg/ml As Analyzed	In sample mg/ml Actual	Error %	Comments
KQA–1	3	4.33	4.12	5.1%	QA/QC Control Sample for Checking of GC
KQA–2	3	2.18	2.13	2.6%	QA/QC Control Sample for Checking of GC
MCMB–2	3	N.D.	0		Method Blank (TPH Area: 14,151)
MC–13	4	0.04	0		Method Blank (TPH Area: 18,033)
KQA–3	4	5.78	5.52	4.8%	QA/QC Control Sample for Checking of GC
KQA–4	4	2.95	2.76	7.0%	QA/QC Control Sample for Checking of GC
KQA–4	5	2.84	2.76	2.9%	QA/QC Control Sample for Checking of GC
KQA–3	6	5.60	5.52	1.4%	QA/QC Control Sample for Checking of GC
KQA–4	6	2.81	2.76	1.9%	QA/QC Control Sample for Checking of GC
KQA–F	7	1.91	1.93	–1.0%	QA/QC Control Sample for Checking of GC
KQA–3	7	5.78	5.52	4.7%	QA/QC Control Sample for Checking of GC
KQA–F	9	1.94	1.93	0.3%	QA/QC Control Sample for Checking of GC
KQA–3	9	5.62	5.52	1.9%	QA/QC Control Sample for Checking of GC
MC–43	10	0.33		R	Method Blank with spike: 1 ml. of 7.638 mg/ml
MC–41	10	0.04	0		Method Blank, no spike (TPH Area: 20,020)
MC–42	10	0.25		R	Method Blank with spike: 1 ml. of 1.92 mg/ml

N.D.: None Detected

R: Spike recovery calculation made separately in Table 14 respectively. Thirty four different samples were analyzed. The results show that the soil concentration varies from less than 35 ppm to 9200 ppm (as received). On a dry basis the concentration ranges from less than 44 to 12,200 ppm. In a number of samples it was observed that there were compounds present, outside the diesel window, towards the higher boiling end. These have not been included in the reported results. There were eight samples in which the concentration (as received) was in the range of 12 to 34 ppm. In these eight samples, the TPH area count is within 3 standard deviations of the area count of the method blanks.

Table 14 is a summary of the spiked sample analyses. Two types of spiked samples were analyzed. First, the soil as received from the field was spiked with a known amount of TPH. Then the spiked soil was extracted and the extract analyzed on the GC/FID. The results were compared (through a mass balance on TPH) with the results of the unspiked field soil to determine the percent recovery. The percent recovery ranged between 200 and 320 percent. It should be noted that the TPH concentration reported in Table 12 has not been corrected by the recovery efficiency.

In the second type of spiking experiment, a method blank was spiked with a known amount of TPH (Table 14). The recovery was calculated by a mass balance on TPH. The mass balance was done by a comparison of TPH mass in unspiked method blank versus the spiked method blank. The recovery of TPH from spiking of the method blanks was in the range of 103 to 130 percent.

Table 15 is a summary of sample duplicates. Four samples were extracted and analyzed in duplicate. The relative percentage difference (RPD) ranges from 2.5 to 100 percent. The low concentration sample gave the 100 percent RPD. In four cases, the prepared extract was injected twice into the GC/FID to test the reproducibility of the instrument. The RPD was in the range of 0.4 to 1.5 percent. In one case, a low concentration (less than 21 ppm) sample was injected three times which yielded a relative standard deviation of 96 percent.

2. Post-Demonstration Soil Samples

The post demonstration soil samples were analyzed in a similar manner as the pre-demonstration soil samples. Even these samples had a long storage period as mentioned earlier.

Twenty one post-demonstration soil samples were analyzed by the California DHS method. The result of these analyses are presented in Table 16. The concentrations of soil moisture and TPH are presented in the table.

TABLE 14. SPIKE RECOVERY

RECOVERY OF TPH SPIKES FROM SOIL

Ref. No.	Sample Nos.	TPH Conc. in Soil as Received ppm	Amount Spiked Equivalent, ppm	Total TPH Conc. in Spiked Soil ppm	Spike Recovery %
5	MC−4 MC−4 spike,dil	6835	50	6995	320
15	MC−6 MC−39	65	46.2	171	229
21	MC−18 MC−40	1049	218	1490	202

RECOVERY OF TPH SPIKE FROM METHOD BLANKS

	Total TPH mg	Recovery %
Unspiked Method Blank:	0.4	---
Method Blank + 1.92 mg spike	2.5	130
Method Blank + 7.64 mg spike	8.25	103

TABLE 15. RESULTS OF DUPLICATE ANALYSIS

RESULTS OF DUPLICATE EXTRACTIONS/GC ANALYSIS

Sample No.	TPH Conc. as received ppm	Sample No.	TPH Conc. as received ppm	Sample No.	TPH Conc. as received ppm	Sample No.	TPH Conc. as received ppm
MC-5	4287	MC-25	463	MC-20	2435	MC-9	0
MC-5dup	3964	MC-3	906	MC-38	2318	MC-17	52
Average	4136		686		2377		26
R.P.D	3.7%		32.0%		2.5%		100.0%

RESULTS OF DUPLICATE GC INJECTIONS

Sample No.	TPH Conc. as received ppm	Sample No.	TPH Conc. as received ppm	Sample No.	TPH Conc. as received ppm	Sample No.	TPH Conc. as received ppm	Sample No.	TPH Conc. as received ppm
MC-20	2443	MC-2	351	MC-5DUP	3964	MC-33	3126	MC-14	21
MC-20RE	2426	MC-2RE	341	MC-5DUPRE	4003	MC-33RE	3148	MC-14RE	12
								MC-14RE	0
Average	2434.5		346		3983.5		3137		11
R.P.D	0.4%		1.5%		0.5%		0.4%		

TABLE 16. POST DEMONSTRATION SOIL ANALYSIS FOR TPH BY CALIFORNIA METHOD AND MOISTURE BY WEIGHT LOSS IN OVEN
(Preliminary Results Subject to Review and Correction)

Sample Hole Location	Sample Depth Code	Depth Interval ft.	Percent Water	Gas Chromatograp Sample No.	Gas Chromatograp File No.	Date Injected	Regression Reference	TPH Conc. In extract mg/ml	TPH Conc. In soil, ppm as received	TPH Conc. In soil, ppm dry basis	No. of Peaks In Diesel Range	Was Extract Diluted? Yes/ No	Comments
EC02A	U0608	6-8	22.5%	F112	Final116	05/18/94	NSCAL08	0.22	32	41	53	N	
EC02A	U2022	20-22	4.4%	F117	Final125	05/18/94	NSMSTR02	16.91	1772	1854	39	N	
EC02A	U2022	20-22	4.4%	F117Dil	Final154	05/21/94	NSMSTR03	25.52	2673	2797	41	Y	
EC03A	U0002	0-2	8.8%	F169	Final121	05/18/94	NSMSTR02	0.19	24	26	54	N	
EC03A	U1820	18-20	9.4%	F75	Final162	05/21/94	NSMSTR03	29.01	4845	5350	37	N	
EC03A	U1820	18-20	9.4%	F75Dil	Final183	05/25/94	NSCAL09	34.12	5699	6293	34	Y	
EC03A	U2224	22-24	8.4%	F88	Final119	05/18/94	NSMSTR02	9.16	1269	1385	38	N	
EC05A	U1012	10-12	0.7%	F160	Final114	05/19/94	NSCAL08	0.04	5	5	52	N	
EC06A	U0204	2-4	0.4%	F90	Final115	05/18/94	NSCAL08	0.07	9	9	49	N	
EC06A	U1820	18-20	4.4%	F82	Final120	05/18/94	NSMSTR02	8.17	1051	1099	27	N	
EC07A	U0406	4-6	2.1%	F68	Final129	05/19/94	NSMSTR02	0.18	27	27	42	N	
EC07A	U1012	10-12	3.3%	F97	Final136	05/19/94	NSMSTR02	1.24	171	177	41	N	
EC07A	U1012	10-12	3.3%	F97Dup	Final202	05/27/94	NSCAL10	1.06	146	151	39	N	
EC08A	U0406	4-6	1.4%	F113	Final135	05/19/94	NSMSTR02	1.33	205	208	38	N	
EC08A	U1416	14-16	14.9%	F114	Final128	05/18/94	NSMSTR02	0.15	28	33	45	N	
EC08A	U2224	22-24	6.4%	F115	Final131	05/19/94	NSMSTR02	17.09	2485	2656	40	N	
EC08A	U2224	22-24	6.4%	F115Dil	Final153	05/21/94	NSMSTR03	18.27	2656	2839	38	Y	
TW01A	U0608	6-8	1.9%	F85	Final 72	05/12/94	NSCAL07	1.65	258	263	44	N	
TW01A	U1416	14-16	11.1%	F106Rex	Final164	05/22/94	NSMSTR03	14.78	5664	6370	38	N	
TW01A	U1416	14-16	11.1%	F106Rex	Final185	05/25/94	NSCAL09	15.59	5972	6716	37	Y	
TW02A	U0406	4-6	1.0%	F87	Final73	05/12/94	NSCAL07	0.23	48	48	45	N	
TW02A	U1416	14-16	1.3%	F91	Final66	05/12/94	NSCAL07	1.40	411	417	43	N	
TW07A	U0406	4-6	12.2%	F92	Final126	05/18/94	NSMSTR02	0.22	33	38	46	N	
TW07A	U1416	14-16	8.4%	F66	Final68	05/12/94	NSCAL07	14.43	1891	2064	49	N	
TW07A	U1416	14-16	8.4%	F66Dil1	Final112	05/17/94	NSCAL08	17.31	2268	2476	43	Y	
TW07A	U1416	14-16	8.4%	F66Dil2	Final159	05/21/94	NSMSTR03	14.90	1953	2131	45	Y	
TW07A	U1416	14-16	8.4%	F66Dil2C	Final199	05/27/94	NSMSTR10	15.02	1968	2148	33	Y	

Rex: Duplicate Extraction of soil, Dup: duplicate injection; Dil: extract diluted

TABLE 16. POST DEMONSTRATION SOIL ANALYSIS FOR TPH BY CALIFORNIA METHOD AND MOISTURE BY WEIGHT LOSS IN OVEN

(Preliminary Results Subject to Review and Correction)

Sample Hole Location	Sample Depth Code	Depth Interval ft.	Percent Water	Gas Chromatograp Sample No.	File No.	Date Injected	Regression Reference	TPH Conc. in extract mg/ml	TPH Conc. in soil, ppm as received	TPH Conc. in soil, ppm dry basis	No. of Peaks in Diesel Range	Was Extract Diluted? Yes/No	Comments
EA01A	U0608	6-8	5.0%	F120	Final20	05/06/94	NSMSTR01	0.91	128	134	49	N	
EA02A	U1416	14-16	18.7%	F116	Final21	05/06/94	NSMSTR01	1.99	360	443	50	N	
EA02A	U1416	14-16	23.4%	F138	Final143	05/20/94	NSMSTR03	50.19	6766	8838	29	N	
EA02A	U1416	14-16	23.4%	F138DIL	Final162	05/25/94	NSCAL09	51.08	6885	8993	35	Y	
EA03A	U1820	18-20	6.1%	F86	Final19	05/06/94	NSMSTR01	15.45	2497	2660	40	N	
EA03A	U1820	18-20	6.1%	F86Dil	Final27	05/09/94	NSCAL04	10.03	1622	1727	32	Y	
EA03A	U1820	18-20	6.1%	F86Dil	Final156	05/21/94	NSMSTR03	15.48	2502	2665	46	Y	
EA04A	U0002	0-2	6.5%	F94	Final40	05/10/94	NSCAL05	0.07	10	11	48	N	
EA04A	U0002	0-2	6.5%	F94DUP	Final195	05/27/94	NSCAL10	0.09	14	15	39	N	
EA04A	U2022	20-22	0.4%	F159	Final23	05/06/94	NSMSTR01	5.31	594	597	37	N	
EA04A	U2022	20-22	0.4%	F159S	Final22	05/06/94	NSMSTR01	9.79	1213	1218	36	N	F159 spiked with 17.1 mg of TPH
EA04A	U2022	20-22	0.4%	F159SDI	Final155	05/21/94	NSMSTR03	10.01	1241	1246	39	Y	F159S Diluted
EA05A	U2223	22-23	1.9%	F121	Final42	05/10/94	NSCAL05	14.76	1753	1786	34	N	
EA05A	U2223	22-23	1.9%	F121Dil	Final51	05/11/94	NSCAL06	5.56	660	672	40	Y	
EA05A	U2223	22-23	1.9%	F121DilI	Final157	05/21/94	NSMSTR03	9.79	1162	1184	37	Y	
EA06A	U1820	18-20	3.0%	F175	Final43	05/10/94	NSCAL05	2.28	279	288	44	N	
EA07A	U0810	8-10	0.3%	F177	Final41	05/10/94	NSCAL05	0.20	26	26	42	N	
EA07A	U1214	12-14	3.0%	F176	Final50	05/11/94	NSCAL06	0.82	123	127	52	N	
EA08A	U1416	14-16	8.7%	F155	Final39	05/10/94	NSCAL05	2.93	440	482	38	N	
EB01A	U0002	0-2	0.5%	F13	Final52	05/11/94	NSCAL06	0.04	5	5	42	N	
EB01A	U0002	0-2	0.5%	F13Rex	Final145	05/20/94	NSMSTR03	0.36	43	43	47	N	
EB01A	U1618	16-18	0.3%	F107	Final53	05/11/94	NSCAL06	0.24	29	29	36	N	
EB01A	U1618	16-18	0.3%	F107Rex	Final163	05/22/94	NSMSTR03	0.41	71	71	38	N	
EB02A	U0406	4-6	0.2%	F12	Final58	05/11/94	NSCAL06	0.05	7	7	49	N	
EB03A	U0204	2-4	0.4%	F39	Final61	05/11/94	NSCAL06	0.13	16	16	39	N	
EB03A	U0204	2-4	0.4%	F39Rex	Final144	05/20/94	NSMSTR03	0.44	61	61	44	N	
EB03A	U0204	2-4	0.4%	F131-1	Final148	05/20/94	NSMSTR03	0.40	48	48	40	N	
EB03A	U0204	2-4	0.4%	F131-2	Final149	05/21/94	NSMSTR03	3.01	348	350	43	N	F131-1 spiked with 31 mg TPH
EB03A	U1012	10-12	2.8%	F73	Final56	05/11/94	NSCAL06	0.03	4	4	44	N	
EB04A	U1618	14-16	3.9%	F34	Final75	05/12/94	NSCAL07	0.73	107	112	35	N	
EB04A	U2022	20-22	7.9%	F6	Final60	05/11/94	NSCAL06	2.09	273	297	38	N	
EB04A	U2022	20-22	7.9%	F6Dup	Final201	05/27/94	NSCAL10	2.21	290	315	34	N	

Rex: Duplicate extraction of soil, Dup: duplicate injection; Dil: extract diluted

3. Removal of TPH

A comparison of the post test and pretest concentration of DRO was done. This is summarized in the attached Table 17. Figure 19 (Page 56) is a plan view of the electrode array which helps to elucidate the various comparisons made in Table 17. Table 17 summarizes the average concentration of DRO TPH as a function of heated soil zones. There are four zones based upon which the comparison was made.

The first zone is the entire heated volume to a depth of less than or equal to 24 ft; in this zone the average concentration in the defined volume was calculated by considering all valid analytical results.

The second zone is defined by the area enclosed by the four corner electrodes A1, C1, C8, A8 and a depth less than or equal to 20 ft. Only valid analytical results for samples which were obtained from this volume were averaged.

The third zone is defined by the area enclosed by the central electrodes A3, C3, C6, A6 and a depth less than or equal to 24 ft.

The fourth zone is defined by the area bounded by the central electrodes A3, C3, C6, A6 and a depth less than or equal to 20 ft. As Table 17 illustrates, the highest removal was obtained in the central zone to a depth of 24 ft or less. In this zone the removal of DRO TPH was 67 to 69 percent. As the volume is enlarged to include the entire surface area (defined by A1,C1,C8,A8) the removal drops to 23 to 29 percent to a depth of 24 ft or less. A review of the soil samples taken from the lateral Volume II indicates that in this region the concentration of the soil may have increased. A similar increase may have occurred in the corresponding volume at the opposite end of the array. This cannot be definitely concluded due to lack of paired before and after samples of soil from this region of the array.

The above data are presented in terms of two depth ranges because the central row of electrodes, the excitor row had a depth of 20 ft and the two outer rows had a depth of 29 ft. The central row was originally designed for a depth of 24 ft. Its depth was decreased in the field because a shallow water table was encountered in the depth interval of 19 to 24 ft. A corresponding depth reduction of the two outer rows was not done due to time and logistics constraints. The heated depth extends below the bottom of the excitor electrodes. This heating is caused by electric fields fringing below the central row of electrodes. It is estimated that fringing fields could extend the heating effect by an additional depth equal to 50 to 60 percent of row separation (that is 2.5 to 3 ft more).

TABLE 17. SUMMARY OF TPH ANALYSIS DONE AT IITRI, PPM

	Pre-Demonstration				Post-Demonstration			
Volume	n	$\bar{x}$	s	R.S.D.	n	$\bar{x}$	s	R.S.D.
Total, for all depths ≤24′	33	1518	2636	174	33	1077	2131	198
For volume defined by (A1, C1, C8, A8) Depth ≤20′	26	1280	2866	224	28	984	2261	230
For volume defined by (A1,C1,C2,A2) Depth ≤24′ (Volume II)	7	706	975	138	8	2405	3495	145
For volume defined by (A1,C1,C2,A2) Depth ≤20′	6	348	257	74	7	2348	3771	161
For volume defined by (A3, C3, C6, A6) depths ≤24′	18	2347	3300	141	17	730	1467	201
For volume defined by (A3, C3, C6, A6) depths ≤20′	14	2208	3707	168	14	717	1610	225

The data were presented in terms of two areal zones because the maximum temperature rise was confined to the central zone as defined by electrodes A3, C3, C6, A6.

A graphical comparison of the soil concentrations before and after the demonstration experiment was made. The data for samples obtained from ground row A is shown in Figure 30. A two-dimensional pattern is revealed regarding the distribution of sampling points. This pattern may have biased the results for the following reasons:

- It is known that the concentration of TPH increased with depth, and that it was higher in the depth interval of 12 to 25 ft. As the figure shows, deep samples were taken below the 20 ft zone (below the bottoms of the excitor electrodes).
- There were no samples taken in the middle of the heated zone, that is, the zone defined by Electrodes A3 to A6 and depth interval of 2 to 20 ft. This was the area of highest temperature increase in Ground Row A.
- Samples taken at depth may be confounded by the presence of the water table for depths larger than 24 ft.

Based on the comparison of the post test and pre-test average concentration, there was no removal of TPH in the vertical plane defined by ground row A. The average pre-test concentration in this plane was 1340 ppm and the post test average was 1478 ppm.

Figure 31 illustrates the distribution of contaminant concentration in the vertical plane represented by the excitor row electrodes. This plane includes the two thermowells TW1 and TW2. The location of sampling points are such that no obvious pattern can be discerned from Figure 31, which is the desired random distribution of the sampling points. The average pre-test concentration of TPH in this plane was 809 ppm. The average post test concentration was 710 ppm if all the data are included. There is one post test sample which seems to increase the post test average from 127 ppm to 710 ppm. This is the sample in TW1 from the depth interval of 14 to 16 ft. The analyzed concentration is in excess of three standard deviations of the average of the remaining samples.

Figure 32 illustrates the concentration profile for TPH in the vertical plane represented by ground row C. The distribution of sampling point locations does not reveal any pattern, which was the desired outcome. The average concentration of all the pre-test samples was 2271 ppm. The average of all the post-test samples was 1079 ppm, which represents a concentration decrease of

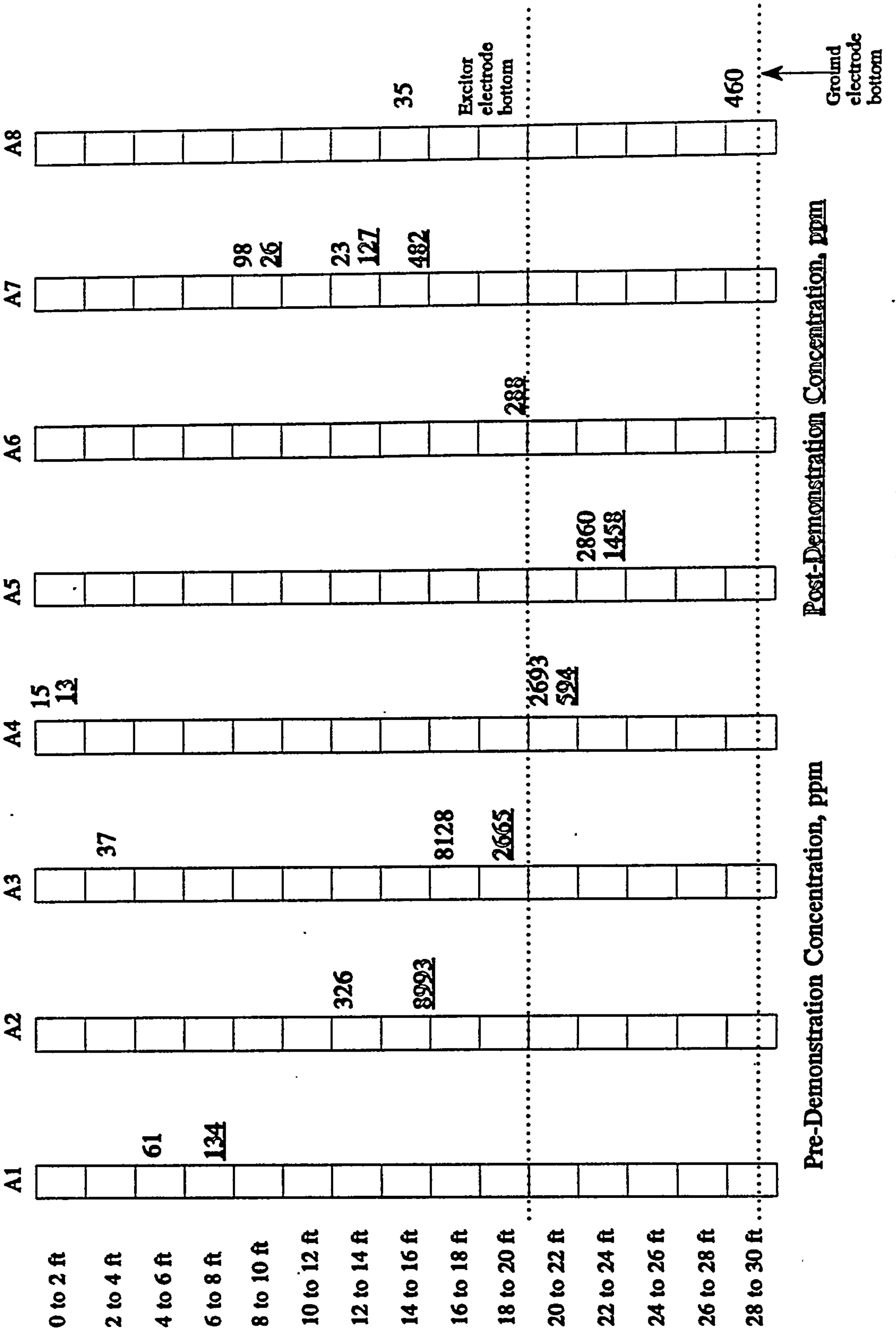


Figure 30. Pre and Post Demonstration TPH Concentration in Electrode Row A as a Function of Depth

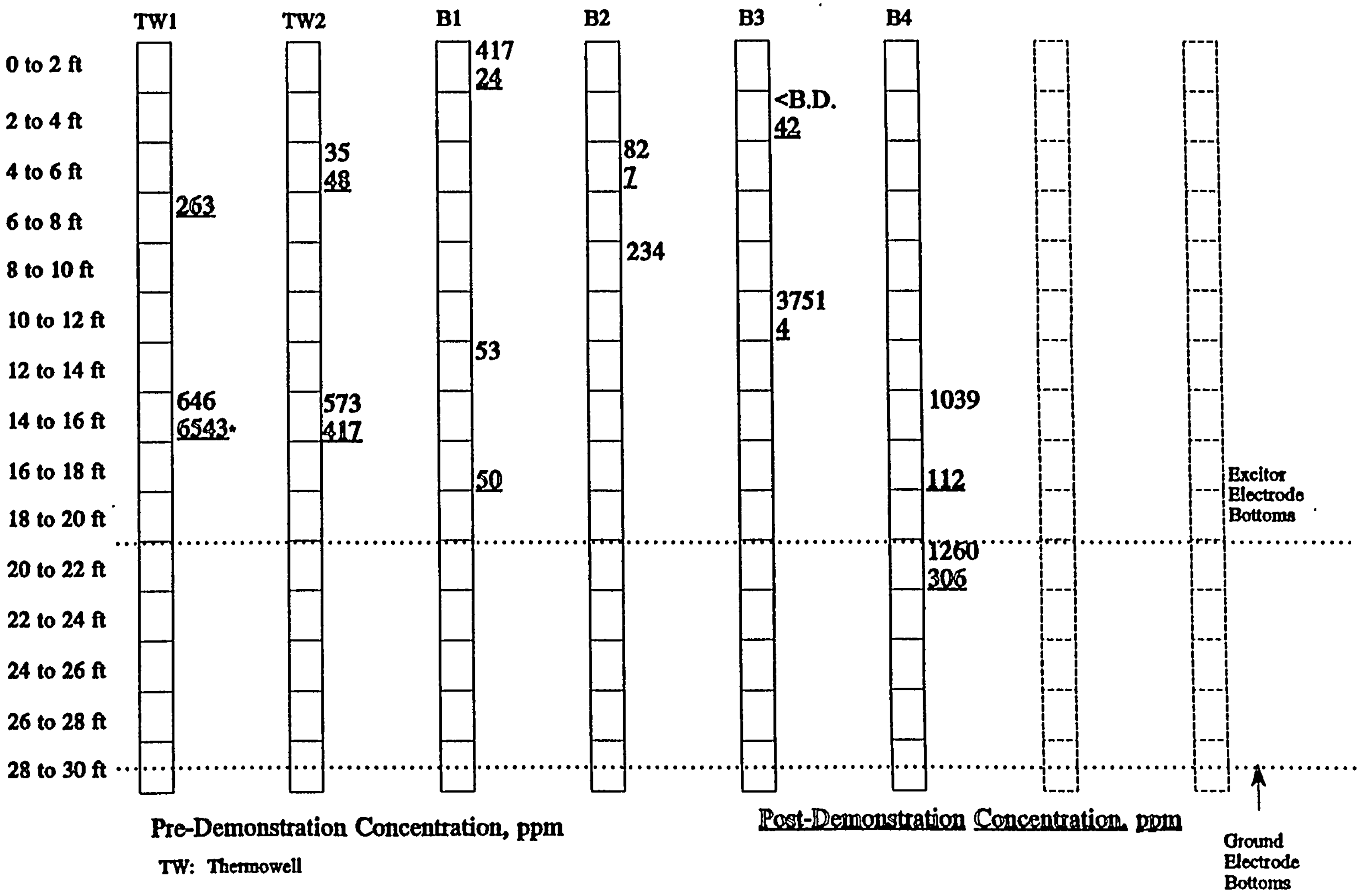


Figure 31. Pre- and Post-Demonstration TPH Concentration in Electrode Row B as a Function of Depth

* Outside 3 standard deviations of the average of all the other post-test samples in this plane

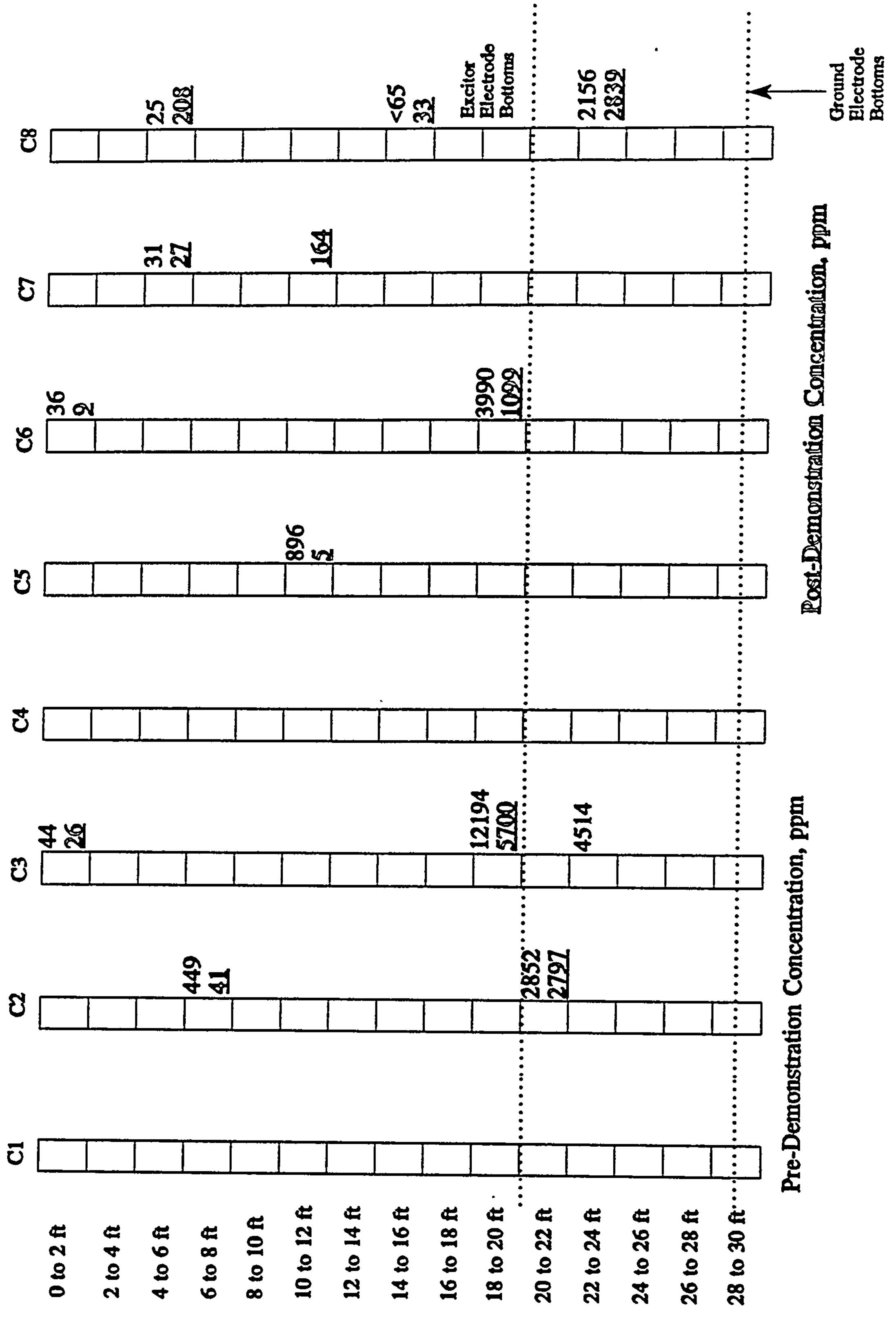


Figure 32. Pre- and Post-Demonstration TPH Concentration in Electrode Row C as a Function of Depth

approximately 53 percent. If the samples taken below the depth of 20 ft are removed then concentration decrease is approximately 63 percent.

C. TRACER INJECTION EXPERIMENT

Towards the end of the heating portion of the demonstration a tracer experiment was done to show that soil fluids were moving into the heated zone. The tracer experiment was performed on May 30, 1993 between 9:00 and 15:30 hrs. The results of the tracer experiment are summarized here along with a description of the procedures.

Halon 2402, dibromotetrafluoroethane, was used as a chemical tracer. The tracer was injected outside the heated array, in cool soil at a depth of 7 feet. The injection point was located on a center line approximately 9 ft from the western edge of the array. The distance from the center of the array was approximately 14 ft. The soil temperature at the injection point was 32.3°C. The tracer was injected into a 0.25-in. O.D. copper tubing which was placed in a bore hole at the time of system installation. After introduction into the copper tube the tube opening was closed to prevent the escape of the tracer. The raw gases leaving the heated zone were sampled and analyzed for the presence of Halon 2402. A gas chromatograph equipped with an electron capture detector was used for the analysis. The purpose of the tracer experiment was to prove that the tracer moves into the heated zone. Thus only qualitative analysis was performed.

1. Materials and Equipment

Halon 2402 is a liquid at ambient temperature, boiling at 47.3°C. The liquid density is 135 lb/cu. ft. at 70° F. The vapor specific gravity is 8.97 (Air =1).

A Packard gas chromatograph, Model 427 equipped with a Nickel -63 electron capture detector was used for the analysis of Halon 2402. A stainless steel column, 1/8 in O.D. packed with 80/100 mesh Porapak Q was used for separation. The column was purchased from Altech. The GC operating conditions were: Injector temperature 220°C; oven temperature 220°C; detector temperature 230°C; carrier gas zero grade nitrogen supplied at a head pressure of 60 psig which gives a flow rate of approximately 20 ml/min.

Gas tight syringes were used to inject the gas sample into the GC. The retention time of Halon 2402 was in the range of 1.6 to 1.65 minutes. It was found by injecting the gas from the head space of a vial containing pure Halon 2402.

After the injection of the halon tracer into the soil the raw gases leaving the soil were sampled and analyzed for the presence of Halon 2402. The sampling system is illustrated in Figure 1 and the procedure is described below.

2. Procedure for Performing the Tracer Experiment

The overall procedure for performing the tracer experiment has four part:

- Set up of GC and confirmation of Halon 2402 peak elution time.
- Set up of a raw gas sampling train
- Collection of preliminary and background data and information prior to tracer injection
- Collection of gas samples and their analysis after tracer injection

Set Up of GC and Determination of Elution Time

The ECD GC was set up and several injections were made to determine the elution time of the Halon tracer. The base line was verified to be clean after the tracer peak had eluted. When injecting room air the chromatogram showed a response for air and then had a clean baseline. The sensitivity of the detector should was set in the medium range, about 3 to 4. The retention time of Halon 2402 was in the range of 1.6 to 1.65 minutes.

Gas Sampling Equipment and Procedure

Figure 33 illustrates the method of setting up the gas sampling train. The gas sample point for the tracer study was the same point on the ejector system where Halliburton personnel had been taking samples for volatile and semi-volatile analysis. But existing tygon tubing was replaced with 0.25 in. O.D. teflon tubing. The sample was conveyed to a glass flask in which any water droplets in the line were separated. The outlet port of the flask was connected to a diaphragm pump. A Thomas pump was used. This pump has a teflon-lined rubber diaphragm. This is a positive displacement pump and will generate high pressure if the outlet is blocked or restricted.

The outlet of the pump was connected to valve V1. The line leaving V1 was connected to a Tee. Valve V2 was connected to the branch leg of the Tee. The run-leg of the Tee was connected to teflon tubing which was connected to the glass gas sampling bottle by means of a short length of tygon tubing.

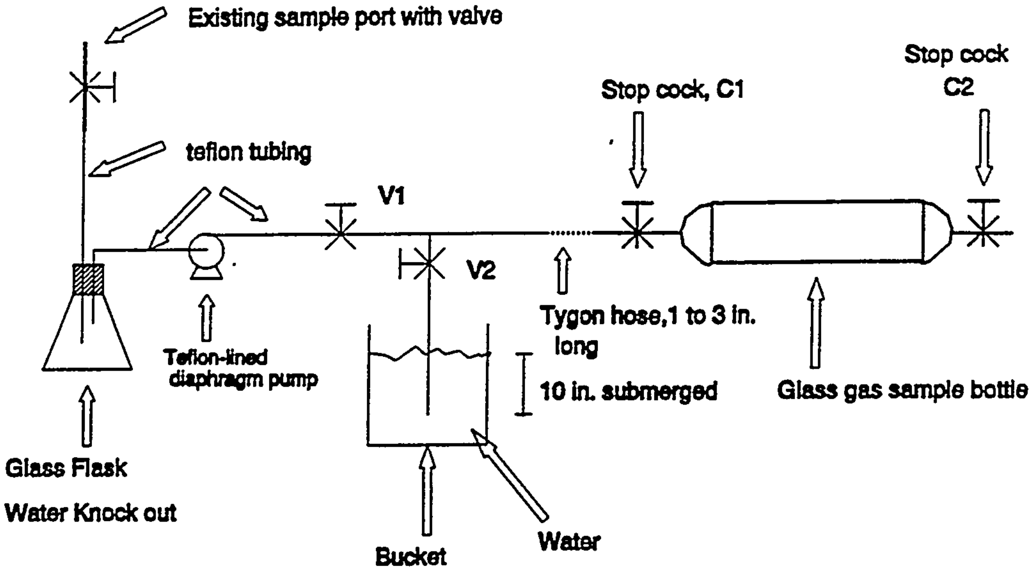


Figure 33. Gas Sampling Scheme for the Tracer Experiment

The line leaving from the branch leg of the Tee was connected to Valve V2. The line leaving valve V2 was submerged in 10 in. of water. This line was made from tygon hose. The purpose of this line was to allow the filling of the gas sample bottle under pressure of 10 in. of water.

The gas sample train was started and used in the following manner:

First the pressure was set as follows:

- With valve V1 open, valve V2 was cracked open. Stop cock C1 was closed. Pump was turned on. Valve V2 was adjusted so that the air just bubbled out of the submerged tubing.

Gas was sampled as follows:

- With the pump running as above, stop cocks C1 and C2 were turned on.

- Gas was flushed through the gas sample bottle for about 3 min. Then stop cock C2 was closed followed by stop cock C1. Pump was switched off. The sample bottle was labelled with date and time.

Sampling the Gas Bottle for GC Injection

A rubber septa was attached on one outlet end of the filled gas sample bottle. The stop cock at the same end was opened. The gas was sampled with the syringe needle inserted through the septa. After removing sample the stop cock was closed.

Collection of background information prior to tracer injection:

- Insert a thermocouple into the tracer injection well (0.25 in tubing) and measure the temperature and the depth of the hole. **CAUTION: RF power must be switched off while inserting and using the thermocouple.**
- Before injecting the trace the following operating conditions were recorded:
    - All the RF power input parameters
    - All the data from the vapor collection system.

Injection of tracer

A 5 ml. syringe was filled with the liquid tracer and it was injected into the copper tracer injection tubing inserted in the ground. The time and date were recorded. The copper injection tubing was capped.

Immediately after the injection of the tracer a gas sample was taken. New gas samples were taken after every 15 minutes until 120 minutes had elapsed.

Prior to reuse, the gas sample bottles were thoroughly flushed out and cleaned. The cleanliness of the sample bottle was verified by analyzing a sample taken from the bottle after it had been flushed.

3. Trace Injection Results

The results of the gas samples analyzed for the presence of the tracer gas in the raw gas stream collected from the heated soil zone are presented in Table 18.

TABLE 18. RESULTS OF TRACER INJECTION EXPERIMENT

Tracer Injection Time	Sample No.	G.C. Run No.	Sampling Time Start	Sampling Time Finish	Elapsed Time min.	Sample Injection Volume ml.	Area Response	Normalized Area Response per ml. sample
5/30/93	*	17				0.05	1,442,000	28,840,000
9:04	3	18	09:07	09:10	4.5	0.05	1,128,900	22,578,000
	4	19	09:32	09:35	29.5	0.1	797,460	7,974,600
	5	20	09:59	10:02	56.5	0.1	567,310	5,673,100
	6	21	10:23	10:26	80.5	0.1	707,970	7,079,700
	7	22		Estimated	110	0.1	1,575,500	15,755,000
	8	24	11:32	11:35	149.5	0.1	880,460	8,804,600
	9	25	12:02	12:05	179.5	0.1	799,350	7,993,500
	10	26	12:32	12:35	209.5	0.1	1,359,100	13,591,000
5/30/93	11	27	13:11	13:14	12.5	0.1	0	0
13:00	11	28	13:11	13:14	12.5	0.1	1,356,300	13,563,000
	12	29	13:25	13:28	26.5	0.2	1,276,800	6,384,000
	13	30	13:50	13:53	51.5	0.2	0	0
	14	31	14:12	14:15	73.5	0.2	626,480	3,132,400
	15	32	14:42	14:45	103.5	0.2	110,760,000	553,800,000
	15	33	14:42	14:45	103.5	0.2	159,270,000	796,350,000
	16	37	15:06	15:09	127.5	0.2	8,217,600	41,088,000

* Blank sample comprising of the atmospheric air at the site

Halon 2402 was first injected into the injection well at 09:00 hrs on May 30, 1993. Approximately 5 ml. of the tracer was injected. The first sample of raw gas from the vapor collection system was obtained between 09:07 and 09:10 hrs. Additional samples were obtained every 15 to 20 minutes. A sample of the gas was injected into the GC/ECD and the peak elution time and peak area were noted. The data are summarized in Table 18. As shown by the results of samples 3 through 10 the presence of tracer in the raw gas stream could not be conclusively proven although it appears that sample 7 had increased levels of the tracer.

One reason that the tracer response was so low is that we had injected insufficient amount of the tracer and it was getting diluted by the air and gases flowing into the vapor collection system. Thus another larger injection of the tracer was made later the same day at 13:00 hrs four hours after the first injection. Twenty five ml. of the liquid tracer was injected. A large increase in the GC response was observed for sample number 15 which was taken approximately 104 minutes after the second tracer injection.

These results show that the liquid tracer injected outside of the heated zone migrated inside and was collected by the vapor collection system. Because of the way the experiment was done, it is not possible to rule out the fact that the observed increase of the tracer concentration in the gas samples may have been due to the first tracer injection and not the second. If this is indeed the case, then the tracer could have taken as long as 5 hr and 40 minutes to be collected by the vapor collection system.

D. ELECTRICAL DATA

1. RF System Performance

The operational performance of the RF heating system used for the Kelly AFB demonstration test was evaluated by monitoring the RF power delivered and absorbed by the array, by tracking the electrode array's input impedance and by continuously adjusting the matching network to achieve the most efficient energy delivery between the source and the array. Figures 34, 35, and 36 illustrate the applied or input RF power to the array, the cumulative RF energy delivered, and the effective RF power source utilization, respectively, as function of time.

Both the forward and reflected RF power at the output of the RF power source were continuously monitored throughout the test. Additionally, the forward and reflected RF power was monitored at the input to the stage 1 matching network, adjacent to the array. By periodically adjusting the variable components of the stage 2 matching network, the reflected power to the RF power source was

Figure 34

INPUT POWER LEVEL vs. TIME

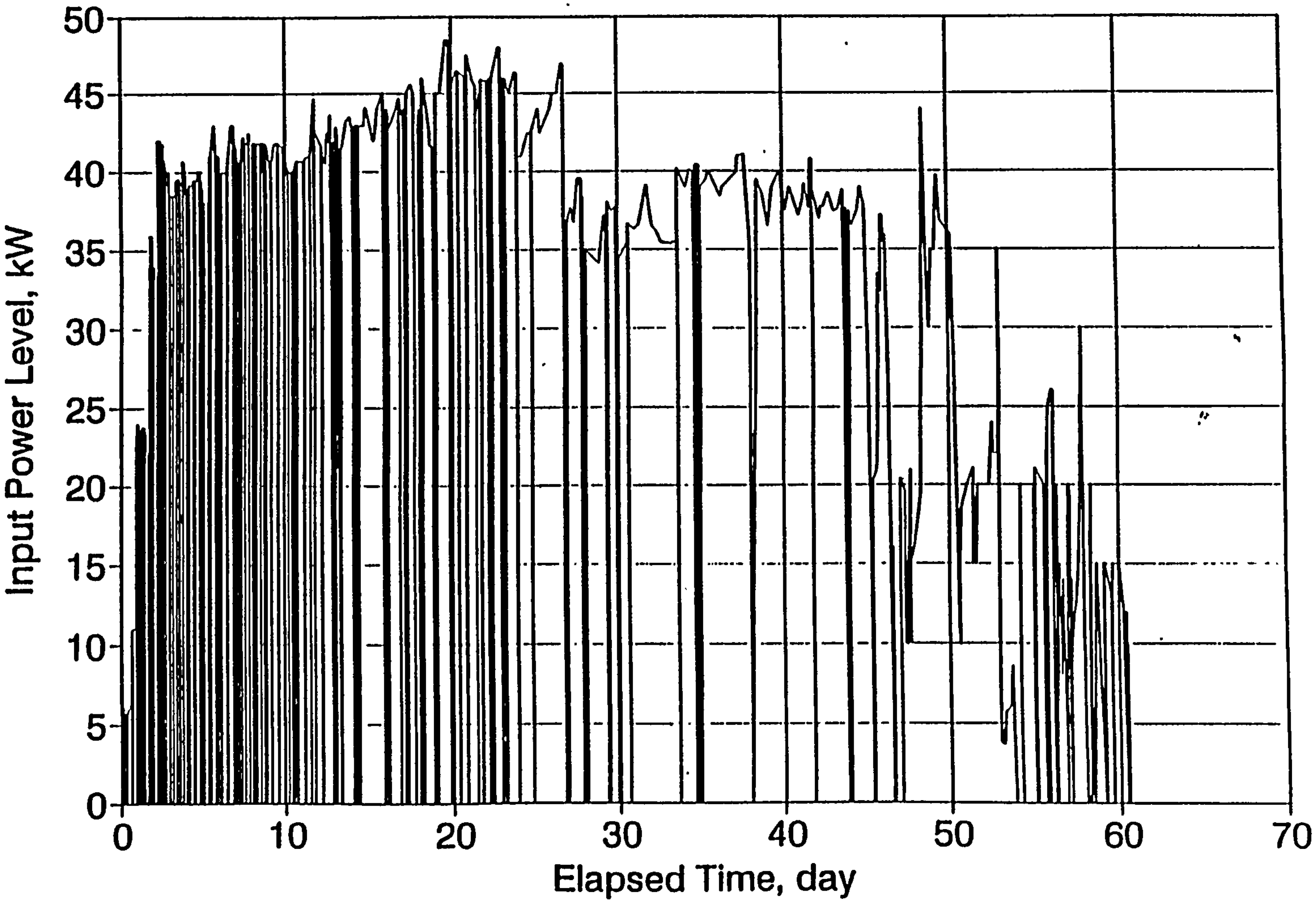


Figure 35

CUMULATIVE RF ENERGY vs. TIME

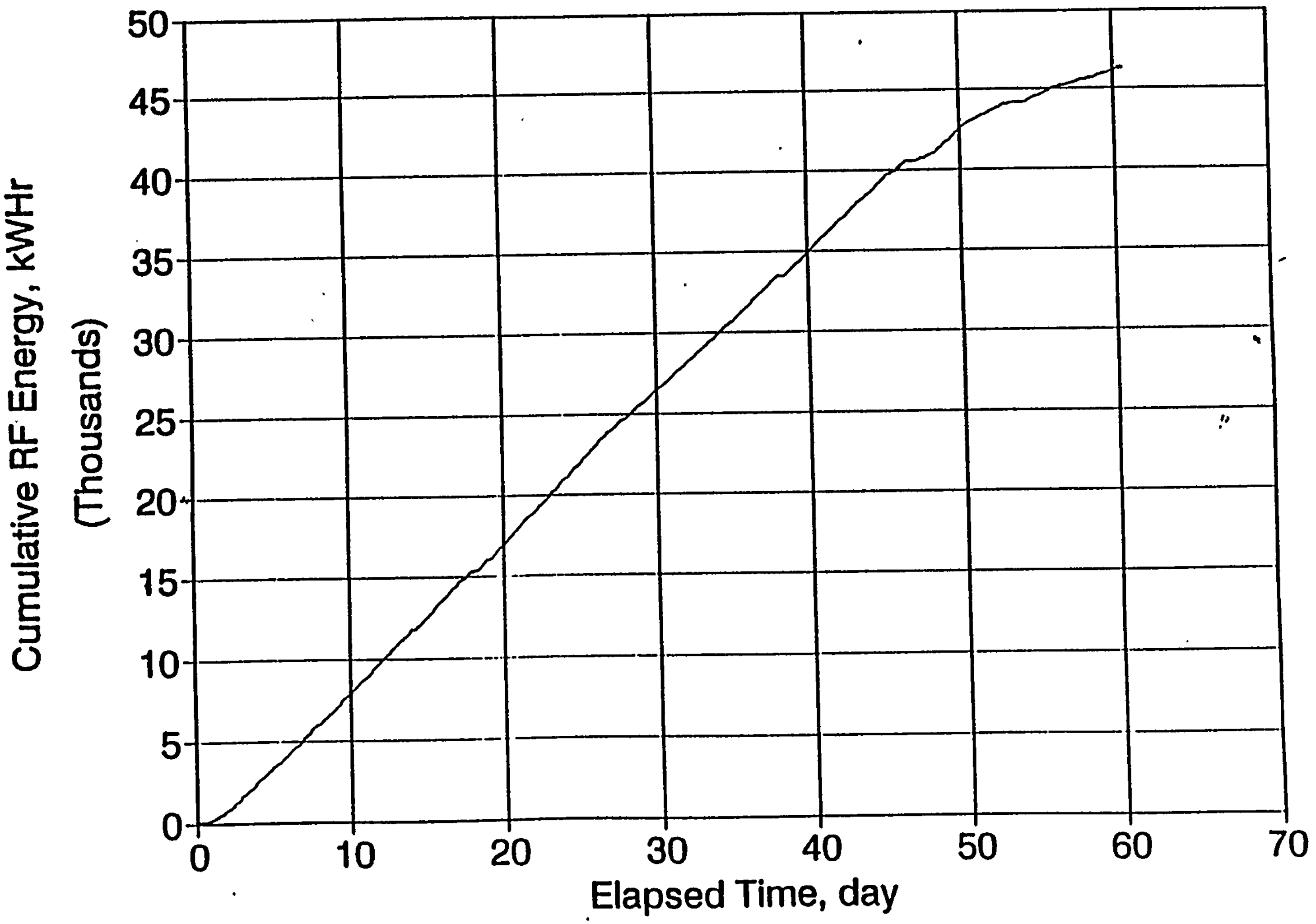
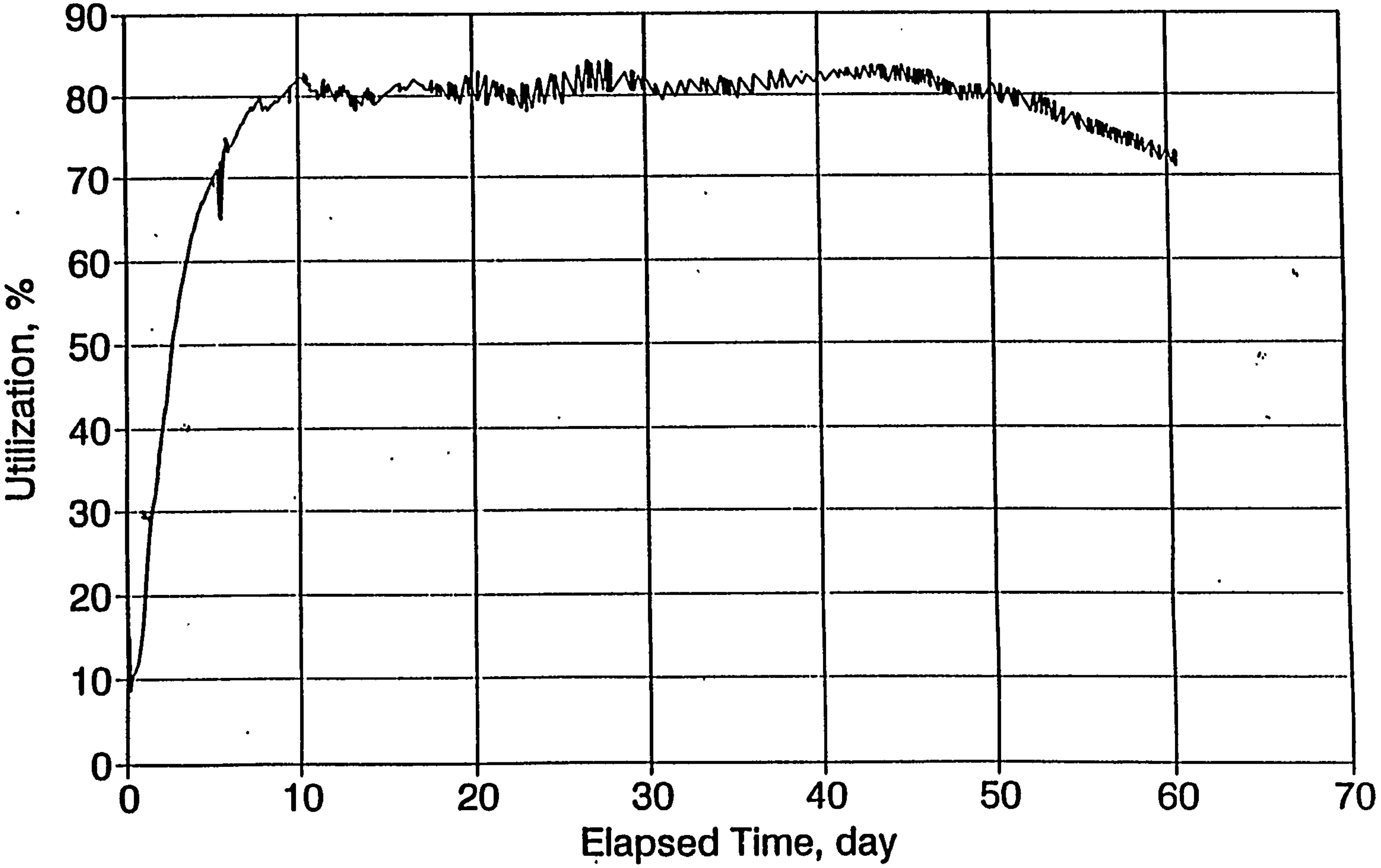


Figure 36

RF POWER SOURCE UTILIZATION vs. TIME

(Percent of Capacity)



minimized or maintained at zero. Finally, by recording the measurements obtained from the IITRI designed in-line impedance meter, changes in trends in the input impedance to the electrode array were tracked as a function of time. By monitoring the trends in this impedance, a qualitative assessment of the performance of the RF heating system was performed.

During the operation of the test it was determined that the use of the single RF frequency of 6.78 MHz would be sufficient. All subsequent RF data is for a fundamental applied frequency of 6.78 MHz. Figure 37 illustrates a calculated Smith chart representation of the array's input impedance as would be measured at the soil surface , if possible, as a function of time for the first 33 days of the demonstration test. During this period of the test, the track of the array's input impedance appears, for the most part, as would be expected for the RF heating of this specific triplate array. Figure 38 shows a calculated Smith chart representation of the array's input impedance at the soil surface for the final month of the test. The erratic pattern indicates that major impedance variations were occurring within the triplate array throughout the majority of the final two to three weeks of the heating.

2. RF Emissions Monitoring

Near and far-field electromagnetic field measurements were made at and around the test area. Near-field refers to the immediate vicinity of the test site (within ~15 feet of the array); far-field refers to locations 100 to 1600 meters from the test site. All far-field locations were selected in consultation with Kelly AFB communication personnel. The purpose of these measurements was to ensure that any radiated RF power levels were below permissible FCC and Air Force standards, that no interference was generated with base communications, and that no personnel safety problem areas existed.

These measurements were made in two different phases. The first phase or series of measurements were conducted before the initiation of the actual test by applying low RF power levels (~5 kW) to the electrode array and monitoring both near and far-field radio frequency interference (RFI) electric field intensity values in order to identify any potential problem areas. The second series of measurements were conducted during the test. These near and far-field RFI measurements were made while full power was being applied to the electrode array. Ambient field levels were measured by momentarily turning the RF source off to the electrode array at each measurement point or location.

Figure 8, previously illustrated an overview of the Kelly AFB; Site S-1 demonstration test layout. RFI safety measurements were

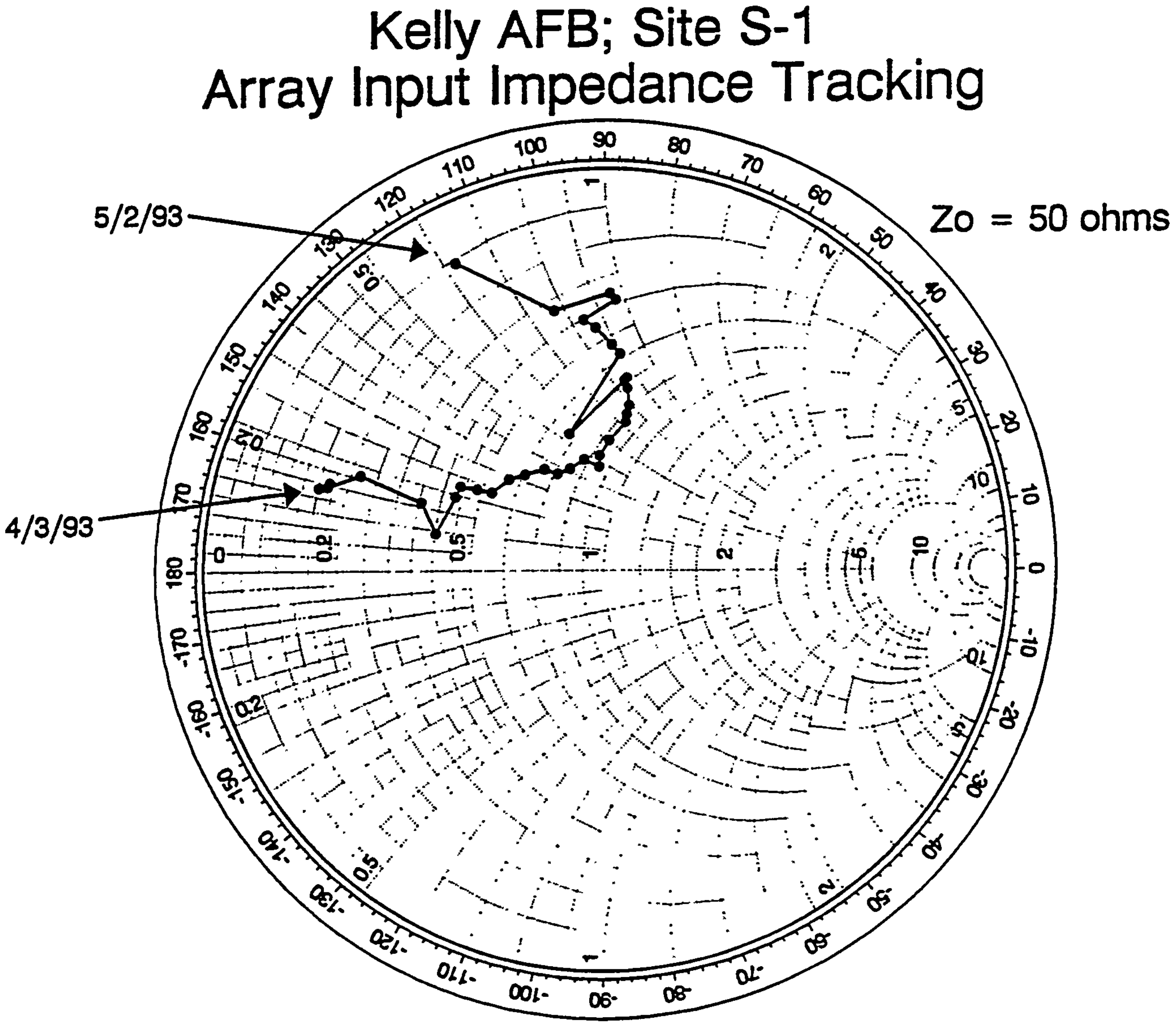


Figure 37. Kelly AFB; Site S-1.

Kelly AFB; Site S-1
Array Input Impedance Tracking

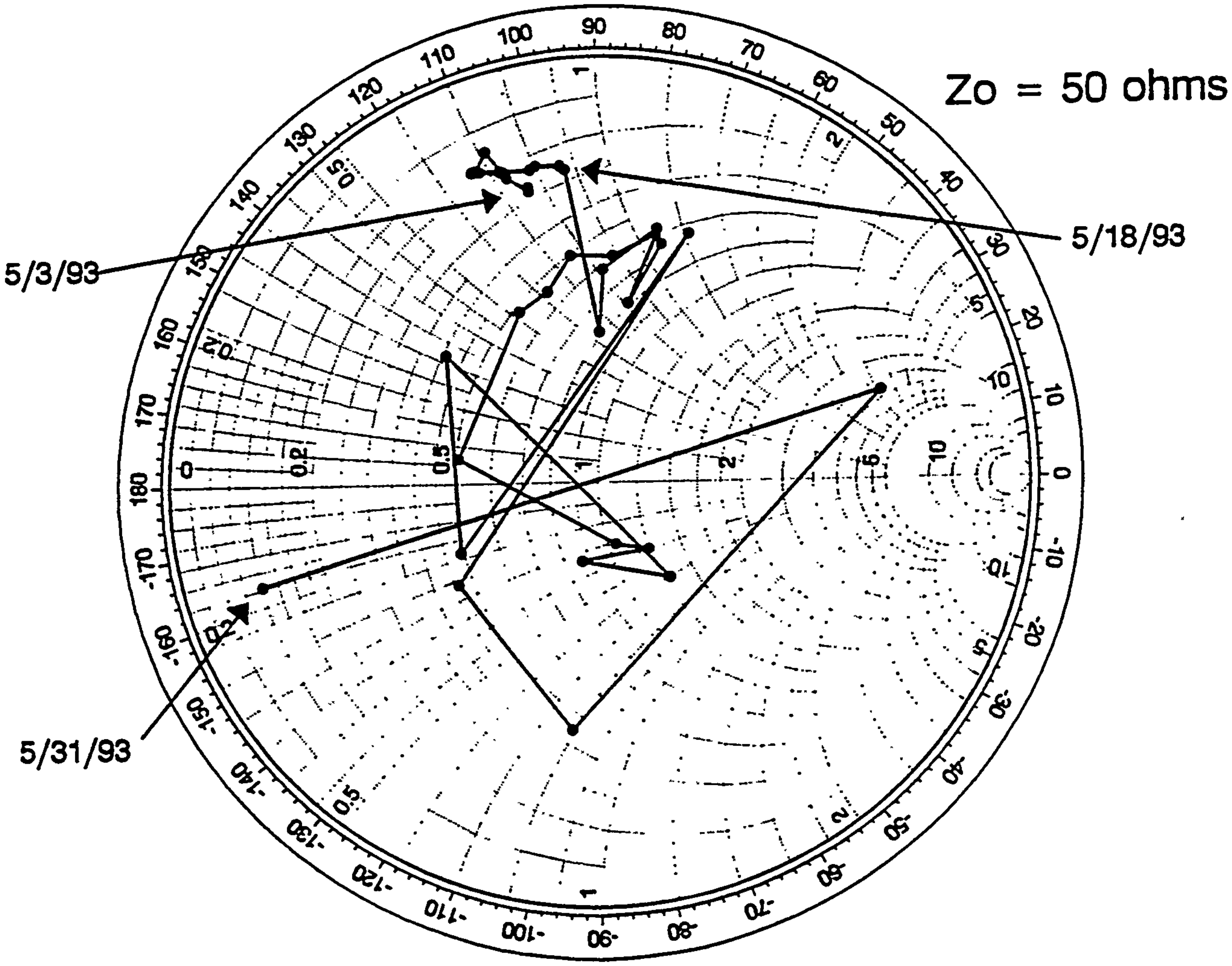


Figure 38. Kelly AFB; Site S-1.

conducted periodically during the test throughout the area shown in the figure. These safety measurements consisted of recording the RF power density as measured by a hand held RF field strength or exposure probe. The maximum measured RF power density was found just below the 6 ⅛ inch coax RF choke. The maximum value recorded at full power (40 kW applied to the array) was 0.16 mW/cm^2 which is less than 1% of the maximum permissible exposure limit (19.6 mW/cm^2 at 6.78 MHz) as identified by IEEE C95.1-1991 (Reference 5). There were no measurable RF power densities within the area except in the proximity of conducting materials. The average RF power density measured within 6 inches of the coaxial transmission lines was 4 μW/cm^2. This represents 0.02% of the permissible limit.

Table 19 contains the maximum measured electric field strengths for both near and far-field RFI safety measurements. Also illustrated in this table are the appropriate limits identified by the Institute of Electrical and Electronic Engineers (IEEE) and accepted by the American National Standards Institute (ANSI) and the National Institute of Occupational Safety and Health (NIOSH) for near-field continuous exposure to electric fields at this frequency of operation. The maximum measured electric field strength of 40 mV/m at a distance of 10 meters is more than three orders of magnitude below the minimum of these two ratings. In addition, no electromagnetic interference was experienced by any of the air base communication staff throughout the duration of the demonstration.

No out-of-band electric field strengths were measurable at frequencies that were not, themselves, ISM band frequencies. Out-of-band refers to measurements at frequencies other than the operating or fundamental frequency directly generated as part of its operation (harmonics, spurious radiation, etc.).

The fact that all RFI measurements, near and far-field met personnel safety limits and were within permissible standards, indicates that more than sufficient efforts were employed during the design, fabrication and installation of this demonstration test to insure adequate site personnel safety and not pose any interference to the surrounding community.

TABLE 19. RFI SAFETY MEASUREMENTS NEAR/FAR-FIELD
(APPLIED FREQUENCY = 6.78 MHz, APPLIED POWER = 40 KW)

Distance from Array (meters)	**Electric Field Strength (millivolts/meter)**	**Personnel Safety Continuous Exposure Electric Field Strength Standards (Volts/meter)**	
		IEEE/ANSI	**NIOSH**
10	40.0	121.5	192.
100	1.30		
400	0.071		
800	0.126		
1600	0.016		

VIII. CONCLUSIONS

A. TPH REMOVAL

In the central row of electrodes, the excitor Row B, high removal of TPH was observed due to the high temperature achieved in this row. The residual concentration of TPH in this row was in the range of 4 to 112 ppm. Higher concentrations were observed below the tips of the excitor electrodes (305 ppm) and towards the edges of the row where the temperature was lower. Thus, in thermowell TW2 the concentration range was 48 to 417 ppm and in TW1 it was 263 to 6543 ppm. The high reading in TW1 is probably an outlier as explained in Section VII. The average temperature in the excitor row ranged from 125°C to 650°C (Figure 21). The average temperature in this row was in the range of 125 to 150°C from 200 to approximately 700 hours of elapsed time. After 700 hours, the temperatures at the tips of the excitor electrodes shot up and so did the average.

The results of the Bench Scale Treatability study (Reference 2a) had shown that treatment at a temperature of 150°C with a residence time of 100 hours was sufficient to reduce the TPH concentration to 60 to 90 ppm. The percent removal depends upon the initial concentration of soil and it ranged from 75 to 97 percent in the laboratory studies. Thus, the residual concentrations observed in Row B were consistent with the results of the treatability study.

Comparison of the initial and final concentrations of samples obtained from Row B indicate that there was a 84 percent reduction of TPH concentration. We have omitted the outlier in this calculation. If all the data points are considered, including the outlier, then the reduction in TPH concentration is only 12 percent.

The residual concentration of TPH in ground Row C was in the range of 5 to 5700 ppm. There were 12 post demonstration soil samples. Of these 2 were in the depth range of 20 to 24 ft which is below the tips of the excitor electrodes and they may have also been very close to, if not below the water table surface. These two samples had a concentration of 2800 to 2840 ppm. The average temperature in ground rows A and C at a depth of 24 foot did not exceed 45 to 50 °C (Figure 22). Thus the above results are not surprising considering the sample locations and the temperature history.

There were another two samples, in the depth range of 18 to 20 ft, with residual TPH concentration in the range of 1100 to 5700 ppm. There are no temperature data in the depth range of 18 to 20 ft. But by interpolating between data of depth ranges 12 and

24 ft, one can see that the temperature in the depth range of 18 to 20 ft was in the range of 45° to 70°C.

The remaining 8 samples of Ground Row C were from the depth range of 0 to 16 ft. with a residual TPH concentration in the range of 5 to 210 ppm with an average of 64 ppm. The initial concentration of these 8 locations was in the range of 25 to 896 ppm with an average of 221 ppm. Thus, the percentage removal in the 0 to 18 ft depth interval of Row C was 70 percent. If all the samples of Row C are considered in the calculations of initial and residual average concentrations then the following results are obtained: Initial average concentration: 2271 ppm, and final average concentration: 1079 ppm for a reduction of 52.5 percent.

The concentration data for ground Row A is more difficult to interpret because of the way the sampling points happen to fall in relation to the water table, and the extent of the heated zone. It was pointed out earlier that most of the samples were taken from area where the temperature rise was inadequate or else they were taken close to the water table. The average concentration of all the 11 pre-demonstration soil samples in Row A was 1340 ppm. The average of all 10 post-demonstration soil samples was 1478, indicating either that the TPH was not removed or it increased slightly. In both Rows A and C the hottest soil region was opposite electrodes in positions 3 to 6, that is A3 to A6, etc. In Row A, there were only 3 post demonstration samples from these electrodes, of which two were in the depth interval of 18 to 20 ft. where the temperature rise was inadequate to remove TPH. In Row A there were 7 post-demonstration samples taken from locations which were either too deep or else were in the fringe area where the temperature rise was insufficient.

The results of the soil sample analysis when considered in relation to the sample location and the temperature history support the conclusion that where ever the soil was heated to a temperature range of 150°C, low residual concentration of TPH was obtained.

B. SOIL TEMPERATURE RISE

As illustrated by the data presented in the figures of Section VII it is clear that the central row of electrodes were abnormally overheated whereas there was severe under heating of zones further removed from the central row of electrodes. The design goal was to heat 122 cu. yd. to a temperature of 150°C. The results show the following:

- Volume of soil where every measurement point exceeded 100°C for long (>100 hr) periods of time was estimated to be 90 cu. yd.

- volume of soil where the average temperature was >150°C was estimated to be 56 cu. yd. But volume within which every measurement point exceeded 150°C was 34 cu. yd.

- Volume of soil where the average temperature was in the range of 60° to 70°C was 37 cu. yd.

These results indicate that the desired volume of soil did not reach the temperature objective of 150°C. The main reason for this was the melting of electrode due to their close proximity to the water table.

The high temperature to which the soil was heated may have contributed to some oxidation of contaminants present in the soil. IITRI has no data to prove or disprove this hypothesis, but it is a reasonable one to make.

C. OPERATION OF THE RF HEATING SYSTEM

After May 18, 1993, sustained operation of the RF power source became difficult. The analysis of data and information now available show clearly that this was due to the high temperature achieved in the central row which led to the melting of the electrodes. Prior to this time the RF system performed quite well considering that the RF power source was 40 to 45 years old and it exhibited signs of age as evidenced by frequent short circuiting due to insulation failure and rectifier problems. However, the matching networks and instrumentation all performed as expected.

It is probable that the electrodes melted due to their close proximity to the water table. But depth of water table below the heated zone is not known in the time period that the demonstration was performed. Due to the design of the array, it was not possible to monitor the water table location. However, water table depth was monitored prior to completion of the electrode array. These data indicate that the water table was 2.5 ft to 3.5 ft below the tips of the excitor electrode in February 1993. The water table level was controlled by means of four dewatering wells that pumped continuously during system installation and operation. It is known that the pumps were able to reduce the water table depth by 1 to 1.5 ft during the nine days ending February 11, 1993.

The measurements of radiated power levels indicated that there were no RFI problems. Safety measurements made in the immediate vicinity of the RF equipment indicated safe levels of E and H fields.

IX. RECOMMENDATIONS

In light of the results of the field demonstration the following recommendations are made:

- Develop, through engineering analysis, sound and reliable criteria which dictate the proximity of the electrode tips and the water table
- For sites which have a shallow water table, means of measuring, while heating, the depth of the water table below the electrode array must be incorporated in the design of the array.
- A review of the impedance data plotted on Smith charts indicates that there were clues developing prior to May 18, 1993, which may have been indicative of the problems which we were to experience in the future. An engineering analysis should be done to catalogue such clues so that the system operating personnel can be alert to the possible mal-operation of the system.
- An analysis of the radiation measurements from the heated zone indicate that the RF shield may have been over designed. Future demonstrations should evaluate other simpler alternatives for the shield design.
- Temperature of the thermowells was measured by means of fiber optic probes. These probes were found to work reliably at temperatures below 200°C. However, for higher temperatures the probes failed due to material failure. Alternative probes should be sought.
- The RF system does not lend itself to an elegant and economical way of measuring temperature of the soil between the two outer rows of electrodes. Due to this reason, thermocouples were inserted inside the excitor electrodes and thermowells were installed. Thermocouples inside the excitor electrodes were read by switching off the RF power. The reason is that no electrical conductor may leave the heated area when the RF power is on. Recent developments in fiber optic tele-metering should be investigated to develop a continuous temperature logging system for both soil and electrode temperatures.
- Means of recovering hot gases and vapors from the excitor electrode row or other central area of the array should be developed. When hot vapors are collected from the

ground rows, they cool and some fraction of these may condense there, depending upon the local temperature and the dew point.

X. REFERENCES

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IITRI Project Nos. C06770 through C06776,
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HALLIBURTON Sub-contract No. GCKF-92-3688-002
September 16, 1994

RADIO FREQUENCY SOIL DECONTAMINATION DEMONSTRATION PROJECT, SITE S-1 KELLY AFB, TX.

Draft Final Report
Volume II of II
Appendices A to C

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FOREWORD

This is Volume II of a Draft Final Report for IITRI Project entitled "Radio Frequency Soil Decontamination Demonstration Project, Site S-1 Kelly AFB, Texas." Volume I contains the main report. The work reported herein was conducted in the period November 2, 1992 to August 1994. The in situ heating portion of the field demonstration experiment was performed from April 3, 1993 to June 3, 1993.

Respectfully submitted,

Harsh Dev
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Table of Contents

List of Tables

List of Figures

Appendix A

SUMMARY OF LOG BOOK ENTRIES FOR RF HEATING

Appendix A

SUMMARY OF LOG BOOK ENTRIES FOR RF HEATING

Table A-1 summarizes the high lights of the log book entries made by the shift operators during the in situ RF heating experiment. These entries pertain to the operation of the RF power source and the thermal data logging system. It should be noted that the experiment was performed with a 40 kW power source which is at least 45 years old and is prone to breakdowns related to age.

TABLE A-1. SUMMARY OF LOGBOOK ENTRIES

Date	Time	Logbook		Individual	Summary of Logbook Entry	
		Number	Page			
04-04-93	21:00	30583	4	Bajzek	Recorded warming of the exciter row thermocouple jacks in the plexiglass housing. Estimated temperature 40°C.	
04-05-03	17:55	30583	5	Suchanek	Heard loud noises from the power source FR7-6.	
04-06-93	13:10	30583	6	Jones	Start full power RFI measurements.	
04-08-93	02:42	30583	8	Suchanek	RF wave form has modulation. Rectifier tube changed.	
04-09-93	00:25	30583	9	Suchanek	Lost power. Sam called. Down for 75 minutes.	
04-10-93		30583	10		Thermocouple connectors for excitor T/C are hot. Tried shielding with Teflon. Plug for B1A is turning black.	
04-10-93	15:00	30583	10		Teflon does not help reduce heating of T/C plugs. Teflon removed.	
04-11-93	23:00	30583	11	Jones	FRJ-T has been down for 4 hours. Switching interlock system to the new power source. Sparking observed at the rear of the third cabinet of FR7-6. Teflon shield applied.	
04-14-93		30583	13	Jones	Match is moving more rapidly than before.	
04-14-93	14:50	30583	13	Jones	Reflected power moved up to 500 watts in a period of 10 minutes.	
04-17-93	17:09	30583 2875 (D)	17 12	Tumarkin Kunstmanas	Arcing under rectifier sockets. Short in C1585 air type capacitor.	
04-18-93	00:05	30583	16	Kunstmanas	HNUS equipment lost power. Power (RF) off. Waited 1-hr. after HNUS power was restored before powering up with RF.	
04-18-93	06:40	30583	16	Kunstmanas	Arcing in transmitter. Shut down.	
04-20-93	19:51	30583 D2875	19 13	Kunstmanas	Problems with transmitter.	
04-21-93	11:26	30583	20		Arcing in the transmitter.	
04-22-93	08:10	30583	20		Arcing in the transmitter.	
04-22-93	1:28	30583	20		Transmitter was shut down because power dropped "radically" 35 to 31 kW then to 20 kW.	
04-23-93	20:29	30583	22		Transmitter tripped off. Circuit breaker tripped. Interlock light on. Breaker reset. Could not find open interlock switch. At 9:08 p.m. light off on its own.	
04-24-93	01:00	30583	22		Interlock opened somewhere. Bypassed. Resume power input to array.	

TABLE A-1. SUMMARY OF LOGBOOK ENTRIES

Date	Time	Logbook		Individual	Summary of Logbook Entry	
		Number	Page			
04-24-93	20:56	30583	23		Arcing in transmitter. Shutdown. Restarted. Sam investigated.	
04-25-93	02:40	30583	23	Suchanek	Over-voltage trip. Shut down. Could not restart. PA motorized switch banged with screwdriver handle. Restarted OK.	
04-25-93	09:35	30583	24	Tumarkin	Shut down to repair the motor driven PA high-voltage breaker.	
04-26-93	00:10	30583	24		Tripped rectified tube was replaced. Down for 80 minutes.	
04-26-93	15:25	30583	24		Watt-hour meter on HNUS transformer was repaired. Reads 0000.	
04-27-93	15:45	30583	25		Read watt hour meter: 1,737.5 kW hr. ≈ 71.41 kW.	
04-28-93	11:05	30585	1		Wave form is "wavy". High voltage rectifier tube out.	
04-29-93	02:20	30585	1		Arcing in transmitter, rear of 3rd cabinet.	
04-29-93	08:20	30585	2		Hard rain. Ponding of water.	
04-30-93		30585	3		Fog. Lots of moisture in air.	
04-30-93		30583	3		Shut down for changes to matching network. Removed bullet capacitor. Change internal capacitor.	
05-01-93	03:30	30585	3	Suchanek	Waveform has a ripple. Replaced 2 rectifier tubes. Down for 3 hrs.	
05-01-93	05:15	30585	3		Rich reported that excitor T/C connector for B1A crumbled.	
05-01-93	10:10	30585	4	Tumarkin	Tested new transmitter into dummy load.	
05-01-93	16:50	30585	4	Tumarkin Jones	Restarted after shut down. T/C wiring was removed and pulled back from the plexi-glass housing. Now the exciter electrode T/C wing has been wound and tied to the center conductor inside the dog house.	
05-01-93	17:45	30585	4	Jones	Transmitter tripped. Small amount of smoke.	
05-02-93	11:15	30585	5		Power down from 11:15 to 00:15 a.m.	
05-03-93	07:40	30585	5		Excitor T/C plugs were replaced.	
05-05-93	04:05	30585	6		Very heavy rain. Rained all day till about 6 p.m. 6" rainfall at San Antonio airport.	
05-06-93			6	Dev	During morning excitor T/C measurement B2A was 253°C. Vapor barrier temperature near TWI bundle was 120°C.	
05-06-93	23:06	30585	7		One T/C in excitor row, B2A, over 300°C.	

TABLE A-1. SUMMARY OF LOGBOOK ENTRIES

Date	Time	Logbook		Individual	Summary of Logbook Entry	
		Number	Page			
05-08-93	07:00	30585	8	Tumarkin	Transmitter down for 3 hrs., 45 minutes.	
05-09-93	15:15	30585	8	Dev	Temperature of vapor barrier was measured. T = 119°C under thermal insulation blanket 18" north of electrode B2. T = 72°C on exposed vapor barrier at B2. (Thermal blanket on top of B2 removed at some prior time.)	
05-10-93	15:20	30585	9		Vapor barrier temperature above B2 - 78°C. 1' north of B2, under blanket 120°C.	
05-11-93	07:20	30585	9		Vapor barrier temperature about the same as the measurement shown in line above.	
05-11-93	15:25	30585 D2877	10 3		B2A was 741.5°C @ 15:25.	
05-11-93	15:30	30585	9		Vapor barrier temperature above B2 : 78°C 1' foot north: 128°C; 2 ft. north 100°C.	15:25, 05-11-93 B2A = 742°C.
05-11-93	16:30	30585	10	Ase	Power down. Power down for ≈ 12 hrs. Resume power to soil at 03:55 hrs. 05-12-93.	
05-12-93	03:55	30585	10	Ase	Power on.	
05-12-93	23:00	30585	10		Vapor barrier temperature 60°C (exposed surface) 125°C under blanket, 2 ft. north.	22:55, 05-12-93 B2A = 869°C.
05-13-93	15:20	30585	11		Vapor barrier temperature 50°C on exposed surface. 120°C under blanket 2 ft. north	15:09, 05-13-93 B2A = 895°C.
05-13-93	23:07	30585	11		Vapor barrier, exposed surface 59°C. 2 ft. north, under blanket 119°C. Power tripped. Resume at 01:40. Ran at 10 kW prior to 1:40, while waiting for Sam.	
05-18-93	11:15	30585	14		High winds; very heavy rain; power in trailer is flickering.	
05-18-93	17:05	30585	14		Reflected power meter moving up and down. Matching network adjusted many times for match.	Max temp. in exciter row = 835°C @ B2A, 15:12 hrs.
05-18-93	18:00	30585	14		Transmitter shut down. Reflected power increased to 4 kW. Called Sam.	
05-19-93	19:00	30585	15	Suchanek	Running at 35 kW. Constant adjustment of match for the last 4 hours.	B2C had no reading at 22:51 hrs, 5-19; B3C unstable.
05-20-93	06:25	D2877	17		Power turned off	B2C, 5/20, 0708 was 1330°C
05-20-93	18:30	30585	15	Suchanek	Power on at 20 kW. (Power was off from 06:25 to 18:30 hrs).	
05-20-93	20:00	30585	15		Many adjustments necessary to match. ~ every 5 minutes.	
05-20-93	21:15	30585	15		Stable	
05-20-93	23:45				Reflected power jumped to 1 kW. Decreased power to 10 kW.	

TABLE A-1. SUMMARY OF LOGBOOK ENTRIES

Date	Time	Logbook		Individual	Summary of Logbook Entry	
		Number	Page			
05-21-93	01:10	30585	15	Dev	Reduced power to 10 kW from 20. Reflected power 0 to 1 kW. Phase angle fluctuations.	
05-21-93	05:30	30585	15	Dev	Power increased to 15 kW.	
05-21-93	13:15	30585	16	Tumarkin	Match is very unstable. Power at 15 kW.	
05-21-93		30585	16		Reference to restarting power time?	
05-22-93	~06:50	30585	16	Kunstmanas	Spent the whole shift gradually bringing power up to 39 kW.	
05-22-93	17:20	30585	16		Thunderstorm, heavy, but short duration.	
05-23-93	05:30	30585	17		Heavy rain for about 30 minutes.	
05-23-93	07:30	30585	17		Heavy rain. Dog house an island. Radio reports 7" of rain.	
05-23-93	20:00	30585	17		Large increase in reflected power, up to 3.8 kW refl. matched to zero. Large change in vector voltmeter readings. Rain ends at 18:00 hrs.	
05-24-93	17:30	30585	17		Power decreased to 20 kW. Reflected power fluctuating.	
05-24-93	22:15	30585	18	Sabato	Stable at 20 kW so tried to increase power up to 25. Became unstable. Backed off to 20 kW.	
05-25-93		30585	18		While at 21 kW reached the limit on capacitor C1. Backed down to 15 kW.	B1C = 1070°C, 5-25-93, 23:08 hr.
05-26-93	09:50	30585	18		Do not increase power beyond 7 kW per Dev.	B3C = 1018 @ 5-26-93, 07:22 hr.
05-28-93		30585	19		New instructions from Dev	
05-28-93		30585	19		New instructions from Dev	
05-28-93		30585	19		Transmitter down form 16:10 to 18:40 hr.	
05-29-93	00:55	30585	19		Reflected power jumped to 2 kW. Then 40 kW circuit breaker tripped. Restarted; rematched; stable.	B4C - no reading, 5-29-93, 13:00 hrs.
05-30-93		30585	20		Very hard rain. Very windy. No entries in logbook C30585 for 6-1-93 or 6-2-93.	
06-03-93	11:00	30585	20		Safety measurements were made prior to shut down.	
06-03-93	12;00	30585	20		RF power off.	

APPENDIX B

SOIL TEMPERATURE DATA

Appendix B

SOIL TEMPERATURE DATA

This appendix contains four tables which have temperature data obtained during the field demonstration:

Table B-1 has temperature data from the two outer rows of electrodes and the outside thermowell TW7.

Table B-2 has temperature data from all the thermowells which were inside the heated zone.

Table B-3 has temperature data measured by thermocouples installed inside the four center row electrodes, the excitor electrodes.

Table B-4 has the temperature data from the data logger. These temperatures were measured in the ground row electrodes and the outside thermowell TW7

The physical location of all the temperature measurement points can be found by referring to the attached Figure B-1, which is a plan view of the electrode array showing the electrode and thermowell numbering system. The temperature measurement point have a number designation composed of two parts: the first part is the number of the electrode or the thermowell. T second part is the depth code. A typical measurement point designation in the excitor row is of the type B1A, B3C, B4B etc. B1A refers to a measurement point in the B1 electrode at a depth 1-ft, which has a depth code of A. B3C means electrode B3 at a depth of 19 ft which has a depth code of C. Similar numbering system is used for temperature measurement points in the two ground rows and the thermowells. The following table defines the depth codes.

Depth Code Letter	Ground Rows A & C	Excitor Row B	Thermowells
A	1 ft	1 ft	1 ft
B	12 ft	10 ft	12 ft
C	24 ft	19 ft	24 ft
D	29 ft	-----	29 ft
E	-----	-----	31 ft
F	-----	-----	34 ft

Figure B-1

ELECTRODE HOLE AND THERMOWELL LAYOUT

(Plan)

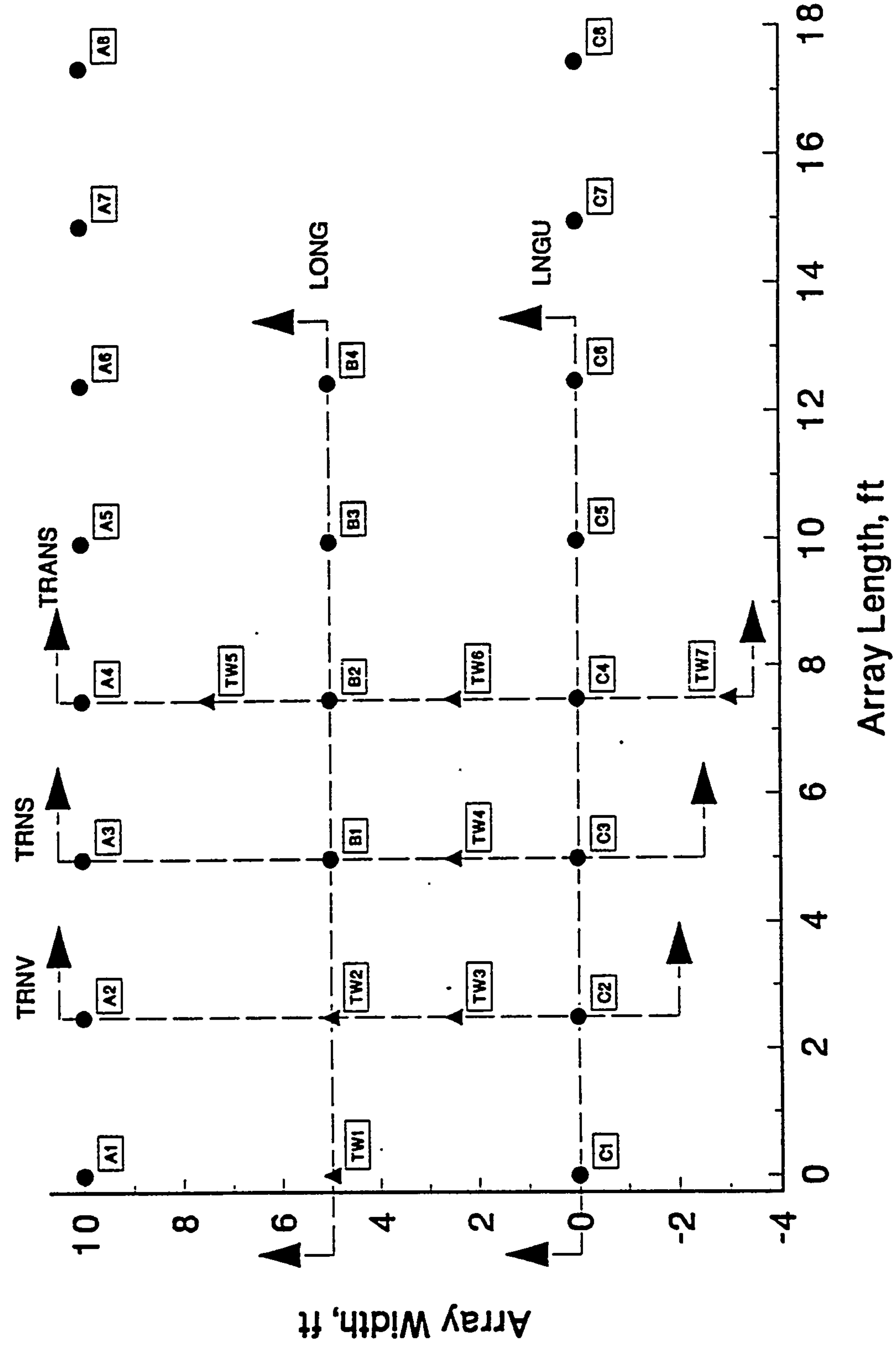


Table B-1 Ground Electrodes and Outside Thermowell (TW7) Temperature (Recorded Manually)

Date	Time	Elapsed Time	A2A 1-ft	A3A 1-ft	A4A 1-ft	C2A 1-FT	C3A 1-ft	C4A 1-FT.	A2B 12-ft	A3B 12-ft	A4B 12-ft	C1B 12-FT	C2B 12-ft	C3B 12-ft	C4B 12-FT.	C6B 12-FT	A2C 24-ft	A3C 24-ft
Maximum Temp. --->			79	86	112	82	98	92	84	95	96	68	84	99	96	91	42	45
04/03/93	16:40	0.00																
04/03/93	17:00	0.33	17.9	18.2	18.1	18.2	18.5	18.8	19.5	19.8	19.5	19.1	19.0	19.8	19.8	21.0	21.7	21.8
04/04/93	17:10	24.50	19.7	21.0	22.7	19.6	21.6	23.3	19.4	19.8	19.4	18.9	18.9	19.7	19.7	20.9	21.8	21.9
04/05/93	19:00	50.33	23.9	25.9	32.4	22.8	27.6	32.7	19.4	19.8	19.3	19.0	19.2	19.9	19.9	20.9	21.8	21.8
04/06/93	17:30	72.83	27.8	30.5	40.4	25.7	32.5	37.4	19.6	20.1	19.9	19.1	19.3	20.3	20.4	21.3	21.9	22.2
04/07/93	22:10	101.50	32.5	36.5	49.2	29.8	38.0	43.8	19.9	20.7	20.8	19.1	19.4	21.2	21.5	22.1	22.0	22.2
04/08/93	21:20	124.67	35.6	41.4	54.1	33.3	43.3	49.9	20.4	21.6	22.0	19.3	20.2	22.5	23.4	23.3	22.2	22.2
04/09/93	21:40	149.00	37.7	45.2	58.4	36.1	47.6	54.2	21.0	22.8	24.3	19.6	21.0	24.6	26.6	25.1	22.3	22.4
04/10/93	17:45	169.08	39.2	47.7	60.7	37.7	50.9	56.8	21.8	24.1	27.0	19.7	21.6	26.6	30.2	26.9	22.3	22.5
04/11/93	18:10	193.50	41.1	50.5	62.5	40.3	54.0	58.9	23.0	26.4	30.7	20.2	23.2	29.7	35.0	29.7	22.7	22.8
04/12/93	18:51	218.18	42.7	53.2	65.3	42.0	57.2	61.6	24.3	28.8	34.7	20.9	24.9	33.1	39.2	32.8	22.7	23.0
04/13/93	03:45	227.08	43.3	54.3	66.9	42.6	58.5	62.7	24.8	29.8	36.6	21.4	25.3	34.5	40.9	33.8	22.6	23.0
04/14/93	05:55	253.25	44.9	57.1	68.3	44.3	61.2	64.4	26.5	32.9	41.6	22.2	27.2	38.6	46.0	36.9	22.8	23.4
04/15/93	07:00	278.33	45.9	59.0	69.5	45.7	62.8	65.4	28.7	36.3	46.9	23.0	29.6	42.7	50.9	40.4	23.1	23.6
04/16/93	08:45	304.08	46.6	59.3	69.1	46.3	63.6	66.0	31.0	40.4	52.9	24.4	32.6	47.1	56.1	42.5	23.2	24.1
04/17/93	08:29	327.82	47.0	60.0	69.5	46.9	64.0		33.2	43.8	57.4	25.3	35.0	51.7	61.6	45.3	23.4	24.1
04/18/93	07:48	351.13	47.3	60.4	68.6	47.0	63.5	64.7	35.5	47.0	61.0	26.6	37.0	56.2	66.4	48.2		24.3
04/19/93	06:40	374.00	48.4	61.9	70.7	48.6	65.2	66.3	37.7	50.4	65.0	27.9	39.4	60.0	73.0	49.9	23.9	24.6
04/20/93	08:46	400.10	49.7	63.4	72.2	50.3	66.7	67.2	40.2	54.1	69.3	29.4	42.3	64.3	78.6	52.5	23.7	24.8
04/21/93	09:00	424.33	50.1	63.9	73.0	51.8	66.7	66.8	43.1	57.6	72.9	31.2	45.2	68.4	81.5	53.8	24.1	25.2
04/22/93	09:18	448.63	50.7	62.9	73.2	52.7	66.9	69.3	45.6	60.9	75.8	32.9	47.7	71.5	83.8	56.2	24.4	25.6
04/23/93	08:00	471.33	51.5	63.5	74.5	54.8	70.3	70.5	48.0	63.7	78.0	34.5	50.1	74.6	86.1	57.8	24.8	26.0
04/24/93	09:15	496.58	52.6	65.1	76.6	56.5	71.6	71.4	50.3	66.6	80.5	36.0	52.6	77.4	89.6	62.4	24.9	26.2
04/25/93	06:42	518.03	54.2	65.7	78.9	58.6	73.0	73.9	52.6	69.2	82.7	37.6	55.1	79.8	91.6	61.9	25.3	26.5
04/26/93	07:15	542.58	57.4	68.0	81.4	60.9	78.2	76.4	55.2	71.6	84.8	39.7	58.1	81.6	93.1	64.8	25.8	27.0
04/27/93	11:05	570.42	59.4	66.9	86.4	63.3	81.3	82.0	57.8	75.0	87.2	41.7	60.7	85.4	95.3	66.6	26.0	27.5
04/28/93	08:00	591.33	61.8	67.9	91.0	65.6	90.5	83.7	60.0	77.2	88.2	43.5	62.2	90.1	96.2	67.2	26.5	27.9
04/29/93	08:20	615.67	63.0	70.4	95.5	68.1	96.1	85.3	62.4	79.4	89.7	45.4	65.3	98.5	96.3	69.0	27.1	28.3
04/30/93	09.00	640.33	63.6	71.3	86.2	68.8	94.7	81.5	64.6	82.3	92.8	47.2	67.6	95.5	87.9	67.5	27.1	28.8
05/01/93	11:36	666.93	63.6	70.1	82.9	69.3	88.4	76.1	66.0	84.1	92.6	48.7	68.6	88.7	90.0	64.9	27.6	29.3
05/02/93	09:20	688.67	61.4	67.4	78.1	67.1	83.1	72.4	66.7	82.9	85.4	50.6	69.7	83.6	85.1		28.5	30.0
05/03/93	12:21	715.68	62.0	73.3	80.5	68.1	89.0	75.0	67.5	85.7	90.0	51.1	69.3	90.2	87.9	66.2	28.3	30.2
05/04/93	15:59	743.32	65.2	84.5	83.0	71.2	91.9	80.7	70.2	89.2	92.1	52.8	71.3	93.2	91.2	68.9	29.2	31.0
05/05/93	07:09	758.48	67.3	85.8	83.8	72.8	94.1	83.2	71.7	90.4	92.4	53.8	72.7	95.5	92.5	69.8	29.5	31.0
05/06/93	08:12	783.53	68.9	82.1	83.6	75.9	94.1	85.7	73.8	91.8	92.4	55.3	74.1	94.6	91.8	70.1	29.8	31.5
05/07/93	21:05	820.42	70.8	79	86.2	75.7	94.2	88.4	76.3	92.9	94.5	57.4	76.4	95.0	92.1	71.6	30.4	32.0
05/08/93	18:12	841.53	70.6	76.8	84.2	76.4	92.5	88.0	76.7	92.1	93.4	58.3	76.8	93.2	89.9	70.5	30.4	32.2
05/09/93	06:04	853.40	72.0	77.5	85.8	77.7	94.1	89.3	78.0	93.0	94.4	59.0	77.4	94.7	91.8	73.1	30.8	32.6
05/10/93	10:11	881.52	73.5	79.6	86.7	80.3	94.6	90.8	79.8	93.8	94.9	60.4	78.5	94.2	88.8	74.0	31.0	33.1
05/10/93	[illegible]	893.30	74.4	80.9	87.6	81.0	95.3	91.5	[illegible]	94.1	94.8	60.9	79.3	95.0	88.9	75.0	[illegible]	31.3

Table B-1 Ground Electrodes and Outside Thermowell (TW7) Temperature (Recorded Manually) [Continued]

Date	Time	Elapsed Time	A2A 1-ft	A3A 1-ft	A4A 1-ft	C2A 1-FT	C3A 1-ft	C4A 1-FT.	A2B 12-ft	A3B 12-ft	A4B 12-ft	C1B 12-FT	C2B 12-ft	C3B 12-ft	C4B 12-FT.	C6B 12-FT	A2C 24-ft	A3C 24-ft
Maximum Temp. --->			79	86	112	82	98	92	84	95	96	68	84	99	96	91	42	45
05/11/93	09:14	904.57	75.2	80.9	87.3	81.5	95.0	91.5	80.8	93.5	95.1	61.7	79.3	94.5	92.6	73.1	31.3	33.7
05/12/93	12:24	931.73	73.2	·78.7	82.6	74.2	92.3	87.7	79.9	92.1	92.1	62.1	79.4	92.0	88.3	74.5	31.6	33.9
05/13/93	09:30	952.83	75.3	83.0	86.4	78.2	95.0	88.5	80.8	93.8	94.5	63.2	81.0	94.8	92.2	78.9	32.6	34.7
05/14/93	04:00	971.33	76.3	82.4	86.6	78.0	94.1	88.9	81.8	94.2	94.1	64.0	81.7	94.1	86.8	75.2	33.2	35.3
05/15/93	09:21	1000.68	77.4	84.0	88.3	78.1	95.0	89.0	82.4	92.3	95.5	64.8	82.3	94.7	92.9	75.4	33.2	36.1
05/16/93	15:43	1031.05	78.2	84.6	89.0	77.8	94.8	89.6	82.9	95.0	95.7	65.5	82.7	94.4	93.9	81.2	34.1	37.0
05/17/93	23:27	1062.78	79.3	85.8	90.0	80.3	95.4	89.9	83.2	94.7	96.2	67.1	83.5	95.5	92.6	88.5	35.6	38.4
05/18/93	09:50	1073.17	78.8	85.5	89.4	79.1	97.9	89.7	84.4	95.0	96.2	67.3	83.7	94.6	93.7	90.6	35.6	38.9
05/19/93	01:53	1089.22	77.7	83.5	87.3	78.0	93.5	87.3	83.0	93.2	94.2	67.8	84.1	93.6	91.2	84.5	36.4	39.4
05/19/93	23:58	1111.30	75.9	82.2	85.6	76.3	92.9	84.1	81.6	91.8	92.2	67.9	81.2	93.1	89.0	79.0	37.2	40.1
05/20/93	23:24	1134.73	72.2	80.1	83.8	73.3	90.2	81.9	79.6	85.3	90.6	67.9	78.7	91.2	86.1	78.8	37.8	40.6
05/22/93	22:00	1181.33	70.9	77.7	82.1	67.3	90.9	82.2	78.1	88.9	90.5	67.9	79.6	91.2	87.7	75.9	38.8	41.9
05/23/93	10:48	1194.13	71.4	78.5	80.7	70.2	90.7	81.8	77.7	88.9	88.7	67.6	78.6	91.4	85.4	75.5	38.2	42.4
05/24/93	11:54	1219.23	71.4	80.2	79.6	69.7	88.9	80.7	78.0	85.6	87.1	67.8	79.5	89.2	86.1	70.5	39.4	42.8
05/24/93	19:10	1226.50	71.0	79.8	81.1	70.4	88.8	81.0	77.4	85.8	86.1	67.6	79.7	89.4	86.2	70.1	39.6	42.9
05/25/93	21:30	1252.83	69.1	77.0	82.4	68.1	87.1	80.5	75.9	85.4	82.6	67.7	78.8	88.1	83.8	72.5	40.5	43.6
05/26/93	19:20	1274.67	66.5	74.3	83.4	64.6	85.4	79.3	74.0	83.7	80.0	66.6	77.6	86.8	82.9	71.3	40.4	43.6
05/27/93	09:12	1288.53	65.6	73.7	84.5	63.1	84.6	77.9	73.7	80.2	78.7	66.7	77.3	85.9	82.6	67.6	40.7	44.1
05/28/93	09:19	1312.65	63.7	72.8	89.3	60.9	83.7	77.5	72.7	82.5	77.6	66.1	76.4	85.1	81.8	71.2	41.2	44.4
05/29/93	05:48	1333.13	62.6	71.4	93.8	60.9	81.9	77.3	72.1	81.8	76.7	65.6	76.3	83.3	83.1	79.0	41.5	44.5
05/30/93	09:30	1360.83	61.8	70.8	98.7	60.8	81.3	77.0	71.3	81.4	75.9	65.0	75.6	83.1	83.3	73.4	41.7	44.9
05/31/93	11:40	1387.00	62.0	70.3	103.0	61.5	80.3	76.1	70.5	80.7	76.4	64.2	74.6	82.2	83.1	77.4	41.6	44.8
06/01/93	09:25	1408.75	61.2	70.8	106.0	61.1	79.7	75.3	70.1	80.3	76.4	64.1	74.3	81.8	82.0	67.8	41.8	45.0
06/02/93	08:00	1431.33	62.9	72.2	110.2	63.3	78.8	77.3	70.0	80.5	78.1	63.8	74.0	81.3	82.7	70.5	42.2	45.3
06/03/93	09:27	1456.78	62.7	73.0	112.0	63.0	78.0	77.3	69.8	80.5	81.0	63.7	73.4	80.7	83.5	73	42.1	45.4
06/03/93	12:00	1459.33	62.4	73	112.1	62.5	77.4	76.3	69.2	79.8	80.3	63	72.9	80.2	81.2	72.6	41.7	44.8

Table B-1 Ground Electrodes and Outside Thermowell (TW7) Temperature (Recorded Manually) [Continued]

Date	Time	Elapsed Time	A4C 24-ft	C1C 24-ft	C2C 24-ft	C3C 24-ft	C4C 24-ft	A3D 29-ft	A4D 29-ft	C2D 29-ft	C3D 29-ft	C4D 29-ft	C6D 29-ft	TW7B 12-ft	TW7C 24-ft	TW7D 29-ft
	Maximum Temp. --->		49	42	49	52	49	32	34	32	33	32	30	62	39	28
04/03/93	16:40	0.00														
04/03/93	17:00	0.33	21.9	21.5	21.6	21.7	21.8	21.9	21.9	21.9	21.9	21.8	21.9			
04/04/93	17:10	24.50	21.9	21.4	21.5	21.6	21.6	21.9	21.9	21.8	21.8	21.6	21.8			
04/05/93	19:00	50.33	21.8	21.5	21.4	21.4	21.5	21.7	21.7	21.7	21.6	21.5	21.7			
04/06/93	17:30	72.83	22.3	21.6	21.6	21.8	21.8	21.9	21.9	21.9	21.9	21.8	21.9			
04/07/93	22:10	101.50	22.2	21.5	21.4	21.6	21.7	21.8	21.8	21.7	21.7	21.6	21.8			
04/08/93	21:20	124.67	22.2	21.6	21.6	21.6	21.7	21.8	21.8	21.8	21.6	21.5	21.6			
04/09/93	21:40	149.00	22.4	21.6	21.6	21.7	21.8	21.8	21.8	21.7	21.7	21.5	21.6			
04/10/93	17:45	169.08	22.7	21.5	21.7	21.8	22.0	21.8	21.8	21.6	21.6	21.4	21.6			
04/11/93	18:10	193.50	23.0	21.7	21.9	22.1	22.5	21.9	21.8	21.7	21.6	21.5	21.7	20.1	21.6	21.6
04/12/93	18:51	218.18	23.3	21.8	22.2	22.4	22.8	21.8	21.8	21.7	21.6	21.6	21.7	20.7	21.6	21.4
04/13/93	03:45	227.08	23.4	21.9	22.4	22.8	23.2	21.8	22.0	21.9	21.9	21.8	21.9	21.1	22.0	21.6
04/14/93	05:55	253.25	23.8	22.0	22.8	23.2	23.6	21.9	22.1	21.9	22.0	21.9	21.9	22.0	22.1	21.7
04/15/93	07:00	278.33	24.0	22.1	22.8	23.4	24.0	21.9	22.1	21.9	21.9	21.8	21.8	23.0	22.1	21.6
04/16/93	08:45	304.08	24.8	22.3	23.4	24.2	24.7	22.1	22.2	22.2	22.2	21.9	21.8	24.2	22.7	21.8
04/17/93	08:29	327.82	24.8	22.3	23.3	24.2	24.7	22.0	22.1	22.0	22.0	21.8	21.6	25.5	22.4	21.5
04/18/93	07:46	351.13	25.1	22.5	23.5	24.5	25.2	22.1	22.3	22.1	22.1	22.0	21.9	27.0	22.6	21.6
04/19/93	06:40	374.00	25.4	22.8	23.9	24.9	25.8	22.2	22.4	22.0	22.1	22.1	22.1	28.6	22.8	21.7
04/20/93	08:46	400.10	25.7	22.9	24.2	25.3	26.3	22.2	22.5	22.1	22.3	22.2	22.1	30.4	23.1	21.9
04/21/93	09:00	424.33	26.2	23.3	24.8	26.1	27.0	22.3	22.6	22.3	22.4	22.2	22.1	32.4	23.5	21.8
04/22/93	09:18	448.63	26.7	23.4	25.2	26.8	28.0	22.5	22.7	22.4	22.6	22.3	22.1	34.2	23.7	21.9
04/23/93	08:00	471.33	27.1	23.8	25.8	27.4	28.7	22.6	22.9	22.5	22.7	22.5	22.3	36.2	24.0	21.9
04/24/93	09:15	496.58	27.4	24.0	26.0	27.9	29.6	22.6	22.9	22.3	22.6	22.4	22.6	38.0	24.3	22.1
04/25/93	06:42	518.03	27.8	24.3	26.3	28.4	30.2	22.7	23.1	22.6	22.8	22.8	22.7	39.8	24.6	22.2
04/26/93	07:15	542.58	28.4	24.8	27.1	29.4	31.6	22.9	23.2	22.7	23.1	23.1	22.9	41.8	25.1	22.1
04/27/93	11:05	570.42	29.1	25.0	27.7	30.3	32.9	22.9	23.4	22.7	23.1	23.1	22.9	43.7	25.7	22.2
04/28/93	08:00	591.33	29.6	25.5	28.3	31.3	34.0	23.0	23.4	22.9	23.3	23.3	23.1	45.4	26.1	22.2
04/29/93	08:20	615.67	30.0	26.1	29.2	32.6	35.2	23.1	23.6	23.0	23.3	23.5	23.4	47.1	26.6	22.1
04/30/93	09:00	640.33	30.7	26.4	30.6	33.7	36.5	23.1	23.7	23.3	23.8	23.5	23.1	48.8	28.3	22.4
05/01/93	11:36	666.93	31.1	26.8	31.4	34.3	37.1	23.2	23.8	23.3	23.9	23.8	23.5	49.6	28.6	22.4
05/02/93	09:20	688.67	31.9	27.7	31.6	35.2	37.7	23.7	24.3	23.9	24.5	24.3	23.8	50.6	28.8	22.7
05/03/93	12:21	715.68	32.1	27.7	31.8	35.1	37.0	23.6	24.3	23.8	24.5	24.4	23.9	50.5	29.2	22.7
05/04/93	15:59	743.32	32.7	28.6	32.6	35.6	37.2	24.2	24.9	24.4	25.0	25.1	24.7	51.4	29.9	23.3
05/05/93	07:09	758.48	33.0	28.8	32.9	35.7	37.1	24.2	25.0	24.5	25.1	25.2	25.0	52.2	29.8	23.4
05/06/93	08:12	783.53	33.6	29.4	34.1	36.0	37.2	24.5	25.3	24.8	25.4	25.5	25.3	53.1	30.3	23.5
05/07/93	21:05	820.42	34.1	30.0	36.9	36.2	37.3	24.8	25.6	25.0	25.6	25.7	25.7	54.3	30.3	23.7
05/08/93	18:12	841.53	34.3	30.2	36.4	36.3	37.2	24.8	25.7	25.2	25.7	25.7	25.8	54.6	30.3	23.6
05/09/93	06:04	853.40	34.9	30.4	36.6	36.1	37.6	25.0	25.9	25.3	25.7	25.9	26.0	55.1	30.7	23.9
05/10/93	10:11	881.52	35.7	30.6	35.9	37.3	37.9	25.0	25.9	25.4	26.1	25.9	25.9	55.7	30.8	23.8
05/10/93	?	893.30	35.8	30.9	35.7	37.0	37.9	25.1	[illegible]	25.4	25.9	25.8	26.2	56.2	30.5	23.6

Table B-1 Ground Electrodes and Outside Thermowell (TW7) Temperature (Recorded Manually) [Continued]

Date	Time	Elapsed Time	A4C 24-ft	C1C 24-ft	C2C 24-ft	C3C 24-ft	C4C 24-ft	A3D 29-ft	A4D 29-ft	C2D 29-ft	C3D 29-ft	C4D 29-ft	C6D 29-ft	TW7B 12-ft	TW7C 24-ft	TW7D 29-ft
Maximum Temp. --->			49	42	49	52	49	32	34	32	33	32	30	62	39	28
05/11/93	09:14	904.57	36.6	31.0	36.2	37.8	38.5	25.2	26.1	25.7	26.4	26.0	25.9	56.3	31.1	24.0
05/12/93	12:24	931.73	36.8	30.9	35.6	37.9	38.8	25.5	26.4	25.7	26.3	26.4	26.3	56.8	31.2	24.1
05/13/93	09:30	952.83	37.8	31.6	36.4	38.8	39.6	25.6	26.6	26.0	26.7	26.4	26.4	57.5	31.6	24.2
05/14/93	04:00	971.33	38.4	32.2	36.7	39.0	40.2	26.1	27.2	26.3	26.8	26.9	27.2	58.2	31.8	24.3
05/15/93	09:21	1000.68	39.6	32.3	37.0	39.9	41.0	26.2	27.4	26.5	27.2	26.9	27.0	58.7	32.0	24.4
05/16/93	15:43	1031.05	40.9	32.7	37.4	40.9	42.2	26.3	27.7	26.3	27.2	27.2	27.5	59.6	32.6	24.6
05/17/93	23:27	1062.78	42.8	33.9	38.7	42.9	44 5	26.9	28.4	26.9	27.8	28.0	28.3	61.0	33.4	25.2
05/18/93	09:50	1073.17	43.3	33.8	39.3	43.4	45.1	27.1	28.5	27.2	28.1	28.1	28.1	61.0	33.7	25.2
05/19/93	01:53	1089.22	43.8	34.5	39.6	44.1	46.0	27.4	28.7	27.2	28.1	28.3	28.2	61.6	33.8	25.2
05/19/93	23:58	1111.30	44.7	35.1	40.6	45.1	46.9	27.6	29.1	27.5	28.4	28.5	28.2	61.8	34.3	25.2
05/20/93	23:24	1134.73	45.0	35.5	41.2	46.0	47.4	27.9	29.5	27.8	28.7	28.9	28.4	61.8	34 9	25.4
05/22/93	22:00	1161.33	46.1	36.6	42.9	47.4	48.4	28.6	30.3	28.4	29.4	29.6	28 9	62.0	37.8	26.0
05/23/93	10:48	1194.13	46.6	37.1	43.1	47.9	48.6	28.7	30.3	28.5	29.6	29.7	28.9	61.7	37.5	26.0
05/24/93	11:54	1219.23	47.1	37.7	45.8	48.9	48.8	28.8	30.6	28.6	29.8	29.8	28.9	61.1	37.4	26.3
05/24/93	19:10	1226.50	47.1	37.8	47.4	49.1	48.9	29.1	30.8	28.9	29.9	30.0	29.3	61.0	37.2	26.4
05/25/93	21:30	1252.83	47.4	38.8	48.0	50.3	49.0	29.5	31.3	29.3	30.4	30.4	29 6	60.8	37.3	26 5
05/26/93	19:20	1274.67	47.3	39.1	48.1	50.6	48.9	29.6	31.3	29.4	30.5	30.4	29.5	60.2	37.2	26.5
05/27/93	09:12	1288.53	47.8	39.8	48.5	51.3	49.0	29.8	31.6	29.8	30.8	30.5	29 3	60.0	37.6	26 6
05/28/93	09:19	1312.65	48.0	40.4	48 4	51.6	49.1	30.2	32.0	30.2	31.2	30.7	29 6	59.7	37.8	26 8
05/29/93	05:48	1333.13	48.0	41.2	48.3	51.6	49 1	30.5	32.3	30.4	31.4	31.0	30.2	59 6	37.8	26 8
05/30/93	09:30	1360.83	48.4	41.8	48.3	51.9	49.3	30.8	32.8	30.8	31.9	31.3	30.2	59.4	38 4	27.2
05/31/93	11:40	1387.00	48.2	41.9	48.1	51.3	48 8	31.1	32.9	31.0	32.0	31.4	30.2	58.4	38.3	27.1
06/01/93	09:25	1408.75	48.2	42.2	48.2	51.2	48 6	31.3	33.1	31.2	32.1	31.2	29 9	58.4	38 3	27.2
06/02/93	08:00	1431.33	48.4	42.4	48.4	51.1	48.8	31.8	33.7	31.7	32.5	31.8	30 4	58.7	38.7	27.7
06/03/93	09:27	1456.78	48.6	42.3	48.3	51.1	48.8	32.2	33.9	32.2	33	32	30 3	58.3	38 9	28 1
06/03/93	12:00	1459.33	48.1	41.8	47.6	50.4	48.2	31.9	33 8	31.8	32.7	31.7	30.2	58	38.5	27.5

Table B-1 Ground Electrodes and Outside Thermowell (TW7) Temperature (Recorded Manually) [Continued]

Date	Time	Elapsed Time	Average Temperatures				
			1-foot	12-foot	24-foot	Opposite Excitors, All	Grand Average
	Maximum Temp. --->		87	88	47	77	72
04/03/93	16:40	0.00					
04/03/93	17:00	0.33	18.3	19.7	21.7	20.1	20.0
04/04/93	17:10	24.50	21.3	19.6	21.7	21.2	20.8
04/05/93	19:00	50.33	27.6	19.7	21.6	23.5	22.6
04/06/93	17:30	72.83	32.4	20.0	21.9	25.5	24.2
04/07/93	22:10	101.50	38.3	20.6	21.8	27.8	26.1
04/08/93	21:20	124 67	42.9	21.6	21.9	29.9	27.8
04/09/93	21:40	149.00	46.5	23.1	22.0	32.1	29.4
04/10/93	17:45	169.08	48.8	24.7	22.1	33.8	30.7
04/11/93	18:10	193.50	51.2	27.2	22.4	36.0	32.5
04/12/93	18:51	218.18	53.7	29.8	22.6	38.3	34.2
04/13/93	03:45	227.08	54.7	30.9	22.8	39.3	35.0
04/14/93	05:55	253.25	56.7	34.0	23.1	41.6	36.8
04/15/93	07:00	278.33	58.1	37.3	23.3	43.8	38.6
04/16/93	08:45	304.08	58.5	40.9	23.8	45.8	40.2
04/17/93	08:29	327.82	57.5	44.2	23.8	42.4	40.4
04/18/93	07:48	351.13	58.6	47.2	24.2	48.9	43.7
04/19/93	06:40	374.00	60.2	50.4	24.5	51.0	44.8
04/20/93	08:46	400.10	61.6	53 8	24.7	53.1	46.3
04/21/93	09:00	424.33	62.1	56.7	25.2	54.5	47.7
04/22/93	09:18	448.63	62.6	59.3	25.7	56.0	49.1
04/23/93	08:00	471.33	64.2	61.6	26.2	57.6	50 5
04/24/93	09:15	496.58	65.6	64.4	26.6	59.4	52.2
04/25/93	06:42	518.03	67.4	66.3	27.0	60.7	53 5
04/26/93	07:15	542.58	70.4	68.6	27.7	62 8	55.5
04/27/93	11:05	570 42	73.2	71.2	28.4	65.1	57.5
04/28/93	08:00	591.33	76.8	73.1	29.0	67.3	59.4
04/29/93	08:20	615.67	79.7	75.8	29.8	69.7	61.6
04/30/93	09:00	640.33	77.7	75.7	30.5	68 4	61.2
05/01/93	11:36	666.93	75.1	75.5	31.1	66 9	60 6
05/02/93	09:20	688.67	71.6	74 9	31.8	59.4	58.8
05/03/93	12:21	715.68	74.7	76 0	31.7	67.1	60 9
05/04/93	15:59	743 32	79.4	78.6	32.4	70.1	63.4
05/05/93	07:09	758.48	81.2	79 9	32.6	71.1	64 5
05/06/93	08:12	783 53	81.7	80.5	33.1	71.1	65.0
05/07/93	21:05	820.42	82.4	82.0	33.8	71.8	66.1
05/08/93	18:12	841.53	81.4	81.4	33 9	70 8	65 5
05/09/93	06:04	853.40	82 7	82.7	34.1	71.9	66 5
05/10/93	10:11	881.52	84.3	83 1	34 5	72 4	67.2
05/10/93	21:58	893.30	85.1	83.4	34.6	72.9	67.6

Table B-1 Ground Electrodes and Outside Thermowell (TW7) Temperature (Recorded Manually) [Continued]

Date	Time	Elapsed Time	Average Temperatures 1-foot	12-foot	24-foot	Opposite Excitors, All	Grand Average
Maximum Temp. --->			87	88	47	77	72
05/11/93	09:14	904.57	85.2	83.8	35.0	73.1	68.0
05/12/93	12:24	931.73	81.5	82.6	35.1	71.4	66.4
05/13/93	09:30	952.83	84.4	84.9	35.9	73.7	68.4
05/14/93	04:00	971.33	84.4	84.0	36.4	73.0	68.2
05/15/93	09:21	1000.68	85.3	85.0	37.0	74.1	69.1
05/16/93	15:43	1031.05	85.7	86.4	37.9	75.3	70.0
05/17/93	23:27	1062.78	86.8	87.7	39.5	76.7	71.4
05/18/93	09:50	1073.17	86.7	88.2	39.9	77.2	71.7
05/19/93	01:53	1089.22	84.6	86.5	40.5	75.5	70.6
05/19/93	23:56	1111.30	82.8	84.5	41.4	74.4	69.6
05/20/93	23:24	1134.73	80.3	82.3	41.9	72.8	68.2
05/22/93	22:00	1181.33	78.5	82.5	43.2	73.1	68.2
05/23/93	10:46	1194.13	78.9	81.7	43.4	72.9	68.1
05/24/93	11:54	1219.23	78.4	80.5	44.4	72.0	67.8
05/24/93	19:10	1226.50	78.7	80.3	44.7	72.0	68.0
05/25/93	21:30	1252.83	77.4	79.4	45.4	71.5	67.5
05/26/93	19:20	1274.67	75.6	77.9	45.4	70.6	66.4
05/27/93	09:12	1288.53	74.9	76.6	45.9	69.8	65.9
05/28/93	09:19	1312.65	74.7	76.7	46.2	70.4	65.9
05/29/93	05:46	1333.13	74.7	77.2	46.3	70.9	66.2
05/30/93	09:30	1360.83	75.1	76.1	46.6	70.7	66.0
05/31/93	11:40	1387.00	75.5	76.1	46.4	71.0	66.0
06/01/93	09:25	1406.75	75.7	74.6	46.5	70.2	65.5
06/02/93	08:00	1431.33	77.5	75.1	46.7	71.2	66.3
06/03/93	09:27	1456.78	77.7	75.7	46.7	71.8	66.6
06/03/93	12:00	1459.33	77.3	74.9	46.1	71.1	66.0

Table B-2 Temperature in Thermowells (Outside Thermowell TW7 in Table B-1)

Date	Time	Elapsed Time	TW1A 1-ft	TW2A 1-ft	TW3A 1-ft	TW4A 1-ft	TW5A 1-ft	TW6A 1-ft	TW7A 1-ft	TW1B 12-ft	TW2B 12-ft	TW3B 12-ft	TW4B 12-ft	TW5B 12-ft	TW6B 12-ft	TW7B 12-ft	TW1-20 20-ft	TW2-20 20-ft	TW3-20 20-ft
Maximum Temp.		--->	103.1	129	104.7	195.1	243	180.6	ERR	93.7	126	110.6	167.5	201.3	206.2	ERR	68.8	117.4	67.4
04/03/93	16:40	0.00																	
04/03/93	20:05	3.42																	
04/03/93	20:45	4.08																	
04/03/93	19:00	2.33	17.9					17.9		18.9					18.6				
04/04/93	16:00	23.33	34.7	36.4	24.7	25.7	29.4	24.8		19.2	19.1	19.1			19.6				
04/05/93	19:30	50.83	72.0	75.0	47.0	50.0	66.0	45.0		19.0									
04/06/93	16:00	71.33	79.0	85.0	59.0	65.0	77.0	62.0		19.0	21.0	20.0	22.0	24 0	25.0				
04/07/93	19:00	98 33	81.0	85.0	67.0	76.0	81.0	72.0		20.0	30.0	22 0	30.0	42.0	41.0				
04/08/93	19:15	122.58	83.1	87 6	71.8	82.8	88.2	81.7		20.6	32.3	25 6	36.5	57.2	58.6				
04/09/93	20:00	147.33	82.6	89 3	74.1	88.5	95.9	90.6		21.9	36.8	28 8	44.1	72 3	79.2				
04/10/93	19:55	171.25	82.1	90.9	76.8	93.5	95 5	95.6		23.6	41.5	32.5	52.5	84 5	88.6				
04/12/93	20:45	220.08	78.4	91.7	78 8	96.5	96 5	97.0		27.0	48.2	39.5	65 8	91.1	93.7				
04/13/93	20:00	243.33	78.5	93 8	82.3	96.4	101.1	97.0		28 6	52.2	43.0	71.8	92.3	95.1				
04/14/93	20:25	267.75	78.0	94.7	85 9	96.7	102.9	97.2		30.4	55.8	47.3	78.0	92 8	95 4				
04/15/93	21:00	292.33	77.0	97.8	90.0	98.0	113.6	98.3		33.4	61.0	52.2	85.5	98.0	98.4				
04/16/93	14:45	310.08	77.2	99.7	92.6	98 5	116.7	98.7		35.1	65.0	55.9	98.4	99 3	99.6				
04/17/93	23:20	342.67	73.9	99.8	98 8	97.8	120.8	103.0		38.1	69.8	61.5	97.9	98.7	99.7				
04/18/93	19:14	362.57	74.5	101.6	95.1	98.7	126.8	107.4		40 3	73.6	65.2	98.4	99.5	101.9				
04/19/93	18:40	386.00	76.2	104.3	96 3	99.5	131.1	110 4		43 0	81.5	69 6	98 4	100.2	102.7				
04/20/93	18:50	410.17	77.5	105.9	96.4	101.0	135.2	110.4		45 8	96 8	73.4	98 3	101.1	103.4				
04/21/93	18:53	434.22	75.8	104.9	92.1	102.3	136.3	108 6		48 6	87.3	75 8	98.4	101.6	103.4				
04/22/93	19:14	458.57	76.2	106 0	92.0	103 8	137.3	116.4		51.6	90.7	78.9	98 3	99.6	104.1				
04/23/93	21:25	484.75	78.3	108 6	95.1	108 7	139 5	121.7		54.6	97.3	87 6	97.8	99.0	104 9				
04/24/93	20:00	507.33	80 6	110 9	96 5	108 1	140 5	124.5		57.1	97.6	97 2	97.9	100.4	100.1				
04/25/93	20:50	532.17	81.5	111.9	96.6	110 8	145.6	126.9		59 6	97.9	98 1	98 3	107 6	100 2				
04/26/93	20:30	555.83	84.3	114 7	97.0	112 9	147.6	129 4		62 2	97.7	97.9	98 2	108 7	101 7				
04/27/93	20:55	580.25	88.4	118 0	98.1	127.8	149 7	132.4		66.1	99 2	99 7	115 8	111.6	111 3				
04/28/93	18:35	601.92	89.7	118.3	97.1	117.6	153.1	134 4		67 2	97 8	98 1	98 3	111 3	111 1				
04/29/93	18:35	625.92	90.6	115 4	93 0	120 5	153.4	135 3		70 0	93 5	93 8	97 8	110 7	111 8				
04/30/93	20:00	651.33	83.3	105 5	92 3	122.7	156 7	135.7		70 2	93 4	93 2	96 6	109 5	111 5				
05/01/93	20:30	675.83	82.2	111.9	92 1	123 2	158 8	135.7		72 2	92 3	92 1	95 6	108 6	110 7				
05/02/93	20:35	699.92	77.3	107.4	88 8	120 7	158 1	132 4		69 8	92 3	90 7	94 2	106 7	108 4				
05/03/93	20:40	724.00	82.8	111 6	93.6	125 5	159.9	136 8		72 2	95 6	94 1	97 5	111 2	112 3				
05/04/93	19:08	746.47	85.9	114.6	96.0	128.7	161 5	139.9		74 8	96.7	95 8	100 2	114 6	115 5				
05/05/93	22:30	773.83	82.9	115.7	92.3	130 7	154 7	139 9		76 1	96 1	95 3	101 5	117 3	108 9				
05/06/93	21:00	796 33	85.0	99.0	98.0	132.0	164 0	121.0		79 0	98 0	96 0	107 0	120 0	106 0				
05/07/93	21:44	821 07	91.0	100 0	99.0	134 0	161.0	126.0		81 0	99 0	97 0	111 0	126 0	124 0				
05/08/93	20:04	843.40	91.9	98 9	99.4	140.2	155.5	120.0		81.4	99 4	96 8	114 4	126 9	126 8				
05/09/93	21:07	868.45	96 0	99.5	99.6	136.1				83 2	99 6	98 6	120 2						
05/10/93	2	891.75	101.4	102.2	102.9	141.2	165.1	152.0		87 8	103.0	101 7	127 3	138 8	137 2				

Table B-2 Temperature in Thermowells (Outside Thermowell TW7 in Table B-1) [Continued]

Date	Time	Elapsed Time	TW4-20	TW5-20	TW6-20	TW1C	TW2C	TW3C	TW4C	TW5C	TW6C	Average Temperatures				TW7C	TW1D	TW2D
			20-ft	20-ft	20-ft	24-ft	24-ft	24-ft	24-ft	24-ft	24-ft	1-Foot	12-Foot	20-foot	24-Foot	24-ft	29-ft	29-ft
Maximum Temp. --->			196.5	233.7	204.6	63.3	60.4	90.2	90.1	68	65.4	144	142	133	59	ERR	37.5	37.6
04/03/93	16:40	0.00																
04/03/93	20:05	3.42																
04/03/93	20:45	4.08																
04/03/93	19:00	2.33				20.9												
04/04/93	16:00	23.33										29	19					
04/05/93	19:30	50.83										59	19					
04/06/93	16:00	71.33										71	22					
04/07/93	19:00	98.33										77	31					
04/08/93	19:15	122.58									21.6	83	38		22			
04/09/93	20:00	147.33									22.3	87	47		22			
04/10/93	19:55	171.25							22.8		23.2	89	54		23			
04/12/93	20:45	220.08										90	61					
04/13/93	20:00	243.33				21.8	23.5	22.7	24.1	26.1	25.0	92	64		24			
04/14/93	20:25	267.75						22.7	24.6		25.3	93	67		24			
04/15/93	21:00	292.33						23.7	25.6		26.5	96	71		25			
04/16/93	14:45	310.08				22.8	24.4	24.1	26.2	28.2	27.3	97	76		26			
04/17/93	23:20	342.67				22.8	24.5	24.1	26.5	28.7	27.6	99	78		26			
04/18/93	19:14	362.57				23.1	25.4	24.9	27.6	29.4	28.7	101	80		27			
04/19/93	18:40	386.00				23.6	26.0	25.4	28.4	30.2	29.5	103	83		27			
04/20/93	18:50	410.17				23.5	26.0	25.6	28.7	30.6	30.0	104	86		27		21.6	21.9
04/21/93	18:53	434.22				23.7	26.8	26.0	29.8	31.3	31.0	103	86		28			
04/22/93	19:14	458.57				24.0	27.3	26.7	30.8	32.2	32.3	105	87		29			
04/23/93	21:25	484.75				24.4	27.8	27.4	31.7	33.1	33.5	109	90		30		21.6	22.0
04/24/93	20:00	507.33				24.8	28.6	29.7	32.9	34.5	34.6	110	92		31		21.7	22.1
04/25/93	20:50	532.17				26.6	29.6	29.0	34.3	35.8	36.3	112	94		32		22.0	22.4
04/26/93	20:30	555.83				25.6	30.2	29.7	35.5	36.5	37.3	114	94		32		21.9	22.3
04/27/93	20:55	580.25				27.0	32.0	31.3		38.2	39.6	119	101		34			
04/28/93	18:35	601.92				26.8	31.6	31.5	38.4	38.3	40.1	118	97		34		22.7	22.9
04/29/93	18:35	625.92				27.6	31.9	31.9	39.0	38.6	41.1	118	96		35			22.3
04/30/93	20:00	651.33				27.4	32.5	33.0	39.7	39.1	41.9	116	96		36		21.7	22.3
05/01/93	20:30	675.83				28.6	33.3	33.9	41.0	40.2	42.5	117	95		37		22.6	22.8
05/02/93	20:35	699.92				28.0	33.6	33.9	40.8	40.4	42.5	114	94		37		21.9	23.0
05/03/93	20:40	724.00				28.8	34.0	34.3	41.2	40.6	42.3	118	97		37		22.5	23.6
05/04/93	19:08	746.47				29.3	34.3	35.6	40.9	41.1	42.1	121	100		37		23.2	23.9
05/05/93	22:30	773.83				28.6	34.0	34.7	40.6	42.0	42.0	119	99		37		22.2	23.4
05/06/93	21:00	796.33				30.0	35.0	36.0	41.0	44.0	43.0	117	101		38		23.0	25.0
05/07/93	21:44	821.07				30.0	37.0	36.0	42.0	46.0	43.0	119	106		39		24.0	26.0
05/08/93	20:04	843.40				31.1	36.7	37.2	42.6	46.4	44.3	118	108		40		24.0	25.5
05/09/93	21:07	868.45				31.7	37.7	37.8	43.3			108	100		38		27.1	29.1
05/10/93	20:25	891.75				34.3	40.4	40.5	46.3	52.1	48.2	127	116		44		26.7	27.9

Table B-2 Temperature in Thermowells (Outside Thermowell TW7 in Table B-1) [Continued]

Date	Time	Elapsed Time	TW1A 1-ft	TW2A 1-ft	TW3A 1-ft	TW4A 1-ft	TW5A 1-ft	TW6A 1-ft	TW7A 1-ft	TW1B 12-ft	TW2B 12-ft	TW3B 12-ft	TW4B 12-ft	TW5B 12-ft	TW6B 12-ft	TW7B 12-ft	TW1-20 20-ft	TW2-20 20-ft	TW3-20 20-ft
Maximum Temp. --->			103.1	129	104.7	195.1	243	180.6	ERR	93.7	126	110.6	167.5	201.3	206.2	ERR	68.8	117.4	87.4
05/11/93	20:10	915.50	103.1	104.0	103.8	141.4	166.4	152.4		89.4	104.8	102.2	131.7	143.4	141.4				
05/12/93	20:00	939.33	100.0	104.4	104.1	139.2	164.0	151.4		89.5	104.3	103.7	133.4	145.5	143.2				
05/13/93	20:17	963.62	102.1	119.8	104.3	141.0	164.2	151.9		91.3	106.2	105.1	137.0	150.2	147.5				
05/14/93	20:20	987.67	101.7	128.2	104.7	141.6	164.0	151.0		92.3	105.9	104.6	139.1	154.2	151.4				
05/15/93	21:00	1012.33	102.9	129.0	104.4	142.4	163.4	150.0		93.7	115.7	104.9	140.9	158.6	155.9				
05/16/93	20:50	1036.17	98.8	125.9	100.0	138.6	158.0	147.3		90.3	112.8	100.5	137.4	156.8	154.2		54.2	82.5	76
05/17/93	20:22	1059.70	98.1	126.2	99.5	139.6	158.7	148.0		90.6	113.7	101.6	133.0	158.6	155.5		55.1	82.4	76 6
05/18/93	21:30	1084.83	96.5	125.4	99.6	138.1	158.2	147.6		90.1	113.9	103.7	130.7	159.3	156.5		56.7	88.2	79.2
05/19/93	20:00	1107.33	91.1.	121.9	99.8	135.0	155.2	145.4		89.9	115.4	110.6	128.1	160.8	157.9		56.4	85	78
05/20/93	22:05	1133.42	83.0	115.1	95.2	125.5	148.4	140.3		86.1	114.6	98.7	140.4	161.8	158.9		56.8	79.8	75 6
05/21/93	21:10	1156.50	78.4	109.9	90.0	122.8	144.3	137.8		84.6	114.6	99.7	142.6	168.8	165.6		57.8		71.6
05/22/93	12:55	1172.25	77.4		88.2	121.3		136.7		85.8		98.6	143.5		171.1		64.4	110.7	85.1
05/23/93	21:25	1204.75	68.2	112.2	84.0	125.6	153.6	111.5		85.7	99.5	98.8	146.6	187.4	184.0		59.2	92.3	84 4
05/24/93	08:00	1215.33	72.1	97.9	86.6	126.0	140.5	138.9		86.4	105.4	99.4	146.2	194.0	189.8		63.2	117.4	86 1
05/24/93	20:10	1227.50	71.1	100.3	89.5	129.6	157.6	126.9		86.2	115.4	100.6	152.0	201.3	195.3		65.4	101.5	86 9
05/25/93	19:00	1250.33	70.4	102.1	90.9	134.7	151.9	146.7		85.7	122.4	101.9	157.9		199.9		68.8	109.4	87.4
05/26/93	20:25	1275.75	70.3	102.3	93.0	141.8	140.8	140.5		85.7	126.0	103.7	165.9		206.2		61.4	102.3	85.7
05/27/93	12:11	1291.52	64.7	100.8	87.6	157.5	145.1	148.0		81.9	124.8	101.0	150.6		201.2				
05/28/93	03:00	1306.33	64.0	103.0	87.7	144.1	152.6	151.0		82.0		101.0	160.0		202.0				
05/28/93	20:20	1323 67	64.7	101.2	91.6	178.6	129.0	156.5		81.3	125.3	101.0	167.5		203.0				
05/29/93	03:30	1330.83					139.4	160.5							204.0				
05/29/93	15:00	1342.33					173.0	162.9							203.3				
05/29/93	19:50	1347.17	62.4	101.6	93.8	193.3	175.9	165.8		80.3	124.3	101.8							
05/30/93	19:28	1370.80	62.3	101.4	96.6	195.1	191.0	174.9		80.3	123.9	101.5							
05/31/93	19:30	1394.83	63.7	103.1	98.5	175.4	243.0	180.1		78.8	121.1	100.6			203.1				
06/01/93	03:40	1403.00	64.4	102.5	97.5	170.6	237.8	180.6		79.3	120.4	100.4			203.1				
06/01/93	19:00	1418 33	65.0	107.5	96.3	166.9	227.1	180.0		78.2	118 8	99.4			202.4				
06/02/93	19:00	1442.33	68.3	102.6	96 3	162.8	218.6	178.6		77.5	116.8	98.3			201.9				
06/03/93	12:30	1459.83	69.6	101.1	95.1	156.8	214.0	176.8		76.3	115.5	96.4			200.3				

Table B-2 Temperature in Thermowells (Outside Thermowell TW7 in Table B-1) [Continued]

Date	Time	Elapsed Time	TW3D 29-ft	TW4D 29-ft	TW5D 29-ft	TW6D 29-ft	TW7D 29-ft	TW1E 31-ft	TW2E 31-ft	TW3E 31-ft	TW4E 31-ft	TW5E 31-ft	TW6E 31-ft	TW7E 31-ft	TW1F 34-ft	TW2F 34-ft	TW3F 34-ft	TW4F 34-ft
Maximum Temp. --->			80.5	37.7	36.2	39.1	ERR	28.1	21.8	23	21.8	ERR	23.2	ERR	26.5	ERR	ERR	ERR
04/03/93	16:40	0.00																
04/03/93	20:05	3.42																
04/03/93	20:45	4.08																
04/03/93	19:00	2.33													21.1			
04/04/93	16:00	23.33																
04/05/93	19:30	50.83																
04/06/93	16:00	71.33																
04/07/93	19:00	98.33																
04/08/93	19:15	122.58																
04/09/93	20:00	147.33																
04/10/93	19:55	171.25																
04/12/93	20:45	220.08																
04/13/93	20:00	243.33																
04/14/93	20:25	267.75																
04/15/93	21:00	292.33																
04/16/93	14:45	310.08																
04/17/93	23:20	342.67																
04/18/93	19:14	362.57																
04/19/93	18:40	386.00																
04/20/93	16:50	410.17	21.9	22.4	22.4	22.3												
04/21/93	16:53	434.22																
04/22/93	19:14	458.57																
04/23/93	21:25	484.75	22.0			22 9				21.7								
04/24/93	20:00	507.33	22.0		23.1	22.8							22.1					
04/25/93	20:50	532.17	22.4		23.5	23.2		21.5	21.8		21.8							
04/26/93	20:30	555.83	22.3		23.6	23.3												
04/27/93	20:55	580.25																
04/28/93	18:35	601.92																
04/29/93	18:35	625.92		23.5														
04/30/93	20:00	651.33	22.9	24.7	23.8	23.7		21.1					23 2					
05/01/93	20:30	675.83	23.3	24.2	24.2	24.2			21.8	22.2			22.1					
05/02/93	20:35	699.92	23.2	24.5	24.5	24.4		21.1		22.1								
05/03/93	20:40	724.00	23.6	25.1	24.9	24.9												
05/04/93	19:08	746.47	24.9	25 6	25.0	25.3		22.5										
05/05/93	22:30	773.83	23.9	25 5	25.1	25.3		21.5	21.8	22.4								
05/06/93	21:00	796.33	25 0	26.0	26.0	26.0												
05/07/93	21:44	821.07	25.0	26.0	28.0	26.0		23.0		23.0								
05/08/93	20:04	843.40	25.5	27.1	27.3	27.1												
05/09/93	21:07	868.45	25.9	37.5		27.5												
05/10/93	20:25	891.75	28.1	29.7	30.1	27.6												

Table B-2 Temperature in Thermowells (Outside Thermowell TW7 in Table B-1) [Continued]

Date	Time	Elapsed Time	TW4-20 20-ft	TW5-20 20-ft	TW6-20 20-ft	TW1C 24-ft	TW2C 24-ft	TW3C 24-ft	TW4C 24-ft	TW5C 24-ft	TW6C 24-ft	Average Temperatures 1-Foot	12-Foot	20-foot	24-Foot	TW7C 24-ft	TW1D 29-ft	TW2D 29-ft
Maximum Temp. --->			198.5	233.7	204.6	63.3	60.4	90.2	90.1	68	65.4	144	142	133	59	ERR	37.5	37.6
05/11/93	20:10	915.50				36.0	42.6	42.3	48.4	55.0	50.3	129	119		46		28.2	29.5
05/12/93	20:00	939.33				36.7	43.5	42.8	49.3	56.2	51.5	127	120		47		28.3	30.0
05/13/93	20:17	963.62				37.3	44.6	44.1	50.7	58.4	53.0	131	123		48		28.9	30.4
05/14/93	20:20	987.67				38.4	45.9	45.3	52.2	60.2	54.7	132	125		49		29.6	31.0
05/15/93	21:00	1012.33				39.0	46.6	46.2	54.4	62.0	56.9	132	128		51		29.7	
05/16/93	20:50	1036.17				36.0	44.7	43.3	52.4	61.4	55.0	128	125		49		28.3	32.8
05/17/93	20:22	1059.70	96.7	104	91.8	36.3	48.6	44.3	54.4	63.7	57.4	128	126	84	51			
05/18/93	21:30	1084.83	90.6	129.7	103.6	37.7	47.4	45.8	56.7	66.1	59.7	128	126	90	52			
05/19/93	20:00	1107.33	97.8	137.4	113.8	38.4	48.4	47.1	58.4	68.0	61.9	125	127	96	54		29.4	37.3
05/20/93	22:05	1133.42	93.5	163.4	119.5	37.9	48.3		58.0	66.8	61.4	118	127	99	54		29.9	37.6
05/21/93	21:10	1156.50	95.9	178.1	128.3	38.2	48.8	47.7	58.8	66.7	62.0	114	129	102	54			
05/22/93	12:55	1172.25	89.7		90.2	38.8		47.1	59.0		62.5	106	125		52			
05/23/93	21:25	1204.75	126.4	233.7	175.7	39.4	51.6	50.0	62.6	66.9	63.3	109	134	133	56			
05/24/93	08:00	1215.33	147.2	201.6	148.7	40.0	53.3	50.2	63.3	67.6	63.5	110	137	122	56			
05/24/93	20:10	1227.50	148.7		165.7	41.9	56.1	52.8	65.6		65.4	113	142	116	56			
05/25/93	19:00	1250.33	186.2			44.2	50.2	56.3	68.5			116	134	110	55			
05/26/93	20:25	1275.75	196.5		204.6	46.1	60.4	58.5	69.6			115	138	133	59			
05/27/93	12:11	1291.52				44.3	54.5	56.6				117	132					
05/28/93	03:00	1306.33										117						
05/28/93	20:20	1323.67				63.3	59.5	57.3	85.0			120	136				29.6	32.5
05/29/93	03:30	1330.83																
05/29/93	15:00	1342.33																
05/29/93	19:50	1347.17				57.6	58.7	90.2	90.1			132					37.5	32.8
05/30/93	19:28	1370.80				46.8	59.2	58.0				137					31.1	34.3
05/31/93	19:30	1394.83				45.8	57.4	56.7				144					30.5	33.5
06/01/93	03:40	1403.00				30.4		56.5				142						
06/01/93	19:00	1418.33				46.1		58.5				140						
06/02/93	19:00	1442.33						55.2				138						
06/03/93	12:30	1459.83				45.2						136					30.8	

Table B-2 Temperature in Thermowells (Outside Thermowell TW7 in Table B-1) [Continued]

Date	Time	Elapsed Time	TW5F 34-ft	TW6F 34-ft	TW7F 34-ft
	Maximum Temp. --->		ERR	21.1	ERR
04/03/93	16:40	0.00			
04/03/93	20:05	3.42			
04/03/93	20:45	4.08			
04/03/93	19:00	2.33		21.1	
04/04/93	16:00	23.33			
04/05/93	19:30	50.83			
04/06/93	16:00	71.33			
04/07/93	19:00	98.33			
04/08/93	19:15	122.58			
04/09/93	20:00	147.33			
04/10/93	19:55	171.25			
04/12/93	20:45	220.08			
04/13/93	20:00	243.33			
04/14/93	20:25	267.75			
04/15/93	21:00	292.33			
04/16/93	14:45	310.08			
04/17/93	23:20	342.67			
04/18/93	19:14	362.57			
04/19/93	18:40	386.00			
04/20/93	18:50	410.17			
04/21/93	18:53	434.22			
04/22/93	19:14	458.57			
04/23/93	21:25	484.75			
04/24/93	20:00	507.33			
04/25/93	20:50	532.17			
04/26/93	20:30	555.83			
04/27/93	20:55	580.25			
04/28/93	18:35	601.92			
04/29/93	18:35	625.92			
04/30/93	20:00	651.33			
05/01/93	20:30	675.83			
05/02/93	20:35	699.92			
05/03/93	20:40	724.00			
05/04/93	19:08	746 47			
05/05/93	22:30	773.83			
05/06/93	21:00	796.33			
05/07/93	21:44	821.07			
05/08/93	20:04	843.40			
05/09/93	21:07	868.45			
05/10/93	20:25	891.75			

Table B-2 Temperature in Thermowells (Outside Thermowell TW7 in Table B-1) [Continued]

Date	Time	Elapsed Time	TW3D 29-ft	TW4D 29-ft	TW5D 29-ft	TW6D 29-ft	TW7D 29-ft	TW1E 31-ft	TW2E 31-ft	TW3E 31-ft	TW4E 31-ft	TW5E 31-ft	TW6E 31-ft	TW7E 31-ft	TW1F 34-ft	TW2F 34-ft	TW3F 34-ft	TW4F 34-ft
Maximum Temp. --->			80.5	37.7	36.2	39.1	ERR	28.1	21.8	23	21.8	ERR	23.2	ERR	26.5	ERR	ERR	ERR
05/11/93	20:10	915.50	29.6	31.4	32.1	31.3												
05/12/93	20:00	939.33	29.9	31.9	32.5	31.8												
05/13/93	20:17	963.62	30.4	32.3	33.3	32.3												
05/14/93	20:20	987.67	31.0	32.8	33.8	32.7												
05/15/93	21:00	1012.33	31.3	33.2		37.7		28.1							26.5			
05/16/93	20:50	1036.17	28.4	33.3	32.3	33.2												
05/17/93	20:22	1059.70																
05/18/93	21:30	1084.83																
05/19/93	20:00	1107.33	29.5	35.6	35.6	37.0												
05/20/93	22:05	1133.42	30.5	37.7	36.2	39.1												
05/21/93	21:10	1156.50																
05/22/93	12:55	1172.25																
05/23/93	21:25	1204.75																
05/24/93	08:00	1215.33																
05/24/93	20:10	1227.50																
05/25/93	19:00	1250.33																
05/26/93	20:25	1275.75																
05/27/93	12:11	1291.52	32.8															
05/28/93	03:00	1306.33																
05/28/93	20:20	1323.67	32.1															
05/29/93	03:30	1330.83																
05/29/93	15:00	1342.33																
05/29/93	19:50	1347.17	80.5															
05/30/93	19:28	1370.80	33.8															
05/31/93	19:30	1394.83	33.2															
06/01/93	03:40	1403.00																
06/01/93	19:00	1418.33																
06/02/93	19:00	1442.33																
06/03/93	12:30	1459.83																

Table B-3 Temperature in Excitor Electrodes

Date	Time	Elapsed Time	B1A	B2A	B3A	B4A	B1B	B2B	B3B	B4B	B1C	B2C	B3C	B4C	Average Temperature			
			1-ft	1-ft	1-ft	1-ft	10-ft	10-ft	10-ft	10-ft	19-ft	19-ft	19-ft	19-ft	1-foot	10-Foot	20-Foot	Overall
		Time	B1A	B2A	B3A	B4A	B1B	B2B	B3B	B4B	B1C	B2C	B3C	B4C				
Maximum Temp.---->			433.2	1150	464.2	330.1	725.4	1304	1280	1008.1	1170	1330	978.3	1021.1				
04/03/93	16:40	0.00	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
04/03/93	20:05	3.42	55.3	44.0	42.0	24.4	18.9	18.7	18.8	19.2	21.4	21.9	21.9	22.0	41	19	22	27
04/03/93	20:45	4.08	43.4	36.2	33 5	22.8	19.0	19.0	19.4	19.6	21.7	21.9	22.4	22.4	34	19	22	25
04/03/93	22:40	6.00	32.2	29.2	27.1	21.3	18.8	19.1	19.3	19.6	21.4	22.0	22.5	22.4	27	19	22	23
04/04/93	08:45	16.08	67.6	56 8	50.4	27.8	19.3	19.3	19.5	19.6	21.7	22.2	22.2	22.5	51	19	22	31
04/04/93	10:30	17.83	87.1	74.0	66.3	30.0	18.6	18.8	18.8	19.1	20.9	21.7	21.7	21.8	64	19	22	35
04/04/93	12:30	19 83	92.0	83 0	73 0	33.0	18.4	18.5	18.9	19.3	20.5	21.4	21.3	21.2	70	19	21	37
04/04/93	14:33	21.88	92.3	92.2	77.6	33.9	18.3	18.5	18.6	18.7	20.5	21.4	21.3	21.2	74	19	21	38
04/04/93	17:00	24.33	117.0	110 0	98.0	42.0	17.1	17.3	17.7	17.6	19.4	20.1	20.4	20.2	92	17	20	43
04/04/93	19:00	26.33	119.0	122.0	107.0	51.0	17.2	17.5	17.5	18.0	19.2	20.0	20.5	20.2	100	18	20	46
04/04/93	21:00	28.33	122.0	124.0	110.0	57.0	17.9	18.1	17.9	17.9	19.4	20.4	21.2	20.9	103	18	20	47
04/04/93	23:00	30.33	127.0	126.5	102.4	63 9	17.8	18.4	18 3	18.4	19.7	20.8	21.0	20.4	105	18	20	48
04/05/93	01:00	32.33	128.3	124.7	98 4	65.2	18 6	20.2	18 9	18.7	19.6	20.8	21.4	21.3	104	19	21	48
04/05/93	03:00	34.33	132.1	130 2	98 8	69.0	19.9	21.4	19.4	19.2	20.4	21.3	21.9	21.9	108	20	21	50
04/05/93	05:00	36.33	133.0	129.4	98 9	71.6	21.6	23 5	19.6	19.4	20.8	21.7	21.9	22.0	108	21	22	50
04/05/93	07:00	38.33	137.0	136 2	99.1	74.7	25.6	24.7	19.4	19.3	21.4	22.0	21 8	22.1	112	22	22	52
04/05/93	09:00	40.33	139.0	139 5	99.4	77.0	34.3	26.3	19.4	19.3	24.4	21.7	21 8	22.1	114	25	23	54
04/05/93	11:00	42.33	144.8	146 5	90.7	80.4	51.9	27.4		17.6	20.1	20.3	20.1	20.0	116	32	20	58
04/05/93	13:00	44.33	148.0	149.3	97.7	85.4	77.3	35 8	18.3	17.4	19.8	20.3	19.9	20.3	120	37	20	59
04/05/93	15:00	46 33	146.0	150.3	99 0	90 0	106 0	57.0	18 0	18.0	20.2	19.0	20 0	20.0	121	50	20	64
04/05/93	22:00	53 33	156.0	159.0	138 0	100 0	149.0	104 0	23.0	21.0	73.0	23.0	22 0	23.0	138	74	35	83
04/06/93	02:00	57.33	160.3	167.1	146.4	104.0	147.7	133 5	24.8	21.0	100.3	24.4	23 0	22.5	144	82	43	90
04/06/93	04:00	59.33	160.2	167.5	145.3	112.6	144.4	139.4	27.2	21.4	102.3	27.0	23 6	23.0	146	83	44	91
04/06/93	06:00	61.33	159.2	169 7	149.2	128.7	142.3	151.6	28 9	21.7	104.0	34.3	23 8	23 0	152	86	46	95
04/06/93	08:00	63.33	156.8	168.1	149 8	137.5	139.5	159.4	30.0	21.1	107.8	69.5	24.1	21.7	153	88	56	99
04/06/93	14:40	70.00	154.0	167.0	156.0	158 0	137.0	157.0	44 0	78 0	102 6	98 0	25 0	22 0	159	104	62	108
04/06/93	22:00	77.33	155.0	165.0	161.0	172 0	135 0	143 0	123 0	117.0	105 0	114 0	26 0	23 0	163	130	67	120
04/07/93	02:00	81.33	152.4	163.2	161.8	175 0	134.6	140.0	131 8	135 0	104 8	113 8	26 6	23.7	163	135	67	122
04/07/93	06:00	85.33	151.0	162.1	163.3	179.7	133.5	139 5	142 0	146 5	105 1	114 3	26 6	24 5	164	140	68	124
04/07/93	08:30	87.83	149.7	160.5	162.1	178 8	132.4	138.2	143.8	149.5	104.6	112 8	26.4	25 8	163	141	67	124
04/07/93	17:00	96.33	145.0	155 0	152.0	166 0	127.0	133 0	148 0	137.0	87 4	103.0	50 0	82 0	155	136	81	124
04/07/93	22:00	101.33	143.6	154.6	154.0	168.0	126.6	134 8	151.5	134 2	81.0	96.0	84 5	75 5	155	137	84	125
04/08/93	06:00	109.33	144.1	153.9	151.1	162.6	128.4	136.4	136.9	125.1	80 5	96 0	106 0	70 2	153	132	88	124
04/08/93	19:00	122.33	149.1	158.7	155 6	164 1	130 3	138.9	135 2	123.8	78.9	93 4	115 2	70 6	157	132	90	126
04/09/93	04:00	131.33	145.1	155 9	153 4	158.9	129.6	137.7	130 7	121.1	78 0	88 9	113 7	70 6	153	130	88	124
04/09/93	13:45	141.08	150 4	160 9	159 6	163 5	130 8	140 4	134.1	123 6	81.4	92.2	117 2	74 6	159	132	91	127
04/09/93	18:30	145 83	150 5	161.4	160 8	162 2	130.3	139.9	132 6	123 0	84 2	92 8	116 4	75 1	159	131	92	127
04/10/93	03:00	154.33	153.3	163 6	162.2	164.1	132 0	140 6	133 7	124 6	84 5	94 7	117.7	77 4	161	133	94	129
04/10/93	11:40	163 00	153.7	164.0	161.8	163.7	131.2	139.6	132 0	123.9	83 6	94 2	115 9	78.7	161	132	93	129

Table B-2 Temperature in Thermowells (Outside Thermowell TW7 in Table B-1) [Continued]

Date	Time	Elapsed Time	TW5F 34-ft	TW6F 34-ft	TW7F 34-ft
	Maximum Temp. --->		ERR	21.1	ERR
05/11/93	20:10	915.50			
05/12/93	20:00	939.33			
05/13/93	20:17	963.62			
05/14/93	20:20	987.67			
05/15/93	21:00	1012.33			
05/16/93	20:50	1036.17			
05/17/93	20:22	1059.70			
05/18/93	21:30	1084.83			
05/19/93	20:00	1107.33			
05/20/93	22:05	1133.42			
05/21/93	21:10	1156.50			
05/22/93	12:55	1172.25			
05/23/93	21:25	1204.75			
05/24/93	08:00	1215.33			
05/24/93	20:10	1227.50			
05/25/93	19:00	1250.33			
05/26/93	20:25	1275.75			
05/27/93	12:11	1291.52			
05/28/93	03:00	1306.33			
05/28/93	20:20	1323.67			
05/29/93	03:30	1330.83			
05/29/93	15:00	1342.33			
05/29/93	19:50	1347.17			
05/30/93	19:28	1370.80			
05/31/93	19:30	1394.83			
06/01/93	03:40	1403.00			
06/01/93	19:00	1418.33			
06/02/93	19:00	1442.33			
06/03/93	12:30	1459.83			

Table B-3 Temperature in Excitor Electrodes (Continued)

Date	Time	Elapsed Time	B1A	B2A	B3A	B4A	B1B	B2B	B3B	B4B	B1C	B2C	B3C	B4C	Average Temperature			
			1-ft	'1-ft	1-ft	1-ft	10-ft	10-ft	10-ft	10-ft	19-ft	19-ft	19-ft	19-ft	1-foot	10-Foot	20-Foot	Overall
		Time	B1A	B2A	B3A	B4A	B1B	B2B	B3B	B4B	B1C	B2C	B3C	B4C				
Maximum Temp.---->			433.2	1150	464.2	330.1	725.4	1304	1280	1008.1	1170	1330	978.3	1021.1				
05/09/93	23:10	870.50	164.4	385 8	159.1	177.4	176.9	158.1	195.3	177.4	219.2	201.2	246	166.6	222	177	208	202
05/10/93	07:10	878.50	162.9	398.3	157.4	176.9	162.9	160	196.2	177.6	220.5	203.1	248.9	168.6	224	174	210	203
05/11/93	07:15	902.58	162.1	472.6	156.6	175.5	173.1	164.8	198	178.8	221.9	204.5	247.8	171.4	242	179	211	211
05/12/93	07:00	926.33	156.1	512.6	152.9	166.9	163.9	167.5	194.4	175.6	208.1	192.1	227.6	160.8	247	175	197	207
05/13/93	07:08	950.47	161.4	685.7	155.4	170.9	173.1	181.3	200.6	179.6	209.4	237.4	244	171	343	184	215	247
05/14/93	07:00	974.33	158.7	658.6	154.7	169.5	174.7	192 8	200.6	180 2	207.6	262.9	236 3	170.6	335	187	219	247
05/15/93	07:14	998 57	159 8	871.2	156 8	170.9	177.5	206.4	204.6	182.6	212.9	353.1	243 8	176.2	340	193	247	260
05/16/93	07:33	1022.88	161.2	860.6	156.6	170.7	178.2	206.3	212.1	183.8	216.9	775.5	257.6	180.1	337	195	358	297
05/17/93	23:00	1062 33	167.2	859.9	158	169	179.5	194.4	230.4	186.4	227.9	528.1	421.9	192.8	339	198	343	293
05/18/93	23:30	1086.63	158.6	679 6	154.9	160.6	167.9	195.7	256.1	186.1	226.7	445.2	850.9	201.1	288	202	431	307
05/19/93	22:50	1110.17	156	651.8	158.4	155.5	158 7	210.8	325.8	203.6	223.7				280	225	224	249
05/20/93	07:08	1118.47	152.3	614.8	154	151.6	153.8	223.6	376.6	202.2	218.9	1330			268	239	774	358
05/20/93	17:25	1128.75	147.5	494.5	148.6	145.1	147.3	206.8	277.7	195.8	211.6			237	234	207	224	221
05/21/93	23:05	1158.42	157.3	636.5	147	142.5	145 2	323.3	596.8	209.5	215.7		834 5	230.6	271	319	427	331
05/22/93	22:35	1181.92	164.7	680.2	154	147.3	158 6	820	976.3	254	230.6	719.4	978 3	334.2	337	552	566	485
05/23/93	23:05	1206.42	171.5	983.4	163.5	152.2	172.2	984.4	882.4	275.8	244.2	858 2	891.2	399.5	368	579	598	515
05/24/93	22:55	1230.25	183.1	847.8	168 8	148.3	213.1	880.1	572.1	273.8	895.7	847 6	551.2	314.3	337	485	652	491
05/25/93	23:08	1254.47	212.8	912.9	186.7	150 5	329.7	796.3	840.6	284.7	1069.8	847.2	839	346.6	366	563	776	568
05/26/93	22:55	1278.25	236.6	1150.0	208.0	152.0	498.5	1304.0	1119.0	284.7	1170.0	861.9	555.0	295.1	437	802	721	653
05/27/93	07:01	1286.35	227.4	1055.2	208.1	151.5	517.6	1174.0	1238 0	282.5	1028.0	995 0	507.0	275 7	411	803	701	638
05/28/93	07:06	1310.43	244 9	895.2	219 8	156.9	725 4	993.3	1280 0	290.4	997.2	950 0	474 7	330 5	379	822	688	630
05/29/93	07:15	1334 58	433.2	928.0	232.5	165.3	219 5	856.9	1220.0	308.1	885.2	806.7	483 0	578 8	440	651	688	593
05/30/93	07:20	1358.67	298.1		229.3	169.3	166 3			302 8		468.6	439 5	873 6	232	235	594	368
05/31/93	07:10	1382.50	238.1		223.7	178.4	155.0			388 6	603 0	363.1	405 8	637.9	213	272	502	355
06/01/93	05.00	1404 33	251.1	895.7	218.3	181.8	155 0	1120.0		605 6	996.0	328.2	396 9	609.0	387	627	583	523
06/02/93	05:50	1429.17	219 8		241.1	330.1	154 9			1008.1		324 6		1021.1	264	582	673	471
06/03/93	12:07	1459.45	248.0		464.2		121.8		630 0			347.7		194 6	356	376	271	334

Table B-3 Temperature in Excitor Electrodes (Continued)

Date	Time	Elapsed Time	B1A	B2A	B3A	B4A	B1B	B2B	B3B	B4B	B1C	B2C	B3C	B4C	Average Temperature			
		Time	1-ft B1A	1-ft B2A	1-ft B3A	1-ft B4A	10-ft B1B	10-ft B2B	10-ft B3B	10-ft B4B	19-ft B1C	19-ft B2C	19-ft B3C	19-ft B4C	1-foot	10-Foot	20-Foot	Overall
Maximum Temp.---->			433.2	1150	464.2	330.1	725.4	1304	1260	1008.1	1170	1330	978.3	1021.1				
04/10/93	20:33	171.88	155.3	166.3	162.6	165.7	131.6	140.2	131.9	125.4	83.7	94.5	116.7	80.2	162	132	94	130
04/11/93	12:42	188.03	156.4	167.9	164.2	163.2	133.3	139.6	132.6	127.1	83.7	95.4	115.3	84.9	163	133	95	130
04/11/93	22:00	197.33	145.5	156.0	148.3	151.4	125.0	129.0	121.3	117.0	72.6	85.1	100.0	75.1	150	123	83	119
04/12/93	13:15	212.58	152.4	163.7	157.0	162.0	131.5	136.0	127.4	123.2	78.8	91.7	108.1	83.1	159	130	90	126
04/13/93	06:00	229.33	157.8	169.8	163.7	170.1	134.7	139.0	132.8	128.4	86.1	95.7	111.9	90.9	165	134	96	132
04/14/93	05:00	252.33	161.2	172.7	165.8	172.7	134.9	138.3	134.2	130.2	92.3	97.8	112.2	94.8	168	134	99	134
04/15/93	04:00	275.33	165.8	176.4	168.0	176.3	138.3	140.0	136.0	132.9	97.2	103.8	114.5	97.5	172	137	103	137
04/16/93	05:00	300 33	169.4	179.8	172.8	182.4	138.7	141.1	138.5	137.1	106.5	111.2	115.7	100.5	176	139	108	141
04/17/93	06:00	325.33	172.7	181.8	174.8	185.2	140.7	141.6	139.9	139.1	116.9	115.1	117.2	103.2	179	140	113	144
04/18/93	05:16	348 60	169.5	177.5	170.0	179.1	139.1	138.6	137.1	136.3	112.3	111.8	114.2	98.5	174	138	109	140
04/19/93	04:35	371.92	178.5	185.3	178.5	192.4	143.9	141.7	142.0	142.6	127.9	132.6	136 2	123.2	184	143	130	152
04/20/93	05:30	396 83	181.5	188 2	180.7	196.2	146.8	141.3	143.3	144.9	136.5	141.1	144.0	131.5	187	144	138	156
04/21/93	11:35	426.92	182.1	188 5	180.7	194.9	149 8	141.0	143.4	145.9	144.4	143.2	145.9	132.7	187	145	142	158
04/22/93	06:00	445.33	181.6	189.7	181.7	196.6	151.5	142.0	144.2	147.3	149.8	142.2	149.9	136.2	187	146	145	159
04/23/93	06:00	469.33	182.3	189 8	182.2	197.4	152.5	141.4	145.6	148.1	153.6	148.1	152.7	138.8	188	147	148	161
04/24/93	06:00	493.33	182.3	190.3	182.8	196.8	154.4	140.8	144.6	148.6	157.1	146.8	152.9	139.2	188	147	149	161
04/25/93	06:00	517.33	184.2	193.5	184.6	199.5	159.6	141.6	146.5	151.5	168.6	149.6	158.6	146.1	190	150	156	165
04/26/93	06:00	541.33	182.9	192.8	183.7	197.5	161.9	141.6	146.7	152.1	171.6	148.8	157.2	144.3	189	151	155	165
04/27/93	05:05	564.42	187.0	196.4	187.2	201.5	169 0	142.8	149.3	155.7	188 6	154.4	166.1	153.1	193	154	166	171
04/28/93	05:30	588.83	185.6	197.1	187.4	201.2	173.2	142.9	150 6	157.4	198.7	154.7	169.1	155.9	193	156	170	173
04/29/93	08:20	615.67	187.2	199.3	189.1	203.4	179 4	143 9	153.9	160 3	213.4	158.2	176.2	161.5	195	159	177	177
04/30/93	06:10	637.50	189.5	198.4	187.4	199 0	186 2	141.8	158.4	168.3	211.1	146 5	168 9	157.7	194	164	171	176
05/01/93	14:10	669.50	183.1	195 3	182.9	189.4	203.6	138 8	162.0	162.4	194.9	135 2	162 9	142.6	188	167	159	171
05/02/93	21:06	700.43		180.9	155 0	173.7		136.5	162.7	157.7		130.6	156 5	127.6	170	152	138	153
05/03/93	07:55	711.25	164.4	171.2	150.8	172.0	171.2	138.2	164 8	159.8	183 8	130 0	156 9	131.7	165	159	151	158
05/04/93	07:25	734.75	167.7	201.3	155.5	175.3	176.3	141.8	171 5	164.3	194.6	139 5	168 5	140.1	175	163	161	166
05/04/93	23:00	750.33	170.2	213.9	158.6	177.9	180.3	143 6	176 2	166.9	201.5	147.7	178 3	145 2	180	167	168	172
05/05/93	23:00	774.33	178.2	233.4	157.1	179 0	178.0	145.9	180.9	170.3	206.3	153 3	188 3	149.4	187	169	174	177
05/06/93	07:00	782.33	165.7	252.8	155.5	178.1	177.6	146.3	181.5	170.7	206.7	154.5	190 4	149.4	188	169	175	177
05/06/93	15:50	791.17	168.2	283.4	158.9	178.1	177.7	146 6	183 0	170.9	207.8	159.7	195 3	149.6	197	170	178	182
05/06/93	23:05	798.42	168.1	304.7	158.5	179.1	179.7	148 0	184 7	172.1	209.3	171.6	203 0	151.2	203	171	184	186
05/07/93	07:10	806.50	169.4	326.7	157.9	179.6	179.8	149.2	186 5	173 3	211 6	183.3	212 4	153 2	208	172	190	190
05/07/93	15:30	814.83	168.0	339.7	159.0	179.2	178.9	149 9	187.4	173.7	211.7	188 8	217.5	154 5	211	172	193	192
05/07/93	22:53	822.22	166.2	351.9	158.8	179 8	179.0	151.2	189 0	174.5	213.5	193.4	224.5	156.7	214	173	197	195
05/08/93	07:00	830.33	166.2	356.9	157.8	178 9	177.9	152.4	189 2	174 8	213.9	194 5	227.4	158.7	215	174	199	196
05/08/93	15:25	838.75	162.4	332.8	156.7	174.6	173	152.4	186.5	172.6	206 8	185.5	218 1	154	207	171	191	190
05/08/93	23:00	846 33	163.5	355.1	157.3	176.8	175.7	153.9	190.5	174.5	212.7	193 9	236 7	159.4	213	174	201	196
05/09/93	07:06	854.43	163.9	368	157.7	177.3	176.5	155.7	192.7	175 6	215 6	197.5	237 1	162.5	217	175	203	198
05/09/93		862.58	163.6	375.9	158.8	176.5	176	156 3		175.7	217.1	198 6	240 7	164	219	175	205	200

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
	Maximum Temp.--		78.5	84.2	42.3	86.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
04/08/93	20.00	123.3	35.3	20.5	22.2	41.1	21.6	22.3	21.9	53.7	22.0	22.3	21.8	19.5	21.5	21.7	21.8	19.4	21.7	33.0	20.2	21.7	21.8	42.8	22.4	21.7	21.7	49.6	23.2	21.8	21.7	23.2
04/09/93	00.00	127.3	35.9	20.5	22.3	42.0	21.9	22.5	22.0	54.9	22.5	22.6	22.0	19.6	21.7	21.8	21.8	19.4	21.7	33.6	20.3	21.8	21.9	43.9	22.8	21.9	21.9	50.7	23.8	21.9	21.8	23.6
04/09/93	04:00	131.3	36.0	20.5	22.1	42.3	22.0	22.3	21.9	55.1	22.7	22.5	21.9	19.4	21.6	21.6	21.7	19.4	21.6	33.6	20.3	21.7	21.8	44.0	22.9	21.7	21.7	50.5	24.0	21.9	21.6	23.7
04/09/93	08.00	135.3	36.2	20.6	22.2	43.0	22.3	22.5	21.9	55.8	23.3	22.7	21.9	19.5	21.8	21.8	21.8	19.4	21.6	33.9	20.4	21.9	21.8	44.9	23.2	22.0	21.9	51.4	24.4	22.2	21.8	24.0
04/09/93	12.00	139.3	36.4	20.6	21.9	43.0	22.4	22.4	21.7	56.1	23.7	22.6	21.7	19.2	21.8	21.8	21.6	19.3	21.4	33.7	20.1	21.9	21.8	45.2	23.3	22.1	21.9	51.8	24.7	22.1	21.7	24.4
04/09/93	16.00	143.3	36.8	20.6	21.8	43.6	22.5	22.3	21.7	56.9	23.8	22.4	21.7	19.2	21.5	21.5	21.5	19.1	21.2	34.4	20.3	21.6	21.6	45.9	23.6	21.8	21.6	52.5	25.3	21.9	21.4	24.4
04/09/93	20.00	147.3	37.4	21.0	22.3	44.8	22.6	22.3	21.8	57.8	24.0	22.4	21.8	19.5	21.3	21.5	21.7	19.5	21.7	35.7	20.9	21.6	21.6	47.1	24.4	21.5	21.5	53.8	26.1	21.7	21.5	24.9
04/10/93	00.00	151.3	38.2	21.3	22.4	45.7	23.1	22.6	22.0	58.8	24.7	22.6	21.9	19.7	21.5	21.6	21.8	19.7	21.9	36.4	21.2	21.9	21.9	48.1	24.9	21.9	21.7	54.6	27.1	22.0	21.7	25.4
04/10/93	04.00	155.3	38.2	21.3	22.3	46.1	23.3	22.6	21.9	59.2	25.2	22.7	21.9	19.6	21.6	21.6	21.8	19.7	21.6	36.5	21.3	21.9	21.8	48.6	25.3	22.0	21.8	55.0	27.8	22.2	21.7	25.7
04/10/93	08:00	159.3	38.3	21.4	22.2	46.5	23.5	22.6	21.8	59.6	25.8	22.7	21.8	19.6	21.6	21.6	21.5	19.6	21.5	36.5	21.3	21.9	21.8	49.2	25.6	22.1	21.7	55.5	28.3	22.2	21.5	25.9
04/10/93	12:00	163.3	38.6	21.5	22.0	46.6	24.1	22.8	21.9	59.4	26.6	23.1	21.9	19.4	22.0	21.8	21.7	19.8	21.6	36.4	21.2	22.2	21.9	49.4	25.8	22.5	21.9	55.2	28.7	22.5	21.8	26.1
04/10/93	16.00	167.3	38.8	21.5	22.0	47.1	24.0	22.5	21.7	60.2	26.7	22.8	21.7	19.5	21.5	21.5	21.4	19.5	21.3	37.1	21.3	21.7	21.5	50.2	26.1	21.9	21.6	56.1	29.6	22.2	21.4	26.6
04/10/93	20:00	171.3	39.6	22.0	22.5	48.4	24.4	22.6	21.9	61.1	27.2	22.7	21.8	19.0	21.4	21.5	21.8	19.9	21.7	38.5	22.2	21.8	21.8	51.5	27.1	22.0	21.6	57.6	30.9	22.0	21.6	27.5
04/11/93	00.00	175.3	40.0	22.1	22.4	49.0	24.8	22.7	21.8	62.0	27.9	22.8	21.9	20.0	21.5	21.6	21.7	20.1	21.7	38.9	22.3	22.0	21.7	52.3	27.5	22.1	21.7	58.2	31.7	22.2	21.6	27.9
04/11/93	04.00	179.3	40.3	22.3	22.5	49.6	25.1	22.7	21.9	62.4	28.5	22.9	21.9	20.0	21.6	21.6	21.8	20.0	21.7	39.1	22.5	22.0	21.8	52.9	28.0	22.2	21.8	58.6	32.6	22.4	21.6	28.4
04/11/93	08.00	183.3	40.4	22.3	22.2	49.8	25.5	22.8	21.7	62.6	29.2	23.0	21.7	19.8	21.7	21.6	21.6	20.0	21.5	39.1	22.4	22.0	21.7	53.3	28.3	22.3	21.7	58.9	33.1	22.4	21.6	28.7
04/11/93	12.00	187.3	40.7	22.7	22.2	50.1	26.0	22.9	21.8	62.9	30.0	23.2	21.8	19.8	22.0	21.9	21.7	20.2	21.5	39.3	22.5	22.3	21.9	53.8	28.5	22.6	22.0	59.4	33.6	22.8	21.8	29.2
04/11/93	16.00	191.3	40.6	22.6	22.3	49.6	26.1	22.7	21.8	61.5	30.5	23.0	21.9	19.0	21.6	21.6	21.6	20.0	21.4	39.4	22.7	22.0	21.6	52.8	29.2	22.3	21.7	56.9	34.4	22.5	21.6	29.0
04/11/93	20.00	195.3	41.4	23.3	22.8	50.9	26.6	22.8	22.0	62.6	30.8	22.9	21.9	20.2	21.5	21.6	21.8	20.5	22.0	40.9	23.6	22.2	21.8	54.5	30.1	22.2	21.7	59.4	35.5	22.5	21.6	30.0
04/12/93	00.00	199.3	41.6	23.3	22.7	51.0	27.1	23.0	22.0	62.7	31.9	23.3	22.0	20.6	21.9	21.9	21.9	20.7	21.9	40.9	23.6	22.4	21.0	54.7	30.6	22.6	21.9	59.6	36.1	22.8	21.9	30.5
04/12/93	04.00	203.3	41.8	23.5	22.6	51.6	27.3	22.9	21.9	63.2	32.4	23.2	21.9	20.5	21.7	21.7	21.7	20.7	21.8	41.1	23.9	22.2	21.8	55.4	31.2	22.5	21.8	60.2	36.8	22.9	21.7	31.0
04/12/93	08.00	207.3	41.9	23.7	22.5	51.9	27.8	23.0	21.8	63.8	33.2	23.2	21.8	20.6	21.8	21.6	21.6	20.7	21.7	41.1	24.0	22.2	21.7	55.9	31.6	22.5	21.7	60.5	37.3	22.9	21.7	31.4
04/12/93	12.00	211.3	42.0	24.0	22.7	52.1	28.2	23.1	21.9	63.9	33.9	23.5	22.1	20.6	22.0	21.8	21.8	20.9	21.8	41.1	24.2	22.5	21.9	56.0	32.1	22.8	21.9	60.2	37.8	23.0	21.9	31.7
04/12/93	16.00	215.3	42.3	24.0	22.4	52.5	28.5	22.9	21.8	64.7	34.3	23.2	21.8	20.4	21.8	21.5	21.5	20.7	21.5	41.4	24.3	22.1	21.6	56.7	32.6	22.5	21.6	61.2	38.5	22.9	21.5	33.0
04/12/93	20:00	219.3	42.9	24.7	23.0	53.5	28.9	23.2	22.1	65.6	35.0	23.4	22.1	21.0	21.8	21.6	22.0	21.2	22.1	42.4	25.2	22.4	21.9	57.5	33.5	22.7	21.9	61.6	39.5	23.0	21.8	33.0
04/13/93	00.00	223.3	43.2	24.8	22.9	54.0	29.5	23.2	22.0	66.4	36.0	23.5	22.1	21.1	22.0	21.8	22.0	21.3	22.0	42.6	25.3	22.5	22.0	58.1	34.0	22.9	22.0	62.4	40.3	23.2	21.9	33.5
04/13/93	04.00	227.3	43.4	24.9	22.8	54.4	29.9	23.1	22.0	67.0	36.7	23.4	22.1	21.2	22.1	21.9	21.9	21.4	21.9	42.7	25.4	22.5	21.9	58.5	34.6	22.9	21.9	62.8	41.0	23.2	21.8	33.8
04/13/93	08.00	231.3	43.5	25.1	22.8	54.8	30.4	23.2	22.0	67.4	37.5	23.5	22.1	21.3	22.1	21.8	21.9	21.5	22.0	42.9	25.7	22.5	21.9	58.9	35.1	23.0	22.0	62.9	41.7	23.2	21.9	34.3
04/13/93	12.00	235.3	43.6	25.3	22.5	54.8	30.6	23.2	21.8	67.6	38.1	23.5	21.8	21.0	21.9	21.6	21.6	21.3	21.6	42.8	25.7	22.4	21.7	59.2	35.4	23.0	21.7	63.1	42.1	23.3	21.6	34.4
04/13/93	16.00	239.3	44.1	25.8	22.9	55.6	31.1	23.3	22.0	68.2	38.8	23.7	22.0	21.5	22.0	21.8	21.9	21.7	22.0	43.5	26.4	22.5	21.9	59.9	36.3	23.1	21.9	63.5	43.1	23.3	21.8	35.1
04/13/93	20.00	243.3	44.6	26.0	23.0	56.2	31.8	23.5	22.1	68.7	39.7	23.9	22.1	21.8	22.0	21.8	22.0	21.9	22.1	44.0	26.7	22.7	22.0	60.5	37.0	23.1	22.0	64.0	44.1	23.5	21.9	35.7
04/14/93	00.00	247.3	44.7	26.2	23.0	56.5	32.3	23.4	22.1	69.0	40.5	23.8	22.2	21.9	22.2	21.7	22.0	22.1	22.0	44.1	26.9	22.7	21.9	60.8	37.6	23.2	22.0	64.1	44.7	23.5	21.9	36.1

Table B-4 Ground Electrode and Outside Thermowell Temperatures
(Recorded by Data Logger)

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
	Maximum Temp.--		79.5	84.2	42.3	86.3	95.5	45.4	32.0	112.2	96.6	46.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	46.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
04/03/93	16:00	-0.7	17.9	19.6	21.8	18.3	19.9	21.9	21.9	18.1	19.6	21.9	22.0	19.3	21.7	21.9	21.9	19.1	21.5	18.3	19.1	21.6	21.9	18.4	19.8	21.7	21.9	18.6	19.8	21.8	21.9	21.0
04/03/93	20:00	3.3	18.5	19.7	22.0	19.0	20.0	22.0	22.0	19.0	19.6	22.0	21.9	19.4	21.7	21.9	22.1	19.3	21.7	18.8	19.2	21.7	21.9	19.1	19.9	21.7	21.9	19.6	20.0	21.8	21.9	21.1
04/04/93	00.00	7.3	18.6	19.7	22.0	19.0	20.0	22.0	22.0	19.1	19.6	22.0	22.0	19.4	21.8	22.0	22.0	19.2	21.7	18.9	19.2	21.6	21.9	19.2	19.9	21.8	21.9	19.6	20.0	21.8	21.9	21.1
04/04/93	04:00	11.3	18.6	19.7	22.0	19.2	20.1	22.1	22.1	19.6	19.6	22.1	22.0	19.5	21.7	22.0	22.1	19.3	21.8	18.8	19.2	21.7	22.0	19.5	20.0	21.8	21.9	20.1	20.1	21.9	22.0	21.3
04/04/93	08.00	15.3	18.8	19.7	22.0	19.4	20.1	22.1	22.1	19.9	19.7	22.1	22.0	19.4	21.8	22.0	21.9	19.3	21.8	18.8	19.2	21.9	22.0	19.7	20.0	21.9	22.0	20.3	20.0	21.9	21.9	21.0
04/04/93	12:00	19.3	19.0	19.4	21.5	19.7	19.9	21.7	21.6	20.5	19.5	21.9	21.7	19.2	21.5	21.6	21.6	19.1	21.3	18.7	18.7	21.5	21.6	20.1	19.6	21.6	21.7	21.1	19.7	21.6	21.6	20.6
04/04/93	16:00	23.3	19.8	19.4	21.8	21.1	19.8	21.9	21.9	22.8	19.5	21.9	21.9	19.1	21.6	21.7	21.7	18.9	21.5	19.5	18.9	21.5	21.7	21.7	19.6	21.5	21.7	23.7	19.7	21.7	21.7	21.0
04/04/93	20.00	27.3	20.6	19.6	22.0	22.4	19.8	21.9	22.0	24.8	19.4	22.0	21.9	19.3	21.6	21.7	21.9	19.1	21.7	20.5	19.2	21.6	21.9	23.2	19.9	21.6	21.8	25.9	20.0	21.6	21.7	21.1
04/05/93	00.00	31.3	21.1	19.6	22.1	23.0	19.9	22.0	22.0	26.0	19.5	22.0	22.0	19.4	21.6	21.8	21.9	19.2	21.7	20.7	19.2	21.7	21.9	23.9	19.9	21.7	21.8	27.1	20.0	21.8	21.8	21.3
04/05/93	04.00	35.3	21.4	19.5	21.9	23.4	19.8	22.0	21.9	27.1	19.4	22.0	21.9	19.3	21.6	21.8	21.9	19.1	21.5	20.8	19.1	21.6	21.9	24.4	19.9	21.6	21.8	28.0	19.9	21.8	21.7	21.0
04/05/93	08.00	39.3	21.9	19.4	21.8	23.8	19.8	21.9	21.9	28.1	19.3	22.0	21.8	19.2	21.5	21.7	21.7	18.9	21.5	20.9	19.1	21.6	21.8	24.9	19.8	21.6	21.8	28.8	19.8	21.6	21.6	20.9
04/05/93	12:00	43.3	22.1	19.2	21.1	23.8	19.6	21.6	21.5	29.0	19.4	21.8	21.5	18.8	21.4	21.4	21.2	18.7	20.9	20.5	18.5	21.4	21.4	25.3	19.2	21.5	21.6	29.9	19.2	21.5	21.3	20.3
04/05/93	16.00	47.3	23.1	19.1	21.4	25.0	19.5	21.6	21.6	30.9	19.2	21.7	21.6	18.7	21.3	21.4	21.3	18.5	21.0	21.6	18.5	21.2	21.5	26.5	19.3	21.3	21.5	31.6	19.4	21.3	21.3	20.5
04/05/93	20.00	51.3	24.2	19.6	21.8	26.3	19.9	21.8	21.8	32.8	19.4	21.8	21.7	19.3	21.3	21.5	21.6	19.1	21.5	22.9	19.4	21.4	21.6	27.9	20.0	21.4	21.6	33.1	20.1	21.4	21.5	20.9
04/06/93	00:00	55.3	24.9	19.6	22.0	27.2	19.9	22.0	21.9	34.3	19.5	22.1	21.9	19.3	21.5	21.7	21.9	19.0	21.6	23.5	19.3	21.6	21.8	28.9	19.9	21.6	21.8	34.1	20.0	21.7	21.7	21.0
04/06/93	04.00	59.3	25.6	19.5	21.8	27.8	19.9	22.0	21.8	35.7	19.5	22.0	21.8	19.2	21.6	21.7	21.6	19.0	21.5	23.8	19.2	21.5	21.8	29.9	19.9	21.6	21.7	35.1	20.0	21.7	21.6	21.0
04/06/93	08.00	63.3	26.1	19.5	21.9	28.5	19.9	22.1	21.8	36.8	19.7	22.1	21.9	19.2	21.7	21.6	21.7	19.0	21.5	24.2	19.1	21.6	21.8	30.4	19.9	21.7	21.8	35.1	20.0	21.8	21.7	21.0
04/06/93	12:00	67.3	26.7	19.6	21.8	29.1	20.1	22.0	21.9	38.1	19.8	22.1	21.9	19.2	21.7	21.7	21.7	19.0	21.4	24.5	19.1	21.7	21.9	31.1	19.9	21.8	21.9	36.0	20.1	21.8	21.7	21.0
04/06/93	16.00	71.3	27.6	19.7	22.0	30.2	20.2	22.2	22.0	39.9	19.9	22.2	22.0	19.3	21.7	21.9	21.9	19.2	21.7	25.5	19.4	21.7	21.9	32.3	20.2	21.8	21.9	37.2	20.4	21.8	21.8	21.3
04/06/93	20.00	75.3	28.4	19.9	21.9	31.2	20.2	22.2	22.0	41.4	20.0	22.2	21.9	19.4	21.8	21.8	21.9	19.2	21.8	26.3	19.5	21.8	21.9	33.1	20.4	21.8	21.9	38.0	20.6	21.8	21.8	21.6
04/07/93	00.00	79.3	29.1	19.8	21.9	32.0	20.2	22.2	21.9	42.7	20.2	22.2	21.8	19.4	21.5	21.6	21.8	19.3	21.5	26.8	19.5	21.5	21.8	34.0	20.5	21.6	21.7	38.8	20.6	21.7	21.7	21.5
04/07/93	04:00	83.3	29.8	19.8	21.8	32.8	20.4	22.1	21.8	44.0	20.3	22.2	21.8	19.4	21.6	21.7	21.7	19.2	21.5	27.3	19.4	21.6	21.7	34.6	20.5	21.7	21.8	39.4	20.7	21.8	21.7	21.7
04/07/93	08.00	87.3	30.4	19.8	21.9	33.6	20.4	22.1	21.9	45.1	20.4	22.1	21.9	19.4	21.6	21.7	21.8	19.2	21.5	27.8	19.3	21.7	21.8	35.4	20.6	21.7	21.8	40.2	20.9	21.8	21.7	21.8
04/07/93	12.00	91.3	31.1	19.8	22.0	34.5	20.5	22.3	21.9	46.2	20.5	22.3	21.9	19.4	21.6	21.7	21.8	19.1	21.6	28.5	19.4	21.6	21.8	36.1	20.9	21.7	21.8	41.1	21.0	21.7	21.8	21.9
04/07/93	16.00	95.3	31.1	19.4	21.4	34.4	20.4	22.0	21.6	46.8	20.5	22.1	21.7	18.9	21.6	21.4	21.3	18.7	21.0	28.1	18.6	21.3	21.5	36.1	20.4	21.6	21.6	41.3	20.6	21.7	21.4	21.5
04/07/93	20.00	99.3	32.2	19.9	22.0	36.0	20.7	22.2	21.8	48.6	20.7	22.1	21.8	19.4	21.5	21.6	21.8	19.2	21.6	29.5	19.5	21.5	21.7	37.6	21.2	21.6	21.7	43.2	21.6	21.7	21.6	22.1
04/08/93	00.00	103.3	32.6	19.8	21.9	36.8	20.8	22.1	21.8	49.6	20.8	22.2	21.7	19.3	21.5	21.6	21.7	19.0	21.5	30.0	19.4	21.5	21.7	38.4	21.2	21.6	21.7	44.5	21.6	21.7	21.6	22.2
04/08/93	04.00	107.3	33.1	20.0	21.9	37.4	21.0	22.3	21.8	50.1	21.2	22.4	21.8	19.3	21.7	21.7	21.7	19.2	21.5	30.3	19.4	21.7	21.8	38.9	21.4	21.9	21.8	44.8	21.8	21.9	21.7	22.3
04/08/93	08.00	111.3	33.7	20.0	22.0	38.4	21.1	22.3	21.8	51.1	21.4	22.4	21.9	19.4	21.6	21.8	21.8	19.2	21.6	30.9	19.7	21.6	21.8	40.1	21.6	21.8	21.8	46.4	22.1	21.8	21.8	22.6
04/08/93	12.00	115.3	33.8	19.9	21.7	38.7	21.1	22.0	21.6	51.4	21.5	22.1	21.6	19.1	21.6	21.7	21.5	19.0	21.2	30.8	19.4	21.6	21.6	40.6	21.5	21.7	21.7	46.9	22.0	21.8	21.5	22.3
04/08/93	16.00		34.4	19.9	21.8	39.7	21.2	22.1	21.7	52.1	21.8	22.3	21.7	19.2	21.6		21.5	19.0	21.3	31.6	19.5	21.5	21.6	41.3	21.8	21.6	21.6	47.3	22.5		21.6	22.8

Table B-4 Ground Electrode and Outside Thermowell Temperatures
(Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
	Maximum Temp.--		79.5	84.2	42.3	86.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
04/19/93	12.00	379.3	48.4	37.8	23.4	61.6	51.0	24.5	22.1	70.7	65.9	25.6	22.2	28.6	23.0	21.7	21.9	28.1	22.5	48.4	39.3	24.1	22.1	65.5	60.4	25.1	22.2	66.5	73.8	25.9	21.9	51.1
04/19/93	16.00	383.3	48.6	38.3	23.5	62.0	51.4	24.5	22.1	70.7	66.3	25.4	22.3	28.9	22.8	21.5	21.8	28.2	22.5	48.8	39.9	23.9	21.9	65.4	61.1	24.8	22.0	66.7	74.8	25.7	21.8	51.8
04/19/93	20.00	387.3	49.2	39.1	24.1	62.9	52.1	24.6	22.3	71.5	66.8	25.3	22.4	29.5	22.7	21.5	22.2	28.9	23.1	50.0	41.2	23.9	22.1	66.2	62.4	24.8	22.0	67.4	76.1	25.7	22.0	52.4
04/20/93	00.00	391.3	49.4	39.5	23.9	63.3	52.9	24.8	22.4	72.2	67.9	25.7	22.6	29.8	23.0	22.0	22.3	29.0	23.0	49.8	41.5	24.2	22.2	66.6	63.0	25.3	22.3	67.8	77.1	26.1	22.3	51.3
04/20/93	04:00	395.3	49.5	39.9	23.9	63.5	53.5	24.8	22.2	71.9	68.6	25.7	22.5	30.1	23.1	21.8	22.2	29.2	23.0	50.0	41.8	24.1	22.2	66.6	63.6	25.2	22.2	67.4	77.8	26.1	22.2	52.7
04/20/93	08:00	399.3	49.7	40.4	24.0	63.7	54.1	24.9	22.3	72.4	69.3	25.8	22.5	30.5	23.1	21.9	22.1	29.5	23.0	50.6	42.4	24.3	22.2	66.8	64.3	25.4	22.3	67.4	78.7	26.4	22.1	53.1
04/20/93	12:00	403.3	50.0	40.9	24.1	63.9	54.9	25.1	22.5	72.6	70.2	26.1	22.6	30.8	23.5	22.1	22.3	29.9	23.1	50.6	42.9	24.5	22.3	67.1	65.1	25.8	22.5	68.0	79.4	26.7	22.3	54.5
04/20/93	16.00	407.3	49.6	40.9	23.9	63.4	55.2	24.9	22.3	72.4	70.5	25.9	22.5	30.8	23.3	21.8	22.1	29.7	22.8	50.1	42.9	24.2	22.0	66.1	65.3	25.5	22.2	66.4	79.9	26.5	22.1	54.3
04/20/93	20.00	411.3	50.3	41.7	24.3	64.2	55.7	24.9	22.4	72.7	71.0	25.8	22.7	31.3	23.2	21.9	22.4	30.3	23.3	50.8	43.9	24.3	22.4	67.0	66.5	25.4	22.4	67.2	80.7	26.5	22.4	54.2
04/21/93	00:00	415.3	50.2	42.3	24.4	64.1	56.5	25.2	22.5	72.7	71.6	26.1	22.7	31.8	23.3	21.9	22.5	30.8	23.4	51.0	44.5	24.5	22.3	66.3	67.4	25.8	22.4	66.4	80.9	26.8	22.4	52.6
04/21/93	04.00	419.3	50.3	42.8	24.4	64.2	57.2	25.2	22.5	73.2	72.2	26.2	22.8	32.2	23.5	22.0	22.4	31.0	23.4	51.7	45.0	24.6	22.4	66.7	68.0	25.9	22.5	66.8	80.6	26.9	22.5	54.5
04/21/93	08.00	423.3	50.2	43.1	24.3	64.1	57.7	25.4	22.5	73.3	72.9	26.4	22.8	32.4	23.5	21.9	22.3	31.3	23.4	51.7	45.3	24.8	22.5	66.6	68.5	26.2	22.6	66.4	81.4	27.1	22.5	54.4
04/21/93	12.00	427.3	49.8	43.0	23.8	63.3	57.9	25.0	22.3	72.5	73.2	26.1	22.5	32.4	23.4	21.9	22.2	31.1	23.0	51.3	45.2	24.5	22.2	65.6	68.6	26.0	22.4	70.0	80.4	27.0	22.3	54.3
04/21/93	16.00	431.3	49.6	43.2	24.0	62.2	58.2	25.2	22.3	71.1	73.0	26.2	22.6	32.6	23.5	21.8	22.2	31.2	23.0	50.5	45.7	24.5	22.1	64.5	69.0	25.9	22.3	64.3	81.0	27.1	22.1	52.0
04/21/93	20:00	435.3	50.2	44.1	24.3	63.0	58.8	25.1	22.5	72.3	73.5	26.1	22.6	33.2	23.2	21.8	22.4	31.7	23.3	51.2	46.7	24.5	22.3	66.3	69.9	25.9	22.4	66.2	81.4	27.1	22.3	55.7
04/22/93	00.00	439.3	50.5	44.7	24.6	63.2	59.6	25.5	22.5	72.8	74.2	26.4	22.8	33.8	23.5	21.9	22.5	32.3	23.5	52.0	47.2	24.9	22.3	66.6	70.5	26.3	22.4	66.5	82.3	27.5	22.4	56.5
04/22/93	04.00	443.3	50.5	45.1	24.5	63.2	60.0	25.5	22.5	73.2	74.9	26.5	22.7	34.0	23.5	21.8	22.4	32.4	23.5	52.8	47.6	24.9	22.3	66.7	70.9	26.4	22.4	67.0	82.2	27.6	22.4	55.8
04/22/93	08.00	447.3	50.8	45.7	24.6	63.3	60.8	25.7	22.6	73.6	75.8	26.8	22.8	34.3	23.8	21.9	22.3	33.0	23.6	53.3	47.9	25.2	22.6	67.3	71.6	26.7	22.7	67.8	82.8	27.9	22.4	55.8
04/22/93	12.00	451.3	50.5	45.5	24.3	62.9	61.0	25.6	22.4	73.0	76.0	26.7	22.6	34.1	23.9	22.0	22.2	32.7	23.3	52.8	47.6	25.1	22.3	67.1	71.8	26.7	22.6	67.2	84.2	27.8	22.4	57.5
04/22/93	16.00	455.3	50.2	45.7	24.3	61.9	61.3	25.4	22.3	72.5	76.0	26.5	22.6	34.4	23.5	21.6	22.2	32.9	23.1	51.6	47.9	24.8	22.1	66.6	72.3	26.4	22.3	65.5	83.8	27.9	22.1	51.9
04/22/93	20.00	459.3	50.5	46.4	24.6	62.5	61.7	25.5	22.4	73.4	75.5	26.4	22.7	35.0	23.5	21.6	22.4	33.2	23.6	52.4	48.7	25.0	22.2	67.2	73.1	26.4	22.3	67.1	84.0	27.7	22.2	56.9
04/23/93	00.00	463.3	51.0	47.1	24.7	63.1	62.6	25.7	22.5	73.7	76.6	26.8	22.8	35.6	23.8	21.8	22.5	33.8	23.8	53.9	49.3	25.3	22.3	68.0	73.7	26.9	22.5	67.5	84.7	28.3	22.5	57.6
04/23/93	04.00	467.3	51.3	47.4	24.8	63.5	63.1	25.8	22.5	74.0	77.2	26.9	22.8	35.9	23.9	21.8	22.5	34.2	23.8	54.1	49.7	25.4	22.4	69.5	74.0	26.9	22.6	68.1	85.8	28.7	22.5	57.6
04/23/93	08.00	471.3	51.4	48.0	24.8	63.6	63.7	25.9	22.7	74.6	78.0	27.2	23.0	36.2	24.2	22.0	22.4	34.5	23.9	55.0	50.1	25.8	22.6	70.7	74.7	27.3	22.8	68.9	86.2	28.7	22.6	58.9
04/23/93	12.00	475.3	51.3	47.6	24.3	63.3	63.8	25.7	22.3	74.4	78.3	27.1	22.6	36.0	24.0	21.8	22.1	34.2	23.5	54.2	49.7	25.6	22.3	69.0	74.4	27.2	22.5	68.6	86.3	28.7	22.3	58.9
04/23/93	16.00	479.3	51.4	48.2	24.5	63.6	64.2	25.7	22.4	74.5	78.5	27.0	22.7	36.5	23.9	21.7	22.2	34.6	23.5	54.1	50.4	25.6	22.2	69.0	75.0	27.1	22.4	68.9	86.7	28.6	22.3	59.9
04/23/93	20.00	483.3	51.9	49.0	25.1	64.6	65.0	25.9	22.6	75.2	79.1	27.0	22.9	37.0	23.8	21.8	22.4	35.0	24.0	55.4	51.4	25.9	22.5	70.0	75.9	27.1	22.5	69.7	87.9	28.5	22.5	60.8
04/24/93	00.00	487.3	52.2	49.6	25.1	64.7	65.7	26.1	22.7	75.7	79.6	27.3	23.0	37.6	24.2	22.0	22.6	35.6	24.1	56.2	51.9	26.0	22.6	70.5	76.5	27.6	22.7	70.4	88.1	29.2	22.7	59.7
04/24/93	04.00	491.3	53.5	49.9	25.0	64.8	66.1	26.2	22.6	75.7	80.1	27.5	23.0	37.9	24.4	22.1	22.7	35.8	24.1	56.1	52.1	26.1	22.5	71.0	76.8	27.8	22.7	70.6	88.4	29.4	22.7	61.3
04/24/93	08.00	495.3	52.7	50.3	25.0	65.0	66.5	26.2	22.6	76.1	80.4	27.4	22.9	38.1	24.3	22.0	22.5	36.0	24.0	56.6	52.6	26.1	22.4	71.2	77.1	27.8	22.7	71.2	89.2	29.5	22.6	61.9
04/24/93	12.00	499.3	52.7	50.6	25.1	65.1	66.9	26.2	22.7	76.6	81.0	27.4	23.1	38.2	24.5	22.0	22.6	36.2	24.1	56.5	52.8	26.2	22.5	71.3	77.4	27.9	22.9	71.4	89.8	29.6	22.7	61.6
04/24/93	16.00	503.3	52.7	50.9	24.9	64.8	67.4	26.1	22.5	76.4	81.2	27.5	22.9	38.2	24.3	21.7	22.4	36.3	23.8	55.5	53.1	25.9	22.2	70.8	77.3	27.8	22.5	72.5	90.2	29.5	22.4	64.6

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
	Maximum Temp.--		79.5	84.2	42.3	66.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
04/14/93	04:00	251.3	44.9	26.5	23.0	57.0	32.8	23.4	22.0	68.7	41.4	23.8	22.2	22.0	22.2	21.7	22.0	22.2	22.1	44.4	27.1	22.8	22.0	61.1	38.2	23.2	22.0	64.4	45.6	23.6	22.0	36.7
04/14/93	08.00	255.3	45.1	26.9	23.0	57.3	33.3	23.5	22.1	68.3	42.1	23.8	22.2	22.2	22.2	21.8	22.0	22.3	22.1	44.6	27.5	22.7	22.0	61.4	38.9	23.2	22.0	64.4	46.5	23.6	21.9	37.1
04/14/93	12:00	259.3	45.1	27.0	22.7	57.3	33.5	23.3	21.8	68.0	42.7	23.9	21.8	22.0	22.1	21.6	21.7	22.2	21.8	44.4	27.6	22.8	21.8	61.4	39.1	23.3	21.8	64.4	46.9	23.6	21.7	37.1
04/14/93	16:00	263.3	45.6	27.4	23.0	57.9	33.9	23.4	21.9	68.5	43.6	23.9	21.9	22.2	22.0	21.6	21.6	22.4	21.9	45.2	28.1	22.7	21.7	62.0	39.9	23.1	21.7	65.0	47.8	23.6	21.6	37.6
04/14/93	20:00	267.3	46.1	28.0	23.4	58.8	34.9	23.6	22.1	68.9	44.5	23.9	22.0	22.6	22.0	21.6	21.9	22.8	22.4	46.1	28.9	22.8	21.9	62.8	41.0	23.2	21.8	65.6	48.9	23.7	21.8	38.5
04/15/93	00.00	271.3	46.1	28.3	23.3	58.9	35.5	23.6	22.1	69.6	45.5	24.1	22.2	22.9	22.2	21.8	22.0	22.9	22.2	46.0	29.2	22.9	22.0	62.9	41.7	23.4	22.0	65.6	49.7	24.0	21.9	39.2
04/15/93	04.00	275.3	46.1	28.5	23.2	59.1	36.0	23.6	22.1	69.7	46.4	24.2	22.1	23.0	22.2	21.7	21.9	23.1	22.3	45.9	29.5	22.9	22.0	62.8	42.3	23.5	22.0	65.4	50.3	24.2	21.9	39.6
04/15/93	08:00	279.3	46.0	28.8	23.1	58.9	36.5	23.7	22.0	69.5	47.2	24.2	22.1	23.1	22.2	21.7	21.7	23.2	22.1	45.7	29.8	23.0	22.0	62.8	42.9	23.5	22.0	65.5	50.9	24.1	21.7	40.0
04/15/93	12.00	283.3	45.8	28.7	22.7	58.4	36.9	23.5	21.7	69.0	48.0	24.1	21.8	22.8	22.2	21.5	21.5	23.0	21.8	45.3	29.6	22.8	21.6	62.4	43.1	23.5	21.8	65.1	51.4	24.0	21.6	40.0
04/15/93	16.00	287.3	45.8	28.9	22.8	58.5	37.1	23.4	21.8	69.2	48.5	24.0	21.8	23.1	22.1	21.4	21.5	23.1	21.7	45.6	29.9	22.6	21.6	62.7	43.6	23.3	21.6	65.2	52.2	23.9	21.4	40.3
04/15/93	20:00	291.3	46.5	29.7	23.2	59.3	38.0	23.7	22.0	69.7	49.5	24.0	22.2	23.6	22.1	21.7	22.0	23.6	22.3	46.8	31.2	22.9	21.9	63.4	44.9	23.4	21.8	66.0	53.6	24.0	21.8	41.3
04/16/93	00:00	295.3	46.6	30.3	23.5	59.6	38.8	23.9	22.2	69.8	50.6	24.4	22.2	24.0	22.2	21.7	22.0	24.0	22.4	46.8	31.9	23.0	22.0	63.6	45.9	23.7	21.9	66.2	54.7	24.3	21.9	41.9
04/16/93	04.00	299.3	46.6	30.5	23.3	59.6	39.4	23.9	22.1	69.5	51.4	24.4	22.2	24.1	22.2	21.7	22.0	24.0	22.2	46.6	32.3	23.1	22.0	63.6	46.4	23.7	22.0	66.0	55.5	24.4	21.8	42.3
04/16/93	08.00	303.3	46.4	30.8	23.2	59.4	40.1	23.9	22.0	69.2	52.4	24.6	22.2	24.3	22.4	21.8	21.9	24.2	22.2	46.3	32.6	23.1	22.0	63.5	47.0	23.9	22.0	65.9	56.2	24.5	21.9	42.6
04/16/93	12:00	307.3	46.4	31.0	23.1	59.1	40.6	23.9	22.1	68.9	53.3	24.5	22.2	24.2	22.6	21.8	21.9	24.2	22.2	46.1	32.7	23.2	22.0	63.5	47.5	24.0	22.1	65.9	56.7	24.5	22.0	42.8
04/16/93	16:00	311.3	46.4	31.2	23.2	59.3	40.9	23.8	21.9	68.9	53.7	24.4	22.1	24.5	22.2	21.5	21.7	24.4	22.0	46.4	33.1	22.9	21.8	63.6	48.2	23.7	21.8	65.9	57.5	24.4	21.6	43.2
04/16/93	20:00	315.3	47.0	32.0	23.5	60.0	41.8	24.0	22.1	69.4	54.8	24.5	22.2	24.9	22.3	21.6	22.0	24.8	22.5	47.2	34.1	23.1	22.0	64.1	49.5	23.8	21.9	66.2	58.9	24.4	21.9	44.0
04/17/93	00.00	319.3	46.8	32.3	23.6	59.8	42.5	24.1	22.2	68.9	55.8	24.7	22.3	25.2	22.5	21.8	22.1	25.1	22.5	46.9	34.4	23.3	22.0	63.1	50.3	24.2	22.1	64.9	59.8	24.8	22.1	43.6
04/17/93	04:00	323.3	46.9	32.7	23.4	60.0	43.1	24.1	22.1	69.5	56.5	24.8	22.3	25.4	22.5	21.7	22.0	25.2	22.4	46.9	34.7	23.2	22.0	63.9	50.8	24.2	22.0	66.1	60.5	24.8	22.0	44.5
04/17/93	08:00	327.3	47.0	33.1	23.4	60.2	43.7	24.2	22.2	69.5	57.4	24.8	22.3	25.6	22.5	21.7	21.9	25.4	22.5	47.0	35.1	23.4	22.0	64.1	51.7	24.3	22.1	66.1	61.6	24.9	21.9	45.4
04/17/93	12:00	331.3	47.0	33.3	23.5	60.1	44.0	24.1	22.1	69.4	57.9	24.7	22.2	25.6	22.4	21.6	22.0	25.4	22.4	46.8	35.2	23.2	21.9	64.0	52.4	24.1	22.0	66.1	62.1	24.8	21.9	45.5
04/17/93	16.00	335.3	47.0	33.4	23.1	59.9	44.6	24.0	21.9	69.4	58.7	24.9	22.1	25.8	22.5	21.5	21.7	25.5	22.1	46.8	34.9	23.2	21.8	64.0	52.8	24.2	21.9	66.0	63.2	24.9	21.6	46.0
04/17/93	20:00	339.3	47.0	34.1	23.7	59.9	45.3	24.2	22.2	68.4	59.2	24.8	22.3	26.4	22.4	21.7	22.0	26.1	22.6	47.3	35.9	23.3	22.0	62.8	54.3	24.1	22.0	64.4	64.4	24.8	21.9	45.5
04/18/93	00:00	343.3	47.3	34.7	23.7	60.3	46.1	24.3	22.2	69.0	60.1	25.0	22.3	26.6	22.5	21.6	22.1	26.3	22.6	47.5	36.3	23.5	22.0	63.6	55.0	24.4	22.1	65.5	65.2	25.0	22.0	46.9
04/18/93	04:00	347.3	47.3	35.1	23.6	60.3	46.6	24.4	22.2	69.0	60.5	25.0	22.3	26.9	22.6	21.8	22.0	26.5	22.7	47.3	36.7	23.6	22.0	63.5	55.7	24.4	22.0	64.8	65.8	25.2	22.0	47.0
04/18/93	08:00	351.3	47.4	35.5	23.7	60.4	47.2	24.5	22.2	68.7	61.2	25.2	22.3	27.1	22.7	21.7	21.9	26.7	22.7	47.1	37.1	23.7	22.1	63.6	56.3	24.6	22.1	64.8	66.4	25.4	22.0	48.5
04/18/93	12:00	355.3	47.2	35.5	23.2	59.9	47.5	24.3	22.1	68.5	61.7	25.2	22.1	27.0	22.8	21.7	21.7	26.7	22.4	46.9	36.8	23.6	22.0	63.6	56.2	24.8	22.2	64.9	66.6	25.4	21.9	48.7
04/18/93	16:00	359.3	47.5	36.0	23.4	60.3	47.9	24.2	22.0	68.9	62.1	25.0	22.1	27.3	22.6	21.5	21.8	26.8	22.4	47.5	37.5	23.5	21.9	64.0	57.0	24.5	21.9	65.4	67.7	25.3	21.8	49.5
04/18/93	20.00	363.3	48.0	36.7	24.0	61.2	48.6	24.5	22.3	69.4	62.9	25.2	22.4	28.0	22.7	21.7	22.2	27.5	23.0	48.6	38.6	23.7	22.1	64.6	58.3	24.6	22.1	65.9	69.9	25.4	22.0	50.4
04/19/93	00.00	367.3	48.2	37.2	23.8	61.6	49.4	24.6	22.3	70.0	63.9	25.3	22.5	28.3	22.7	21.8	22.2	27.7	22.9	48.5	38.9	23.8	22.2	65.2	59.0	24.8	22.2	66.5	71.2	25.6	22.2	50.9
04/19/93	04:00	371.3	48.3	37.4	23.7	61.7	49.9	24.6	22.2	70.5	64.6	25.4	22.4	28.4	22.9	21.7	22.1	27.8	22.8	48.4	39.2	23.8	22.0	65.2	59.6	24.9	22.2	66.5	72.3	25.7	22.0	50.4
04/19/93	08.00		48.4	37.9	23.7	62.0	50.5	24.7	22.3	70.9	65.3	25.5	22.4	28.7	22.9		22.1	28.0	22.8	48.7	39.6	24.0	22.1	65.5	60.3	25.0	22.1	66.6	73.4	[illegible]	22.1	51.1

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
	Maximum Temp.--		79.5	84.2	42.3	86.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
04/30/93	04 00	635.3	64.0	64.0	27.2	70.4	81.6	28.7	23.1	86.3	92.3	30.5	23.7	48.8	28.4	22.3	23.4	46.8	26.4	68.5	67.2	30.4	23.2	95.1	96.2	33.4	23.6	80.2	92.8	36.2	23.6	66.9
04/30/93	08.00	639.3	63.0	64.7	27.5	71.3	82.3	29.0	23.4	86.4	92.8	30.8	23.8	49.1	28.4	22.4	23.4	47.3	26.7	69.0	67.7	30.8	23.5	94.9	95.8	33.8	23.9	80.2	92.1	36.6	23.7	68.4
04/30/93	12.00	643.3	64.9	64.7	27.5	70.6	82.5	28.9	23.4	85.9	92.6	30.6	24.0	49.1	28.3	22.6	23.8	47.5	26.7	69.0	68.1	30.8	23.4	93.4	94.2	33.7	23.9	78.9	92.5	36.7	23.9	64.3
04/30/93	16 00	647.3	63.8	65.0	27.4	72.6	82.6	29.0	23.4	84.2	92.7	30.9	23.9	49.2	28.3	22.7	23.5	47.8	26.6	69.0	68.1	31.3	23.5	92.0	92.8	34.0	23.9	77.8	90.7	37.0	23.8	66.0
04/30/93	20:00	651.3	64.0	65.4	27.6	74.7	82.9	29.0	23.3	84.7	93.1	30.7	23.8	49.4	28.1	22.5	23.6	48.0	26.7	69.5	68.6	31.2	23.4	91.6	92.4	33.8	23.7	77.8	90.7	36.8	23.7	67.2
05/01/93	00.00	655.3	64.3	65.7	27.7	72.6	83.4	29.2	23.4	85.3	93.5	31.0	23.9	49.7	28.3	22.3	23.7	48.4	26.9	69.8	68.7	31.2	23.4	91.3	91.9	34.2	23.9	77.6	91.7	37.1	23.9	67.6
05/01/93	04.00	659.3	64.2	66.0	27.8	71.9	83.8	29.3	23.4	85.0	93.4	31.2	24.1	49.9	28.5	22.5	23.7	48.6	27.0	69.9	68.9	31.4	23.5	89.9	90.9	34.3	23.9	77.0	91.5	37.3	23.9	64.9
05/01/93	08:00	663.3	64.0	66.1	27.8	70.9	84.0	29.4	23.4	83.6	92.8	31.2	24.0	50.0	28.6	22.6	23.7	48.9	27.1	70.0	68.7	31.5	23.5	88.4	89.1	34.5	24.0	76.5	90.4	37.3	24.0	65.9
05/01/93	12:00	667.3	64.1	65.6	27.7	69.9	84.2	29.4	23.2	83.1	92.6	31.1	23.9	49.7	28.5	22.4	23.5	48.7	26.9	69.3	68.8	31.4	23.4	88.6	88.7	34.3	23.9	75.8	89.7	37.0	23.8	65.3
05/01/93	16.00	671.3	63.5	65.6	27.9	70.0	84.6	29.5	23.4	82.7	92.0	31.3	24.1	49.8	28.7	22.5	23.7	49.0	27.0	69.2	68.9	31.7	23.4	87.8	87.8	34.6	24.1	75.5	89.6	37.2	24.0	61.9
05/01/93	20.00	675.3	62.3	66.6	28.2	69.8	84.5	29.5	23.4	82.0	89.4	31.1	24.1	50.1	28.5	22.4	23.8	49.5	27.4	68.6	69.5	31.5	23.5	86.8	87.5	34.3	23.9	75.0	89.1	37.0	24.0	60.4
05/02/93	00:00	679.3	63.1	66.9	28.4	69.6	84.2	29.9	23.8	80.8	89.1	31.6	24.4	50.5	28.8	23.0	24.1	50.0	27.6	69.2	69.5	31.9	23.9	85.7	85.9	34.8	24.3	74.4	87.9	37.7	24.5	59.4
05/02/93	04:00	683.3	61.8	66.9	28.5	68.3	83.7	29.8	23.6	79.6	87.0	31.6	24.3	50.6	28.9	22.7	23.9	50.2	27.7	69.0	69.5	31.7	23.7	84.5	85.1	34.9	24.3	73.5	86.6	37.6	24.3	58.2
05/02/93	08 00	687.3	61.2	66.9	28.6	67.6	83.2	30.0	23.8	78.6	85.4	31.8	24.4	50.8	29.0	22.9	24.0	50.6	27.8	68.3	68.8	31.6	23.9	83.4	84.2	35.1	24.4	72.8	85.5	37.8	24.5	57.7
05/02/93	12:00	691.3	60.5	66.4	28.2	67.0	80.9	29.8	23.6	77.2	85.2	31.7	24.2	50.3	29.0	22.8	23.8	50.4	27.4	66.3	69.5	31.2	23.8	82.4	82.6	35.0	24.4	73.0	83.6	37.5	24.4	58.7
05/02/93	16 00	695.3	60.6	66.6	28.4	67.4	82.4	30.0	23.7	77.7	86.7	31.7	24.3	50.4	29.2	22.8	23.9	50.4	27.6	65.6	69.8	31.1	23.7	83.5	82.9	34.8	24.3	72.3	84.8	37.4	24.3	64.1
05/02/93	20 00	699.3	61.0	66.8	28.7	68.7	83.0	29.9	23.7	78.6	87.7	31.7	24.4	50.7	28.8	22.8	24.2	50.8	27.8	66.4	70.2	31.2	23.6	85.5	85.8	34.8	24.3	73.2	85.7	37.2	24.4	62.9
05/03/93	00 00	703.3	62.2	67.4	28.9	70.1	83.5	30.4	23.9	79.6	89.0	32.2	24.6	51.1	29.3	22.9	24.4	51.2	28.1	66.8	70.4	31.7	24.1	87.3	88.6	35.3	24.6	73.9	87.1	37.6	24.7	67.0
05/03/93	04.00	707.3	62.0	67.6	28.9	71.9	81.2	30.4	23.9	80.0	89.4	32.1	24.6	51.1	29.3	22.9	24.3	51.4	28.2	66.6	70.4	31.7	24.0	87.8	88.0	35.2	24.5	74.0	87.4	37.5	24.6	66.1
05/03/93	08 00	711.3	63.4	68.1	29.1	71.0	85.8	30.8	24.1	80.7	89.4	32.7	24.7	51.2	29.5	23.2	24.4	51.9	28.5	68.3	70.2	32.4	24.4	89.0	88.6	35.7	24.9	74.3	88.1	37.8	24.8	63.7
05/03/93	12.00	715.3	62.3	67.7	28.5	72.9	85.8	30.2	23.6	80.6	90.3	32.1	24.3	50.5	29.4	22.9	24.1	51.2	27.9	68.1	69.4	31.9	24.0	89.1	90.2	35.2	24.6	75.1	88.0	37.2	24.5	66.3
05/03/93	16 00	719.3	61.9	67.2	28.5	75.9	86.3	30.2	23.6	81.2	90.6	32.0	24.3	50.5	29.0	22.6	24.0	51.1	27.7	67.7	69.4	31.8	23.7	89.1	88.8	35.1	24.3	75.7	87.4	37.1	24.3	65.8
05/03/93	20.00	723.3	62.7	68.5	29.0	78.6	87.0	30.3	23.8	82.2	90.9	31.9	24.5	50.9	29.0	22.7	24.4	51.6	28.3	68.8	70.4	32.0	24.0	89.8	91.4	34.9	24.4	76.6	89.8	36.8	24.5	68.1
05/04/93	00 00	727.3	63.7	69.3	29.2	80.7	87.8	30.6	24.0	82.8	91.5	32.4	24.7	51.4	29.4	23.1	24.7	52.2	28.5	70.1	70.9	32.5	24.2	90.3	91.8	35.5	24.8	77.6	90.5	37.3	24.9	68.1
05/04/93	04 00	731.3	64.3	69.5	29.1	82.4	88.3	30.8	24.0	83.1	91.9	32.5	24.8	51.4	29.6	23.1	24.6	52.3	28.4	70.7	71.0	32.6	24.2	91.0	92.7	35.6	24.8	78.9	90.3	37.3	24.9	67.5
05/04/93	08 00	735.3	64.5	69.8	29.2	83.1	88.6	30.8	24.0	83.1	91.7	32.6	24.8	51.4	29.6	23.1	24.6	52.5	28.5	70.9	71.2	32.7	24.2	90.9	92.3	35.6	24.8	79.3	90.8	37.3	25.0	66.4
05/04/93	12 00	739.3	64.6	70.1	29.1	83.9	88.1	30.8	24.1	83.1	92.0	32.8	24.8	51.5	29.8	23.4	24.8	52.6	28.5	71.1	71.3	32.8	24.3	91.3	92.9	35.6	24.9	80.1	90.8	37.3	25.0	66.8
05/04/93	16 00	743.3	65.5	70.3	29.2	84.6	89.1	31.0	24.1	83.1	92.1	32.7	24.9	51.5	29.9	23.3	24.8	52.7	28.5	71.2	71.3	32.7	24.3	91.9	93.2	35.6	25.0	80.7	91.2	37.2	25.1	67.3
05/04/93	20 00	747.3	65.2	70.8	29.4	85.6	89.5	30.8	24.2	83.8	92.0	32.6	25.0	51.7	29.4	23.2	25.0	53.1	28.7	71.6	72.1	32.8	24.4	92.6	93.9	35.5	24.9	81.5	91.5	37.0	25.1	66.7
05/05/93	00 00	751.3	65.8	71.2	29.4	85.9	89.9	31.0	24.2	84.2	92.3	32.8	24.9	51.9	29.7	23.4	24.9	53.3	28.8	72.3	72.3	32.8	24.4	93.0	94.4	35.7	24.9	82.2	91.9	37.1	25.1	69.6
05/05/93	04 00	755.3	66.5	71.6	29.4	86.0	90.1	31.1	24.2	84.6	92.5	33.0	25.0	52.0	29.8	23.4	25.0	53.6	28.8	72.8	72.5	32.9	24.4	93.6	95.0	35.7	25.1	82.8	92.1	37.2	25.2	69.3
05/05/93	08 00	759.3	67.6	71.9	29.6	85.8	90.5	31.1	24.3	83.6	92.4	33.0	25.0	52.3	29.8	23.4	25.1	53.9	28.9	73.0	72.8	33.1	24.5	94.2	95.6	35.8	25.1	83.4	92.5	37.2	25.3	68.3

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
Maximum Temp.--			79.5	84.2	42.3	86.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
04/24/93	20:00	507.3	54.2	51.4	25.4	65.5	67.9	26.3	22.7	77.9	81.5	27.6	23.0	38.9	24.2	21.9	22.6	36.8	24.4	56.8	54.0	26.2	22.5	72.2	78.7	27.9	22.7	72.4	90.9	29.5	22.6	61.8
04/25/93	00.00	511.3	54.4	52.0	25.3	65.2	68.5	26.5	22.8	78.5	82.1	27.7	23.2	39.3	24.6	22.2	22.8	37.2	24.4	57.9	54.5	26.3	22.7	72.8	79.1	28.3	22.9	73.2	90.8	30.0	22.9	62.2
04/25/93	04.00	515.3	54.0	52.4	25.2	65.5	69.0	26.5	22.8	78.4	82.4	27.8	23.2	39.6	24.5	22.2	22.8	37.5	24.4	58.5	54.9	26.3	22.6	73.3	79.6	28.4	22.9	73.6	91.5	30.2	22.9	63.2
04/25/93	08.00	519.3	54.2	52.7	25.2	65.8	69.4	26.5	22.8	79.4	82.7	27.9	23.2	39.9	24.6	22.2	22.7	37.7	24.4	58.6	55.2	26.5	22.7	73.8	80.0	28.5	22.9	74.2	91.8	30.3	22.9	61.5
04/25/93	12:00	523.3	53.7	52.8	25.1	70.2	68.3	26.5	22.6	78.6	82.8	28.0	22.9	39.8	24.7	21.9	22.5	37.8	24.2	57.7	55.3	26.5	22.5	73.3	80.0	28.7	22.8	73.6	90.5	30.6	22.7	58.0
04/25/93	16.00	527.3	54.5	53.3	25.3	65.3	69.9	26.5	22.6	79.9	82.9	28.0	23.1	40.2	24.8	21.9	22.6	38.1	24.2	58.5	55.9	26.4	22.5	73.7	80.3	28.6	22.8	74.3	91.5	30.6	22.7	64.0
04/25/93	20.00	531.3	55.9	54.0	25.7	65.7	70.6	26.8	22.8	80.7	83.4	28.1	23.2	40.9	24.9	22.0	22.9	38.6	24.7	59.0	56.6	26.8	22.7	76.5	80.9	28.9	22.9	75.1	92.5	30.8	22.9	63.0
04/26/93	00.00	535.3	55.4	54.6	25.7	65.3	71.2	26.9	22.9	80.8	84.2	28.3	23.4	41.3	25.0	22.3	23.1	39.2	24.8	60.0	57.4	26.9	22.9	76.2	81.9	29.1	23.1	75.9	92.8	31.2	23.2	65.4
04/26/93	04:00	539.3	56.4	55.0	25.9	65.9	71.3	27.1	22.9	81.2	84.5	28.5	23.4	41.6	25.1	22.3	23.0	39.5	24.8	60.7	57.4	27.1	22.8	78.1	82.0	29.4	23.1	76.3	92.7	31.4	23.1	64.9
04/26/93	08.00	543.3	57.8	55.4	25.9	65.8	72.1	27.2	23.0	81.8	85.0	28.7	23.3	42.0	25.3	22.2	22.9	39.9	24.9	60.9	58.2	27.4	23.0	77.5	82.7	29.6	23.2	76.5	93.3	31.7	23.1	64.1
04/26/93	12:00	547.3	56.7	55.2	25.6	71.0	69.3	27.0	22.8	82.2	84.9	28.4	23.1	41.8	25.4	22.2	22.8	39.8	24.6	60.7	57.9	27.1	22.7	76.6	82.6	29.5	23.0	76.9	93.3	31.6	23.0	64.9
04/26/93	16.00	551.3	56.2	55.5	25.5	65.4	72.4	27.0	22.7	83.2	85.0	28.5	23.1	41.9	25.2	21.9	22.7	39.8	24.4	60.9	58.3	26.9	22.5	77.1	82.9	29.5	22.9	77.7	93.6	31.7	22.7	65.1
04/26/93	20:00	555.3	57.6	56.2	25.9	66.8	73.1	27.2	22.8	84.2	85.6	28.4	23.2	42.5	25.0	21.9	22.8	40.4	24.9	61.7	59.3	27.2	22.7	78.5	83.9	29.4	22.9	78.9	94.5	31.7	22.9	66.2
04/27/93	00:00	559.3	58.7	56.9	26.1	67.5	73.7	27.3	22.8	83.9	86.0	28.8	23.3	43.1	25.3	22.1	22.9	41.0	25.0	62.0	59.8	27.4	22.7	79.1	84.3	30.0	23.0	79.8	94.4	32.2	23.0	65.8
04/27/93	04:00	563.3	59.9	57.3	26.1	68.6	74.0	27.4	23.0	84.7	86.7	29.1	23.4	43.4	25.6	22.2	23.1	41.4	25.1	63.2	60.3	27.7	22.9	80.5	84.9	30.3	23.2	80.8	95.1	32.6	23.3	66.7
04/27/93	08.00	567.3	58.9	57.7	26.0	66.9	74.8	27.5	22.9	86.0	87.0	29.1	23.4	43.7	25.7	22.2	23.0	41.6	25.1	63.4	60.6	27.8	22.8	80.5	85.2	30.4	23.2	81.5	95.2	32.9	23.3	66.7
04/27/93	12.00	571.3	59.5	57.9	26.0	66.9	75.0	27.4	22.8	86.1	87.2	29.1	23.3	43.9	25.7	22.2	23.0	41.8	25.0	63.3	60.8	27.7	22.8	81.8	85.6	30.4	23.1	82.2	95.4	33.0	23.2	66.8
04/27/93	16.00	575.3	59.8	58.1	26.1	67.4	75.4	27.5	22.9	88.4	87.0	29.1	23.4	43.9	25.9	22.2	23.0	41.9	25.1	63.7	61.1	27.9	22.9	82.2	85.6	30.5	23.2	82.6	95.4	33.0	23.2	66.7
04/27/93	20:00	579.3	60.3	58.9	26.3	67.9	76.0	27.6	23.1	89.7	87.4	29.3	23.4	44.5	25.7	22.3	23.2	42.5	25.4	64.1	61.9	28.0	23.0	84.9	86.5	30.7	23.3	83.4	96.1	33.3	23.3	66.0
04/28/93	00.00	583.3	61.0	59.2	26.4	67.6	76.3	27.8	23.0	88.6	87.5	29.5	23.5	44.6	26.0	22.2	23.1	42.9	25.4	64.7	62.1	28.3	23.0	86.2	87.0	31.1	23.3	83.4	95.1	33.6	23.3	66.8
04/28/93	04.00	587.3	61.0	59.6	26.4	70.3	75.1	27.8	23.0	89.4	88.0	29.5	23.5	45.1	26.1	22.2	23.1	43.2	25.5	65.3	62.5	28.3	23.0	89.2	88.7	31.3	23.3	83.6	96.0	33.9	23.3	67.1
04/28/93	08.00	591.3	61.8	60.0	26.6	67.9	77.2	28.0	23.1	90.8	88.2	29.7	23.6	45.4	26.2	22.3	23.2	43.5	25.6	65.4	63.0	28.5	23.0	90.6	90.3	31.6	23.4	83.9	96.3	34.1	23.4	67.2
04/28/93	12:00	595.3	61.1	60.3	26.5	73.5	75.6	28.0	23.2	91.4	88.2	29.7	23.7	45.5	26.2	22.5	23.2	43.7	25.6	65.6	62.7	28.5	23.2	91.6	95.7	31.6	23.5	86.4	93.5	34.3	23.5	65.4
04/28/93	16.00	599.3	61.9	60.7	26.5	71.7	77.3	28.0	23.2	91.8	88.6	29.8	23.7	45.9	26.3	22.4	23.3	44.1	25.7	66.2	63.5	28.6	23.2	93.6	97.9	31.9	23.6	84.1	96.2	34.4	23.5	67.9
04/28/93	20.00	603.3	61.7	61.2	26.7	72.7	77.7	28.1	23.2	92.8	89.0	29.8	23.7	46.2	26.3	22.3	23.4	44.5	25.9	66.8	64.1	28.8	23.2	94.7	97.9	32.1	23.6	84.6	96.2	34.6	23.6	68.9
04/29/93	00.00	607.3	63.5	61.6	26.9	71.4	78.4	28.3	23.2	93.8	89.7	30.1	23.8	46.6	26.6	22.6	23.4	44.8	25.9	67.5	64.6	29.1	23.3	95.7	98.5	32.4	23.6	85.9	94.8	35.0	23.6	68.4
04/29/93	04.00	611.3	63.3	62.0	26.9	72.0	78.4	28.3	23.2	94.3	89.7	30.0	23.6	46.8	26.6	22.4	23.3	45.1	25.9	68.2	64.5	29.1	23.2	96.0	98.5	32.5	23.5	85.4	96.2	35.1	23.5	69.0
04/29/93	08.00	615.3	63.2	62.2	27.0	72.5	78.6	28.2	23.0	94.8	89.7	30.0	23.5	47.0	26.5	22.2	23.3	45.3	26.0	68.5	65.2	29.1	23.0	96.3	98.0	32.5	23.4	86.1	96.0	35.2	23.4	69.2
04/29/93	12.00	619.3	62.8	62.8	27.0	70.5	80.1	28.5	23.2	94.5	90.2	30.4	23.8	48.4	28.8	22.6	23.5	45.7	26.1	66.2	65.8	29.7	23.3	95.3	97.8	32.9	23.7	86.2	94.8	35.7	23.7	67.5
04/29/93	16.00	623.3	64.2	62.8	26.9	69.6	80.3	28.4	23.1	93.1	90.3	30.1	23.6	48.4	29.6	22.3	23.3	45.9	26.0	66.6	66.0	29.7	23.0	95.1	98.3	32.9	23.5	83.5	94.0	35.7	23.6	68.2
04/29/93	20.00	627.3	63.9	63.1	27.0	70.9	80.6	28.5	23.1	88.9	91.4	30.3	23.6	48.5	29.0	22.3	23.2	46.2	26.2	66.7	66.4	29.9	23.1	95.1	96.7	33.0	23.6	82.7	91.6	35.9	23.5	67.8
04/30/93	00.00	[illegible]	63.6	63.7	27.1	70.3	81.2	28.6	23.2	86.6	91.9	30.3	23.7	48.6	28.6	22.2	23.4	46.5	26.3	67.7	66.8	30.0	23.2	95.3	96.5	33.2	23.6	81.2	93.0	36.1	23.5	68.0

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
Maximum Temp.--			79.5	84.2	42.3	88.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
05/10/93	20:00	891.3	73.5	79.6	31.3	80.7	93.9	33.0	25.1	87.4	94.6	35.6	26.1	56.0	30.4	23.7	26.2	60.7	30.7	80.1	79.0	35.5	25.4	95.0	95.3	36.9	25.9	91.1	93.0	37.7	25.9	75.6
05/11/93	00:00	895.3	74.1	80.9	31.5	81.8	94.1	33.6	25.4	87.8	95.1	36.1	26.3	56.5	30.9	24.0	26.4	61.2	31.1	81.3	79.5	36.0	25.7	95.4	95.6	37.4	26.2	91.7	93.1	38.3	26.2	74.6
05/11/93	04:00	899.3	75.5	80.7	31.7	82.0	94.5	33.7	25.4	88.3	95.5	36.5	26.5	56.8	31.1	24.2	26.6	61.5	31.2	82.0	79.7	36.1	25.8	95.9	95.4	37.7	26.3	92.1	93.6	38.5	26.3	76.5
05/11/93	08:00	903.3	75.9	81.0	31.8	81.9	94.4	34.1	25.7	87.9	95.4	36.8	26.6	56.8	31.4	24.3	26.4	62.0	31.4	82.0	79.8	36.5	26.0	95.3	94.7	38.0	26.7	91.8	92.9	38.8	26.4	72.0
05/11/93	12:00	907.3	75.1	80.8	31.2	81.6	92.4	33.6	25.3	86.9	95.0	36.4	26.2	56.2	31.2	24.1	26.2	61.4	30.9	81.0	79.1	35.8	25.6	95.0	94.4	37.6	26.3	91.5	92.2	38.4	26.2	74.3
05/11/93	16:00	911.3	74.7	81.0	31.5	82.4	92.6	33.8	25.3	87.2	95.1	36.6	26.4	56.4	31.1	24.0	26.3	61.5	30.9	80.7	79.2	35.9	25.5	95.0	94.8	37.5	26.2	91.3	92.6	38.4	26.2	75.3
05/11/93	20:00	915.3	74.4	80.7	31.7	80.4	92.8	33.5	25.3	85.8	93.0	36.2	26.4	56.7	30.5	23.6	26.2	61.8	31.1	80.5	79.6	35.6	25.6	93.0	93.0	37.2	26.1	89.2	91.3	38.1	26.1	68.5
05/12/93	00:00	919.3	73.8	80.6	32.0	80.4	91.9	34.0	25.5	84.4	92.1	36.8	26.6	57.2	30.9	24.0	26.4	62.3	31.4	80.7	79.4	36.1	25.8	92.0	92.0	37.8	26.4	88.0	90.1	38.8	26.4	63.2
05/12/93	04:00	923.3	73.3	80.2	32.1	79.4	90.5	34.2	25.6	83.1	91.2	36.9	26.8	57.3	31.3	24.3	26.4	62.5	31.5	77.3	80.2	36.1	25.9	90.9	91.0	38.0	26.5	86.9	89.1	39.0	26.6	64.9
05/12/93	08.00	927.3	73.8	80.2	32.2	79.8	91.0	34.5	25.9	83.1	92.1	37.4	26.8	57.3	31.6	24.4	26.4	62.8	31.6	76.3	80.0	36.4	26.2	91.8	91.4	38.5	26.6	87.7	89.5	39.2	26.6	73.2
05/12/93	12:00	931.3	73.7	79.9	31.7	78.8	91.0	34.1	25.5	82.6	92.2	37.0	26.5	56.9	31.4	24.2	26.5	62.3	31.0	74.4	79.4	35.8	25.6	92.4	92.1	38.1	26.5	87.7	89.9	38.9	26.5	73.5
05/12/93	16.00	935.3	73.9	80.1	32.1	79.6	92.5	34.3	25.7	83.5	92.7	37.1	26.8	57.1	31.6	24.3	26.7	62.3	31.2	76.4	79.7	35.7	25.8	93.2	93.0	38.0	26.5	87.9	90.5	39.1	26.5	70.6
05/12/93	20:00	939.3	74.6	80.7	32.3	80.6	93.0	34.3	25.8	84.3	93.0	37.2	26.8	57.4	31.2	24.2	26.9	62.6	31.5	75.5	80.4	35.9	26.0	93.8	93.8	37.9	26.5	88.3	85.2	39.0	26.6	74.4
05/13/93	00.00	943.3	74.6	80.7	32.5	81.1	84.7	34.7	25.8	85.2	93.7	37.6	26.9	57.8	31.6	24.3	27.0	63.0	31.7	77.1	80.9	36.3	26.0	94.4	94.5	38.4	26.7	88.8	91.9	39.5	26.8	70.3
05/13/93	04.00	947.3	75.7	80.5	32.7	81.8	94.0	34.7	25.9	85.9	94.1	37.7	27.0	57.9	31.5	24.2	27.0	63.2	31.8	77.8	81.2	36.3	26.1	94.9	95.1	38.5	26.6	89.0	91.4	39.5	26.7	73.7
05/13/93	08.00	951.3	76.6	79.7	32.7	82.3	94.4	35.1	26.0	86.4	94.6	38.1	27.0	57.9	31.8	24.5	26.8	63.5	32.0	77.9	81.4	36.6	26.3	95.0	95.0	38.9	26.9	89.2	92.3	39.8	26.8	73.9
05/13/93	12:00	955.3	75.8	81.4	32.2	81.9	94.2	34.7	25.8	86.5	94.6	37.7	26.8	57.5	31.7	24.3	26.8	63.1	31.4	76.6	80.9	36.2	26.0	94.8	94.6	38.6	26.7	89.2	92.2	39.5	26.7	73.3
05/13/93	16:00	959.3	75.3	81.7	32.5	81.8	94.4	35.0	25.7	86.8	94.6	37.9	26.9	57.6	31.8	24.2	26.8	63.1	31.6	79.4	80.0	36.1	25.9	94.4	94.4	38.5	26.6	89.2	92.5	39.5	26.6	74.2
05/13/93	20.00	963.3	76.1	81.6	32.7	83.1	94.0	34.8	25.9	87.1	94.4	37.9	27.0	57.9	31.3	24.1	27.1	63.4	31.9	80.0	80.3	36.1	26.1	94.7	94.9	38.6	26.6	89.3	93.1	39.6	26.6	77.0
05/14/93	00:00	967.3	76.5	80.9	33.1	82.8	94.5	35.3	26.0	87.2	94.4	38.4	27.1	58.3	31.5	24.3	27.0	63.9	32.1	78.8	81.5	36.6	26.2	94.6	94.6	39.0	26.8	88.9	93.0	40.0	26.8	71.5
05/14/93	04.00	971.3	76.0	81.8	33.1	82.6	92.9	35.3	26.1	86.6	94.0	38.4	27.2	58.4	31.7	24.4	27.1	64.0	32.1	78.0	81.7	36.7	26.2	94.0	94.2	39.1	26.9	88.7	92.1	40.1	26.9	75.8
05/14/93	08:00	975.3	76.7	81.9	33.2	82.8	94.1	35.8	26.2	86.5	94.6	39.0	27.3	58.5	32.2	24.7	27.0	64.4	32.4	77.8	81.9	37.1	26.5	94.6	94.4	39.6	27.2	88.9	87.0	40.6	27.0	72.9
05/14/93	12.00	979.3	76.2	81.3	32.8	81.7	94.4	35.3	25.9	86.2	94.6	38.5	27.0	57.9	32.1	24.4	26.9	63.7	31.7	76.4	81.3	36.4	26.1	94.2	93.7	39.2	26.8	88.7	92.4	40.1	26.7	76.3
05/14/93	16:00	983.3	76.2	81.7	32.8	81.9	94.5	35.4	25.9	86.7	94.6	38.6	27.1	58.1	31.8	24.2	26.9	63.7	31.7	76.2	81.3	36.4	26.0	94.1	93.8	39.1	26.7	88.8	85.9	40.2	26.6	78.4
05/14/93	20:00	987.3	77.1	82.1	33.3	83.4	94.0	35.4	26.0	87.4	94.7	38.7	27.2	58.5	31.6	24.1	27.2	64.1	32.2	78.1	81.7	36.4	26.1	94.6	94.7	39.0	26.7	88.6	93.5	40.1	26.7	77.4
05/15/93	00:00	991.3	77.5	80.2	33.6	84.0	93.1	35.9	26.2	88.1	95.1	39.2	27.4	58.9	32.0	24.4	27.4	64.6	32.5	78.1	82.5	36.9	26.3	94.9	94.8	39.6	27.0	89.2	93.3	40.7	27.0	76.5
05/15/93	04:00	995.3	77.2	82.4	33.6	84.2	95.1	36.0	26.2	88.5	95.4	39.4	27.4	59.1	32.1	24.5	27.5	64.8	32.5	78.0	82.7	36.9	26.4	95.3	95.3	39.7	27.1	89.1	93.9	41.0	27.1	76.1
05/15/93	08:00	999.3	77.9	82.9	33.8	84.4	95.1	36.5	26.4	88.9	95.8	39.9	27.6	59.1	32.5	24.7	27.3	65.2	32.7	78.5	82.8	37.4	26.7	95.4	95.4	40.3	27.4	89.3	93.9	41.4	27.2	77.2
05/15/93	12:00	1003.3	77.2	80.9	33.3	84.2	95.0	36.1	26.2	38.5	95.5	39.6	27.3	58.7	32.1	24.4	27.2	64.6	32.2	77.4	82.1	37.0	26.3	95.1	94.7	39.9	27.1	88.6	93.2	41.1	27.0	74.8
05/15/93	16.00	1007.3	77.2	81.0	33.3	83.4	94.9	36.2	26.1	88.7	95.6	39.7	27.4	58.8	32.2	24.3	27.2	64.6	32.2	75.8	82.3	36.8	26.2	94.7	94.5	39.9	27.0	89.2	93.4	41.3	26.9	77.3
05/15/93	20:00	1011.3	77.5	83.0	34.0	84.9	95.2	36.2	26.3	89.2	95.8	39.6	27.5	59.2	32.0	24.3	27.6	65.1	32.7	77.1	83.0	36.8	26.4	95.3	95.2	39.8	26.9	89.5	88.9	41.1	27.0	80.3
05/16/93	00.00	1015.3	78.4	83.0	34.1	85.5	95.5	36.6	26.5	89.7	96.0	40.2	27.7	59.7	32.3	24.7	27.7	65.5	32.9	78.3	83.4	37.3	26.5	95.6	95.4	40.4	27.2	89.8	94.8	41.7	27.3	79.6

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
	Maximum Temp.--		79.5	84.2	42.3	86.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
05/05/93	12:00	763.3	68.9	72.0	29.7	85.5	90.8	31.4	24.4	83.2	92.4	33.3	25.2	52.4	30.1	23.7	25.2	54.3	29.0	73.8	73.0	33.3	24.7	94.1	95.2	36.0	25.3	84.3	92.2	37.4	25.5	64.8
05/05/93	16:00	767.3	67.7	72.7	29.8	85.2	91.0	31.4	24.5	83.2	92.5	33.4	25.3	52.6	30.0	23.4	25.4	54.5	29.2	77.0	72.8	33.4	24.7	94.5	95.3	36.0	25.3	84.6	92.2	37.4	25.4	69.4
05/05/93	20:00	771.3	68.8	72.8	29.6	84.4	91.1	31.3	24.3	83.2	92.2	33.2	25.2	52.6	30.0	23.4	25.2	54.6	29.1	77.1	73.1	33.8	24.6	94.1	94.9	35.9	25.2	84.8	92.1	37.2	25.4	69.4
05/06/93	00.00	775.3	68.3	73.2	29.7	83.6	91.3	31.3	24.4	83.2	92.1	33.4	25.2	52.8	29.7	23.4	25.2	54.9	29.2	76.4	73.3	33.9	24.6	94.1	94.6	35.8	25.2	84.9	92.0	37.1	25.3	69.5
05/06/93	04:00	779.3	68.5	73.4	29.7	82.0	91.6	31.4	24.4	83.4	92.3	33.4	25.2	52.9	30.0	23.4	25.2	55.0	29.2	76.7	73.3	33.8	24.6	94.2	94.8	35.9	25.3	85.4	92.0	37.2	25.4	70.8
05/06/93	08.00	783.3	68.8	73.9	29.8	82.0	91.8	31.6	24.5	83.6	92.4	33.7	25.3	53.2	30.3	23.6	25.4	55.4	29.4	76.2	74.1	34.2	24.8	94.1	94.6	36.1	25.4	85.8	91.5	37.4	25.6	69.8
05/06/93	12.00	787.3	68.5	73.9	29.5	80.9	91.8	31.4	24.5	83.1	92.3	33.5	25.2	52.8	30.2	23.5	25.1	55.3	29.3	74.1	74.1	34.6	24.7	93.9	94.2	35.9	25.4	86.0	91.1	37.1	25.4	68.9
05/06/93	16.00	791.3	68.4	74.0	29.7	79.9	91.7	31.5	24.3	83.3	91.9	33.5	25.2	52.9	30.0	23.3	25.2	55.3	29.2	73.7	74.7	35.7	24.6	93.5	94.1	35.8	25.2	85.9	91.3	36.8	25.3	68.3
05/06/93	20.00	795.3	69.0	73.8	29.8	79.9	92.0	31.3	24.5	84.1	92.3	33.4	25.3	53.2	29.8	23.2	25.4	55.7	29.5	74.2	75.1	36.0	24.7	93.8	94.6	35.5	25.2	86.6	87.4	36.7	25.3	67.9
05/07/93	00:00	799.3	69.5	75.1	30.0	79.8	92.3	31.7	24.6	84.6	92.9	33.7	25.4	53.6	30.2	23.7	25.5	55.9	29.7	74.8	75.5	36.5	24.8	94.0	94.8	36.0	25.4	87.1	90.7	37.2	25.5	69.2
05/07/93	04.00	803.3	70.4	75.4	30.1	79.5	92.4	31.6	24.5	85.0	93.3	33.7	25.4	53.7	30.1	23.4	25.5	56.3	29.8	74.9	75.8	37.1	24.7	94.2	95.0	35.9	25.3	87.3	91.9	37.1	25.4	71.0
05/07/93	08:00	807.3	70.8	75.3	30.1	79.3	92.5	31.9	24.7	85.4	93.9	34.0	25.4	53.9	30.4	23.7	25.6	56.7	29.9	75.5	75.9	37.1	24.9	94.2	94.8	36.2	25.5	87.6	90.9	37.3	25.6	69.9
05/07/93	12.00	811.3	70.0	75.9	30.0	79.0	92.8	31.9	24.7	85.4	94.2	34.0	25.5	53.7	30.5	23.7	25.6	56.8	29.9	75.1	75.5	37.6	25.1	94.2	94.6	36.3	25.7	87.8	91.0	37.3	25.7	71.6
05/07/93	16.00	815.3	70.2	76.1	30.2	78.9	92.5	31.8	24.8	85.7	94.1	33.8	25.6	54.0	30.2	23.5	25.7	56.9	30.0	75.2	76.0	37.0	25.0	94.0	94.5	36.1	25.5	87.9	91.6	37.0	25.6	70.4
05/07/93	20.00	819.3	70.6	76.6	30.3	78.9	92.7	31.9	24.8	86.1	94.5	34.1	25.6	54.2	30.3	23.7	25.7	57.3	30.0	75.6	76.4	37.1	25.0	94.1	94.8	36.3	25.6	88.3	92.0	37.2	25.7	72.5
05/08/93	00:00	823.3	71.8	76.4	30.3	78.8	92.8	32.0	24.7	86.2	94.6	34.2	25.5	54.3	30.3	23.7	25.7	57.5	30.0	75.9	76.5	36.6	25.0	94.1	94.7	36.3	25.5	88.6	91.2	37.3	25.6	72.3
05/08/93	04 00	827.3	71.0	77.1	30.4	78.7	93.1	32.1	24.7	86.5	95.0	34.3	25.6	54.5	30.4	23.7	25.8	57.7	30.1	76.4	76.7	37.3	25.1	94.3	95.1	36.4	25.5	88.9	92.3	37.3	25.6	73.0
05/08/93	08.00	831.3	71.0	77.2	30.5	78.0	92.8	32.3	24.8	86.3	94.6	34.5	25.7	54.6	30.4	23.8	25.8	58.0	30.1	76.4	76.8	36.9	25.1	93.7	94.4	36.6	25.8	88.4	91.8	37.5	25.8	68.0
05/08/93	12:00	835.3	70.6	77.0	30.3	76.6	91.8	32.2	24.8	84.6	93.4	34.4	25.7	54.4	30.5	23.8	25.7	58.0	30.1	76.4	76.4	36.5	25.2	92.0	92.3	36.4	25.8	87.6	90.4	37.3	25.8	68.7
05/08/93	16.00	839.3	70.4	77.1	30.6	76.5	92.0	32.3	24.8	84.2	93.3	34.4	25.7	54.5	30.5	23.7	25.7	58.1	30.2	76.5	76.6	36.4	25.1	92.1	92.7	36.3	25.7	87.7	90.6	37.2	25.7	69.4
05/08/93	20.00	843.3	70.8	77.5	30.7	77.3	92.5	32.4	25.1	84.7	93.8	34.6	25.9	54.9	30.5	23.9	26.0	58.6	30.3	76.7	77.2	37.0	25.3	93.1	93.8	36.5	25.8	88.3	91.1	37.3	26.0	72.0
05/09/93	00:00	847.3	71.5	77.1	30.7	77.5	92.8	32.6	25.0	85.0	93.9	34.7	25.8	55.1	30.6	24.1	26.0	58.8	30.4	77.1	77.1	36.6	25.3	93.5	94.2	36.8	25.8	88.7	89.1	37.6	25.9	72.3
05/09/93	04.00	851.3	71.8	78.1	30.7	77.4	93.0	32.6	24.9	85.5	94.1	34.9	25.8	55.2	30.6	23.8	25.9	58.9	30.4	77.4	77.4	36.6	25.3	93.8	94.6	36.8	25.8	89.1	91.8	37.6	25.8	71.1
05/09/93	08 00	855.3	72.0	78.3	30.9	77.9	93.0	32.8	25.1	85.9	94.3	35.0	25.9	55.3	30.8	24.1	26.0	59.2	30.5	78.7	77.5	36.5	25.4	93.8	94.5	37.0	25.9	89.3	91.7	37.8	26.0	70.7
05/09/93	12.00	859.3	72.0	78.3	30.7	77.6	93.2	32.6	25.0	86.0	94.3	35.0	26.0	55.2	30.6	23.9	26.1	59.2	30.4	78.0	77.4	36.2	25.4	93.9	94.4	36.8	26.0	89.7	91.2	37.6	26.0	73.0
05/09/93	16.00	863.3	71.8	78.6	30.8	77.9	93.1	32.7	24.9	85.9	94.3	35.0	25.9	55.1	30.6	23.7	25.9	59.2	30.5	78.3	77.5	36.1	25.2	93.7	94.2	36.7	25.8	89.7	91.7	37.4	25.7	71.8
05/09/93	20:00	867.3	72.3	79.0	31.0	78.4	93.3	32.7	25.1	86.4	94.4	35.0	26.0	55.4	30.8	23.8	26.2	59.6	30.8	78.4	78.0	36.1	25.4	94.1	94.5	36.7	25.9	90.1	91.2	37.5	25.9	73.4
05/10/93	00 00	871.3	73.0	79.3	31.3	79.6	93.5	33.2	25.3	86.9	94.9	35.5	26.2	55.9	30.9	24.2	26.4	60.1	30.9	79.3	78.5	36.3	25.6	94.5	94.9	37.2	26.1	90.5	89.3	38.0	26.2	72.5
05/10/93	04.00	875.3	74.5	79.1	31.3	79.7	93.9	33.2	25.3	87.1	95.1	35.7	26.2	56.0	30.9	24.1	26.4	60.3	30.9	80.1	78.7	36.2	25.6	94.9	94.5	37.2	26.2	90.9	92.7	38.1	26.2	74.4
05/10/93	08.00	879.3	73.9	79.7	31.4	80.5	93.6	33.4	25.4	87.1	95.1	36.0	26.2	56.1	31.0	24.2	26.1	60.7	31.0	81.0	78.9	36.3	25.8	94.8	94.9	37.5	26.3	90.9	84.5	38.2	26.2	71.8
05/10/93	12:00	883.3	73.7	79.8	30.8	81.1	93.7	33.1	25.2	87.1	95.2	35.7	26.1	55.7	30.9	24.0	26.1	60.3	30.5	80.6	78.6	35.7	25.5	95.0	94.6	37.2	26.1	90.3	87.5	38.0	26.1	78.0
05/10/93	16.00	887.3	73.5	79.7	31.2	80.3	93.8	33.1	25.2	87.4	95.0	35.7	26.2	55.8	31.0	24.0	26.2	60.4	30.6	79.5	78.7	35.5	25.4	94.7	94.8	37.1	26.0	90.8	91.8	38.0	26.1	72.3

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
	Maximum Temp.--		79.5	84.2	42.3	86.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
05/21/93	12:00	1147.3	70.3	78.2	37.5	78.6	86.3	40.6	27.9	82.5	90.2	45.1	29.5	61.2	35.1	25.5	28.2	67.3	35.3	71.3	78.6	41.5	27.8	90.2	90.4	46.3	28.9	79.8	85.6	47.4	28.9	78.0
05/21/93	16:00	1151.3	70.1	77.8	37.7	78.2	85.9	40.8	28.1	82.4	90.4	45.2	29.8	61.3	35.4	25.6	28.4	67.1	35.6	71.4	78.6	41.4	27.8	89.9	90.3	46.2	29.0	79.6	85.9	47.6	29.0	78.8
05/21/93	20:00	1155.3	70.0	77.9	38.1	78.7	85.4	40.8	28.3	82.4	90.3	45.1	29.7	61.5	35.1	25.5	28.6	67.3	35.9	71.6	79.0	41.7	28.0	89.6	90.5	46.3	29.0	79.8	86.8	47.4	29.1	79.5
05/22/93	00.00	1159.3	69.7	77.8	38.4	78.8	85.7	41.3	28.4	82.1	90.3	45.5	29.9	61.7	35.6	25.8	28.7	67.4	36.2	70.9	79.1	42.0	28.1	89.4	90.3	46.7	29.2	79.9	86.9	47.9	29.4	79.1
05/22/93	04:00	1163.3	69.1	77.9	38.4	78.6	85.6	41.4	28.4	82.0	90.0	45.6	30.0	61.6	35.9	25.9	28.7	67.4	36.2	70.5	79.2	42.1	28.2	89.0	89.9	47.0	29.2	79.6	86.6	48.1	29.5	79.0
05/22/93	08.00	1167.3	69.1	78.1	38.6	78.8	86.7	41.6	28.5	82.3	90.1	45.8	30.1	61.6	35.9	26.0	28.8	67.4	36.4	71.2	79.2	42.2	28.3	89.6	90.5	47.0	29.3	79.4	86.4	48.2	29.5	81.2
05/22/93	12:00	1171.3	69.0	77.9	38.1	77.9	87.1	41.4	28.4	82.2	90.2	45.7	29.9	61.2	35.8	25.8	28.6	66.9	35.9	70.5	79.0	42.1	28.2	89.7	90.4	46.9	29.3	78.5	86.3	48.0	29.3	81.9
05/22/93	16.00	1175.3	69.1	77.9	38.4	77.7	87.5	41.3	28.5	82.4	90.0	45.7	30.0	61.2	35.7	25.7	28.7	66.9	36.1	70.8	79.3	42.1	28.2	89.9	90.6	46.8	29.3	78.5	86.2	47.9	29.4	80.8
05/22/93	20.00	1179.3	71.2	78.1	38.8	77.2	88.8	41.8	28.6	82.3	91.0	46.2	30.3	62.0	36.1	26.2	28.9	67.3	36.5	65.4	79.6	42.8	28.4	91.8	92.0	47.4	29.5	82.7	87.8	48.4	29.7	75.4
05/23/93	00.00	1183.3	70.9	78.4	38.9	78.1	89.1	42.0	28.7	82.0	89.9	46.3	30.4	62.0	38.3	26.1	28.9	67.4	36.6	69.0	79.7	42.9	28.5	90.6	91.1	47.5	29.5	82.0	87.3	48.5	29.8	76.0
05/23/93	04:00	1187.3	70.7	78.5	39.0	78.5	88.5	42.2	28.7	81.7	89.8	46.4	30.4	62.0	38.0	26.0	28.9	67.5	36.8	68.5	80.1	43.2	28.5	90.9	91.6	47.7	29.5	82.2	88.3	48.6	29.8	75.7
05/23/93	08:00	1191.3	71.7	78.5	39.2	79.2	88.2	42.4	28.8	81.2	89.1	46.7	30.5	61.9	37.7	26.2	29.1	67.7	37.1	70.4	80.0	43.2	28.6	91.1	91.7	47.9	29.7	81.9	87.7	48.7	29.9	75.2
05/23/93	12:00	1195.3	71.8	78.3	39.5	78.9	89.2	42.6	28.9	80.7	88.6	46.8	30.5	61.8	37.7	26.2	29.1	67.8	37.3	70.4	78.7	43.3	28.6	90.9	91.7	48.0	29.7	82.0	87.1	48.8	29.9	74.7
05/23/93	16 00	1199.3	71.8	77.6	39.6	78.8	89.4	42.8	28.9	80.5	88.4	47.0	30.7	61.8	37.8	26.3	29.2	67.9	37.5	70.2	79.6	43.5	28.7	90.9	91.7	48.4	29.8	81.9	87.0	49.0	30.0	75.0
05/23/93	20.00	1203.3	71.4	78.0	39.4	78.9	87.5	42.5	28.7	79.8	87.6	46.8	30.4	61.4	37.4	25.9	28.8	67.6	37.3	69.9	79.3	43.2	28.4	90.4	91.3	48.1	29.5	81.3	86.5	48.6	29.6	73.0
05/24/93	00 00	1207.3	71.9	78.5	39.7	78.7	89.2	42.9	29.0	79.9	87.8	47.1	30.7	61.6	37.5	26.2	29.2	68.0	37.7	70.0	78.7	43.6	28.8	90.4	91.4	48.7	29.9	81.4	86.8	48.9	30.0	75.1
05/24/93	04.00	1211.3	72.2	78.7	39.8	79.4	89.2	43.1	29.1	79.8	87.9	47.2	30.7	61.6	37.7	26.3	29.3	68.2	38.0	70.3	80.3	44.0	28.9	89.8	90.8	48.9	29.9	81.5	86.9	49.0	30.1	74.0
05/24/93	08.00	1215.3	72.1	78.4	39.9	79.8	88.4	43.1	29.1	79.3	87.4	47.3	30.9	61.5	37.7	26.3	29.3	68.1	38.0	70.2	80.3	44.6	28.9	88.6	89.0	49.1	30.0	81.0	87.8	49.1	30.1	72.2
05/24/93	12:00	1219.3	71.5	78.0	39.4	80.2	84.9	42.9	28.9	79.6	87.1	47.0	30.6	61.0	37.3	26.3	28.9	67.7	37.7	69.4	79.9	45.8	28.6	88.9	89.1	48.9	29.8	80.6	86.6	48.8	29.8	70.2
05/24/93	16.00	1223.3	71.0	77.5	39.3	79.7	87.4	42.7	28.9	80.0	86.5	46.8	30.7	60.8	37.1	26.1	29.0	67.5	37.5	69.8	79.6	47.0	28.7	88.7	89.2	48.9	29.8	80.5	85.7	48.6	29.9	69.6
05/24/93	20.00	1227.3	71.0	77.5	39.9	79.8	87.3	43.0	29.0	81.2	85.8	47.0	30.7	61.1	37.0	26.3	29.1	67.9	38.1	70.6	79.9	47.8	28.8	88.9	89.6	49.1	29.8	81.0	86.1	48.7	29.9	71.1
05/25/93	00 00	1231.3	71.1	77.2	40.1	79.6	87.0	43.2	29.2	81.2	85.6	47.3	31.0	61.1	37.3	26.2	29.3	68.1	38.4	70.6	79.8	47.9	29.0	89.1	89.8	49.5	30.1	81.4	84.5	49.0	30.1	71.0
05/25/93	04.00	1235.3	70.7	77.2	40.3	78.8	86.8	43.4	29.4	81.1	85.1	47.4	31.2	61.2	37.4	26.5	29.4	68.2	38.6	70.2	79.6	48.4	29.2	88.8	89.7	49.8	30.3	81.2	84.8	49.1	30.3	68.3
05/25/93	08.00	1239.3	70.3	76.8	40.2	78.3	86.6	43.5	29.4	80.9	84.5	47.5	31.1	61.1	37.4	26.5	29.2	68.1	38.6	69.2	79.3	48.0	29.3	88.5	89.4	50.0	30.4	80.8	84.5	49.1	30.3	70.6
05/25/93	12 00	1243.3	69.6	76.3	39.9	77.7	86.0	43.2	29.2	81.5	83.8	47.3	31.0	60.6	37.3	26.4	29.2	67.7	38.2	68.5	78.7	48.0	29.1	87.8	88.4	50.0	30.1	80.6	82.8	49.0	30.1	69.2
05/25/93	16.00	1247.3	69.3	75.9	40.0	77.2	85.6	43.2	29.4	81.9	83.1	47.1	31.2	60.7	37.2	26.4	29.4	67.4	38.3	68.2	78.5	48.1	29.2	87.2	88.0	49.9	30.3	80.0	84.3	48.9	30.3	69.0
05/25/93	20.00	1251.3	69.1	75.9	40.4	77.1	84.9	43.4	29.4	82.2	82.6	47.4	31.2	60.8	37.2	26.5	29.4	67.6	38.8	68.1	78.7	48.3	29.2	87.1	88.1	50.2	30.3	80.2	84.4	48.9	30.3	71.6
05/26/93	00 00	1255.3	68.9	75.8	40.7	77.0	85.2	43.7	29.7	82.3	82.4	47.6	31.4	60.9	37.4	26.6	29.6	67.8	39.1	67.7	78.8	48.1	29.4	87.0	88.1	50.4	30.5	80.2	84.5	49.1	30.5	72.1
05/26/93	04:00	1259.3	68.0	75.9	40.7	76.7	84.9	43.8	29.7	82.2	82.7	47.6	31.5	60.9	37.5	26.6	29.6	67.6	39.2	66.3	78.7	48.0	29.5	87.1	88.2	50.6	30.6	81.5	84.6	49.3	30.5	73.9
05/26/93	08:00	1263.3	67.9	75.4	40.7	76.3	84.8	43.9	29.8	83.0	82.1	47.7	31.7	60.9	37.7	26.7	29.8	67.6	39.3	66.4	78.5	48.2	29.6	87.0	88.1	50.9	30.7	80.6	84.4	49.3	30.7	72.4
05/26/93	12:00	1267.3	67.6	74.7	40.5	75.3	84.4	43.7	29.6	83.4	81.4	47.6	31.4	60.5	37.6	26.7	29.5	67.2	39.1	65.7	77.8	48.2	29.4	86.2	87.3	50.8	30.6	80.2	83.9	49.2	30.5	74.2
05/26/93	16 00	1271.3	67.2	74.3	40.4	75.4	83.7	43.6	29.7	83.7	80.6	47.4	31.5	60.3	37.4	26.5	29.6	66.8	39.0	65.3	77.6	48.1	29.5	85.7	86.9	50.7	30.6	79.9	83.2	49.0	30.5	72.2

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
Maximum Temp.--			79 5	84 2	42.3	86.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90 1
05/16/93	04:00	1019.3	78.5	83.4	34.3	85.4	95.4	36 9	26 5	90.0	96 3	40.4	27.8	59 9	32.5	24.7	27.8	65.7	32.9	78.8	83.6	37.5	26.6	95.7	95.6	40.6	27.3	90.2	94.1	42.0	27.4	78 9
05/16/93	08:00	1023.3	78 3	83 5	34.3	85 2	95 5	37.0	26.7	89 8	96.1	40.9	27.9	60.0	32.5	24.7	27.6	65 9	33.2	78.7	83.6	37.7	26.8	95.6	95.4	41.1	27.5	90.1	88.4	42.3	27.5	74 7
05/16/93	12:00	1027.3	78.2	83.1	34.0	84 6	94 9	36 9	26.4	88 8	95.8	40 7	27.6	59.4	32.8	24.7	27.5	65.6	32.8	78.1	83.0	37.5	26.6	95.0	94.6	41.0	27.4	89.7	93.7	42.2	27.4	81 8
05/16/93	16.00	1031.3	77.8	82.7	34.2	84.5	95 1	37.1	26 4	89.1	95 6	41.0	27.7	59 6	32 6	24.5	27.5	65.4	32.7	78.0	82.7	37.4	26.4	94 8	94.5	41.0	27.2	89.6	93.6	42 2	27.2	81 6
05/16/93	20:00	1035.3	78.5	81.8	34.6	85 5	95.2	37.1	26 6	89 5	95 6	40 9	27.9	60.0	32.5	24.4	27.9	66.0	33.2	78 7	83.5	37.5	26.6	95.2	95.2	40 9	27 3	89 8	87.7	42.2	27.4	83 8
05/17/93	00 00	1039.3	78 8	83.6	34.9	85.4	95.0	37.5	26.7	89 8	96 0	41.5	28.1	60.4	32 8	24.7	28.0	66.4	33 5	79.2	83 8	37.9	26.7	95.5	95 5	41.5	27.5	90.1	93 8	43.0	27.6	80 6
05/17/93	04:00	1043.3	79.2	82.0	35.0	85.9	95.5	37.7	26 7	89.9	96 2	41.8	28 1	60.5	33.0	24.9	28.1	66.4	33.4	79.3	83.7	38.1	26 7	95 5	95.4	41.8	27.6	90.2	95 0	43 3	27.7	81 9
05/17/93	08.00	1047.3	79.0	83.6	35.1	85 9	95.4	38 0	26.8	89 9	96 3	42.0	28 2	60 6	33.1	24.9	28 1	66.7	33 6	79.5	83 8	38.3	26 9	95.4	95.4	42.1	27.7	90.2	94.7	43.7	27.8	82 7
05/17/93	12:00	1051.3	78.4	83 8	35 0	85 5	95.3	37.9	26.8	89.5	96.2	42.1	28 1	60 4	33.2	24.9	28.0	66.5	33.4	78.9	83 3	38.3	27.0	95.3	95.1	42.2	27 8	90 0	93 3	43.7	27.7	84 3
05/17/93	16.00	1055.3	78.5	83.1	35.1	85 3	95.1	38 1	26 8	89.4	95 9	42.0	28 2	60.4	33.1	24.8	27.8	66.5	33 4	78.7	83 3	38.1	26.7	94 7	94.6	41.9	27.5	89.5	89 6	43 6	27.6	85 7
05/17/93	20.00	1059.3	78 9	83.5	35 3	85.9	93 8	38 0	26.9	89 7	95.7	42 2	28 3	60 8	32.8	24.7	28.1	66.8	33.6	79.5	83 5	38.3	26 8	95 2	95.4	42.2	27.6	89.7	94.6	43.7	27.7	87 9
05/18/93	00.00	1063.3	79.1	84 0	35 6	86.3	95 3	38 5	27.0	90.1	96 3	42 8	28.3	61.1	33 4	25 2	28.2	67.1	33.9	80.4	83 6	38.7	27.0	95.4	95.5	42.9	27.7	90.1	94 8	44 6	27.9	90 1
05/18/93	04:00	1067.3	79.4	84 2	35 7	85.9	95.4	38 6	27.0	90.1	96.3	43.0	28.4	61.1	33.4	24 9	28.2	67.2	34.0	79.6	84.0	38.8	27.0	95 6	95.7	43.0	27.8	90 4	94 8	44.7	27.9	89 4
05/18/93	08.00	1071.3	79.1	83.8	35 8	85.7	95.1	38.8	27.1	89.8	96 0	43 3	28 5	61.3	33 5	25 0	28.1	67.4	34.1	79 3	84.1	39 2	27 1	95 1	95 1	43.3	28 0	89 6	-86 8	45.1	28 0	88 7
05/18/93	12:00	1075.3	79 5	83 9	36.5	85 6	95 3	39 1	27.3	89 9	96 2	43 4	28.6	61.5	33 6	25 0	28 4	67.8	34.5	79.7	84.7	39 3	27.2	95 5	95 7	43.5	27 9	90 2	93 5	45.1	28 1	87 7
05/18/93	16.00	1079.3	78 9	84.1	35.7	84.4	95 0	39 2	27.2	89.2	96 6	43 8	28.7	61 2	34 2	25.4	28.3	67.4	34.0	79 5	83.5	39.3	27 2	94 9	94.9	43.8	28 2	89 7	93 3	45.7	28 3	87 7
05/18/93	20:00	1083.3	78 6	84 0	36 3	84 9	93 0	39 0	27.2	88 6	95 2	43 5	28 7	61.4	33 3	25 0	28 3	67.6	34 3	78 9	84.0	39 2	27.1	94 3	94 5	43 5	28 0	88 6	92 9	45 4	28 2	85 1
05/19/93	00.00	1087.3	77.9	82.8	36 5	84.1	92 9	39 3	27.3	87.8	94 6	43 8	28 7	61.6	33 8	25 2	28 2	67.8	34 5	78 3	84 1	39 6	27 2	93 7	93 9	44 2	28 1	87 7	90 1	45 9	28 3	80 7
05/19/93	04:00	1091.3	77.9	82 8	36 7	83 2	92 9	39 6	27 5	87.1	94 0	44 1	28 9	61.8	34 1	25 3	28 3	68 0	34.7	77.9	83 8	39.8	27.3	93 5	93 7	44 4	28 3	87 1	91 3	46 2	28 5	81 7
05/19/93	08:00	1095.3	77.3	82 7	36.7	83 1	92 0	39 7	27.5	86 5	93.4	44 4	28 9	61.7	34 1	25 2	28 0	68 1	34 7	77.2	83 7	40 2	27 5	93 3	93 5	44 8	28 4	86 4	87 2	46 4	28 4	78 3
05/19/93	12.00	1099.3	76 7	82 1	36 4	82 3	92.5	39 5	27.4	85 9	92.9	44 2	28 7	61.3	34 2	25 2	28 0	67.7	34 3	77.2	80 6	40 0	27.4	93 0	93 0	44 9	28 3	85 0	89 1	46 4	28 3	82 9
05/19/93	16 00	1103.3	76.7	81.4	36 5	82 1	92.5	39 7	27.4	85 8	92 7	44 3	28 9	61.3	34 2	25 2	28 0	67 5	34 2	77 3	81 2	39 7	27 2	92 9	93.0	44 7	28 2	83 7	89 0	46 4	28 3	81 3
05/19/93	20.00	1107.3	76.4	81.5	36.9	81.9	92.5	39 8	27.5	85.9	92 5	44.4	29 0	61 6	34 1	25.1	28 3	67.7	34 7	76 9	80 9	40 1	27 5	93 3	93 6	44 9	28 3	82 9	89 6	46 6	28 5	81 4
05/20/93	00.00	1111.3	75 8	81.4	37.3	82.1	91 3	40 1	27.6	85 6	92 3	44.7	29 1	61 8	34 3	25 3	28 2	68 0	35 1	76 6	81 3	40 6	27 5	92 9	93 2	45 2	28 4	82 7	89 1	47 0	28 6	70 1
05/20/93	04:00	1115 3	75 5	81.3	37.3	81.8	91.9	40 3	27.7	85.3	92.4	44 9	29.3	61.9	34 6	25 3	28.3	68.1	35 2	76 4	81 0	40 8	27 5	92 7	93 0	45 4	28 6	82 3	89 3	47 2	28 7	77 2
05/20/93	08.00	1119.3	74.9	81.2	37.5	81.7	91.3	40 7	28 0	84.9	91.9	45.3	29 4	62 0	34 9	25 6	28 2	68 4	35 5	75 5	80 8	41 4	28 0	92 2	92 4	46 0	28 9	81 9	88 3	47 6	28 9	76 4
05/20/93	12.00	1123.3	73.4	79 8	36 7	79.7	90.1	39 8	27.4	83.6	90.5	44 4	28 9	61.2	34 3	25 0	27.8	67.4	34 6	74 5	79 7	40 5	27 3	90 8	91 2	45 3	28 4	80 3	87.2	46 8	28 5	78 4
05/20/93	16 00	1127.3	73 0	79 6	37.1	79.9	89.6	40 2	27.7	83.5	90.4	44 8	29 3	61.4	34 8	25.4	28 1	67.4	35 0	73 8	79 6	40.7	27 5	90 4	90 7	45 5	28 5	79 8	87 0	47 0	28 6	74 4
05/20/93	20.00	1131.3	72.5	79 5	37.8	79.7	89.3	40.3	27.9	83.5	90 2	44.7	29.4	61 6	34 5	25 3	28 3	67.7	35 3	73 7	79 9	40 9	27 7	90 3	90 9	45 6	28 6	81 4	86 9	47 1	28 7	79 9
05/21/93	00 00	1135.3	72.1	79 6	37.9	80 4	87.1	40 7	28 0	83.9	90 6	45 1	29 5	61.9	34.9	25 5	28 5	67.9	35 6	73 2	78 8	41.3	27 8	90 8	91.3	46 0	28 8	80 2	87.1	47 5	28 9	79 2
05/21/93	04 00	1139.3	71.6	79 3	37.9	79 8	87.6	40 8	28 1	83 6	90.6	45 2	29 6	61.8	35 1	25 5	28 5	67 9	35 7	72 3	79 6	41 4	27 9	90 9	91.3	46 3	28 9	80 3	88 7	47 6	29 0	75 4
05/21/93	08.00	(	71 0	79 3	38.1	80 0	86 9	41 3	28.3	83.5	90 9	45.7	29 8	61.9	35 6		28 4	68 1	35 9	72 0	79 7	42 1	28 2	91 0	91 1	46 8	29 3	80 6	86 3		29 2	76 8

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
	Maximum Temp.--		78.5	84.2	42.3	86.3	85.5	45.4	32.0	112.2	86.8	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.8	82.0	84.7	48.7	31.9	86.3	88.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
06/01/93	04:00	1403.3	62.0	70.6	42.3	71.4	80.5	45.2	31.6	106.3	76.4	48.4	33.4	58.9	38.6	27.5	30.5	64.4	42.6	62.1	74.9	48.4	31.4	80.2	82.4	51.4	32.3	76.2	83.1	48.9	31.7	69.3
06/01/93	08:00	1407.3	61.7	70.6	42.3	71.3	80.3	45.4	31.8	106.5	76.7	48.7	33.4	58.9	38.7	27.5	30.3	64.5	42.6	61.7	74.8	48.7	31.7	80.3	82.2	51.6	32.5	75.9	83.0	49.0	31.7	65.8
06/01/93	12:00	1411.3	61.4	69.8	41.6	70.5	80.2	44.9	31.4	106.7	76.9	48.2	33.2	56.3	38.4	27.3	30.2	63.8	41.9	61.0	73.9	48.1	31.2	79.3	81.3	51.2	32.2	75.6	80.4	48.6	31.5	65.7
06/01/93	16:00	1415.3	62.1	69.7	41.7	71.4	80.4	45.0	31.6	107.9	77.2	48.2	33.5	58.3	38.5	27.5	30.3	63.6	41.9	62.2	73.9	48.0	31.3	79.0	80.9	50.9	32.3	76.8	82.6	48.7	31.6	69.3
06/01/93	20:00	1419.3	62.5	69.9	42.1	71.6	80.2	44.8	31.6	108.5	76.9	47.9	33.3	58.4	38.0	27.3	30.3	63.8	42.2	63.0	74.3	48.0	31.3	78.9	81.3	50.6	32.2	76.6	82.3	48.2	31.4	69.4
06/02/93	00.00	1423.3	63.0	70.2	42.3	72.2	80.5	45.2	31.8	109.3	77.7	48.3	33.6	58.8	38.6	27.5	30.4	64.0	42.5	63.4	74.4	48.4	31.5	79.0	81.5	51.1	32.4	77.0	82.6	48.7	31.7	67.8
06/02/93	04:00	1427.3	62.8	70.2	42.3	72.3	80.4	45.1	31.8	109.8	77.8	48.4	33.7	58.7	38.6	27.5	30.5	63.9	42.4	63.2	74.3	48.3	31.6	78.9	81.4	51.0	32.5	77.2	82.6	48.7	31.7	69.5
06/02/93	08.00	1431.3	62.9	70.0	42.2	72.2	80.5	45.3	31.8	110.2	78.1	48.4	33.7	58.7	38.7	27.7	30.4	63.8	42.4	63.3	74.0	48.4	31.7	78.8	81.3	51.1	32.5	77.3	82.7	48.8	31.8	70.5
06/02/93	12:00	1435.3	62.7	69.5	41.7	72.9	80.0	44.9	31.7	110.2	77.9	48.1	33.5	58.1	38.4	27.5	30.1	63.4	41.9	62.8	73.4	48.2	31.6	78.2	80.4	50.8	32.5	77.0	82.0	48.4	31.6	69.9
06/02/93	16.00	1439.3	62.5	69.1	41.8	73.7	79.9	44.7	31.6	110.8	77.7	47.9	33.5	57.9	38.3	27.3	30.0	63.1	41.8	63.0	73.1	47.6	31.3	77.7	80.5	50.4	32.3	77.0	81.9	48.2	31.5	70.2
06/02/93	20.00	1443.3	62.6	69.6	42.2	74.4	80.0	44.8	31.8	111.3	78.4	47.9	33.7	58.3	38.0	27.4	30.4	63.4	42.2	63.2	73.9	47.8	31.6	77.8	81.1	50.3	32.4	77.2	82.6	48.0	31.6	73.3
06/03/93	00:00	1447.3	62.6	69.8	42.2	72.8	80.2	45.1	32.0	111.9	79.8	48.2	33.8	58.5	38.5	27.6	30.5	63.5	42.3	63.2	73.9	48.0	31.7	78.0	81.0	50.6	32.5	77.7	82.9	48.4	31.8	73.4
06/03/93	04:00	1451.3	62.4	69.7	42.3	73.1	80.2	45.1	32.0	112.2	80.3	48.3	33.9	58.6	38.6	27.7	30.5	63.5	42.3	63.0	73.9	47.9	31.8	77.8	80.9	50.6	32.6	77.3	83.0	48.5	31.9	73.3
06/03/93	08:00	1455.3	62.3	69.8	42.1	73.1	80.2	45.1	32.0	111.3	80.7	48.3	33.8	58.4	38.6	27.7	30.3	63.5	42.2	62.7	73.6	47.9	31.9	77.9	80.6	50.7	32.7	77.2	82.6	48.5	31.8	72.7
06/03/93	12:00	1459.3	62.4	69.2	41.7	73.0	79.8	44.8	31.9	112.1	80.3	48.1	33.8	58.0	38.5	27.5	30.2	63.0	41.8	62.5	72.9	47.6	31.8	77.4	80.2	50.4	32.7	76.3	81.2	48.2	31.7	72.6

Table B-4 Ground Electrode and Outside Thermowell Temperatures (Recorded by Data Logger) [Continued]

Date	Time	Elapsed Time	A2A	A2B	A2C	A3A	A3B	A3C	A3D	A4A	A4B	A4C	A4D	TW7B	TW7C	TW7D	C6D	C1B	C1C	C2A	C2B	C2C	C2D	C3A	C3B	C3C	C3D	C4A	C4B	C4C	C4D	C6B
	Maximum Temp.--		79.5	84.2	42.3	86.3	95.5	45.4	32.0	112.2	96.6	48.7	33.9	62.0	38.7	27.7	30.5	68.4	42.6	82.0	84.7	48.7	31.9	96.3	98.5	52.0	32.7	92.1	96.3	49.4	31.9	90.1
05/26/93	20:00	1275.3	66.9	74.4	40.8	74.5	83.0	43.8	29.8	83.6	80.0	47.5	31.5	60.4	37.3	26.7	29.6	67.0	39.6	65.2	78.0	48.3	29.6	85.6	87.0	50.7	30.6	79.3	83.4	48.9	30.4	69.0
05/27/93	00.00	1279.3	66.5	74.3	41.0	74.2	83.2	44.0	30.0	83.8	79.8	47.8	31.7	60.5	37.6	26.7	29.7	67.1	39.8	64.7	78.0	48.5	29.6	85.4	86.9	51.2	30.9	78.9	83.2	49.2	30.7	70.6
05/27/93	04.00	1283.3	66.2	74.1	41.0	73.9	83.7	44.2	30.1	84.1	79.4	47.8	31.9	60.5	37.7	26.8	29.8	67.0	39.9	64.1	77.9	48.6	29.9	85.2	86.7	51.3	31.0	78.6	83.0	49.3	30.8	68.6
05/27/93	08.00	1287.3	65.7	73.9	41.1	73.7	83.0	44.2	30.1	84.6	79.1	47.9	31.9	60.4	37.8	26.8	29.7	66.9	40.0	63.4	77.7	48.7	30.0	84.9	86.4	51.5	31.0	78.3	81.8	49.4	30.8	68.7
05/27/93	12:00	1291.3	64.8	73.2	40.5	72.9	82.7	43.6	29.7	84.9	78.0	47.4	31.5	59.8	37.3	26.4	29.4	66.1	39.5	62.2	77.0	48.1	29.7	84.1	85.5	51.0	30.8	77.6	80.3	48.7	30.4	69.0
05/27/93	16.00	1295.3	64.6	72.8	40.5	71.9	82.6	43.7	29.8	85.1	77.6	47.4	31.7	59.6	37.4	26.3	29.3	65.9	39.5	61.8	76.7	48.0	29.6	83.5	85.0	50.9	30.7	76.8	82.3	48.6	30.3	64.6
05/27/93	20.00	1299.3	64.3	73.2	41.0	72.3	82.5	44.0	30.0	85.8	77.7	47.5	31.8	59.9	37.3	26.6	29.6	66.3	40.2	61.6	77.3	48.3	29.9	83.4	85.3	51.1	30.6	76.7	79.3	48.7	30.5	64.5
05/28/93	00.00	1303.3	64.2	73.3	41.3	72.3	82.8	44.4	30.2	87.0	78.2	48.0	32.1	60.2	37.8	26.8	29.8	66.4	40.4	61.6	77.4	48.6	30.2	83.6	85.4	51.6	31.2	77.2	81.6	49.2	30.9	66.5
05/28/93	04.00	1307.3	64.2	73.0	41.3	72.6	82.6	44.4	30.2	87.9	78.2	47.9	32.1	60.0	37.8	26.9	29.8	66.2	40.5	61.1	77.1	48.5	30.1	83.4	85.2	51.6	31.1	77.2	82.2	49.2	30.8	69.7
05/28/93	08:00	1311.3	63.9	72.9	41.4	72.9	82.5	44.5	30.3	89.1	78.1	48.0	32.2	60.0	37.9	26.9	29.9	66.2	40.6	61.1	76.9	48.3	30.2	83.6	85.2	51.7	31.2	77.5	81.4	49.1	30.9	70.3
05/28/93	12:00	1315.3	63.7	72.4	41.0	72.2	82.3	44.4	30.2	89.9	77.0	48.0	32.0	59.6	37.9	27.0	29.7	65.9	40.3	60.9	75.2	48.3	30.2	83.3	84.6	51.7	31.2	77.2	82.4	49.1	30.8	72.2
05/28/93	16.00	1319.3	63.3	72.2	41.2	71.9	81.9	44.0	30.2	90.8	76.0	47.5	32.0	59.4	37.1	26.4	29.7	65.5	40.4	61.2	76.3	47.8	30.0	82.7	84.5	51.0	30.9	76.9	82.9	48.4	30.5	74.4
05/28/93	20:00	1323.3	62.8	72.5	41.6	71.8	82.2	44.6	30.5	91.8	76.1	48.0	32.3	59.8	37.8	26.8	30.1	65.8	40.9	61.5	76.7	48.4	30.3	82.8	84.7	51.6	31.3	77.1	83.1	49.1	31.0	73.5
05/29/93	00.00	1327.3	62.6	72.4	41.6	71.7	81.4	44.7	30.6	92.5	76.7	48.2	32.5	59.9	38.0	27.0	30.1	65.8	41.2	60.9	76.1	48.5	30.5	82.1	84.3	51.8	31.5	77.2	83.3	49.3	31.1	72.8
05/29/93	04:00	1331.3	62.6	72.3	41.6	71.6	82.1	44.7	30.5	93.4	76.8	48.2	32.4	59.7	37.9	27.0	30.1	65.7	41.2	60.7	76.3	48.3	30.5	82.1	84.0	51.8	31.5	77.2	83.4	49.3	31.1	74.9
05/29/93	08:00	1335.3	62.6	72.1	41.6	71.6	82.0	44.8	30.5	94.4	76.9	48.3	32.4	59.7	38.1	27.1	30.3	65.6	41.3	60.9	76.4	48.3	30.5	82.0	83.8	51.8	31.6	77.3	83.1	49.3	31.1	77.9
05/29/93	12:00	1339.3	62.4	71.8	41.3	70.9	81.8	44.7	30.6	94.8	76.7	48.2	32.4	59.3	38.0	27.0	30.1	65.4	41.1	60.7	75.5	48.3	30.5	81.6	83.2	51.8	31.7	77.1	82.8	49.1	31.1	77.8
05/29/93	16.00	1343.3	62.3	71.3	41.2	70.7	81.4	44.4	30.4	95.6	76.0	47.9	32.3	59.0	37.8	26.7	29.9	64.9	41.1	60.8	75.5	47.8	30.3	81.1	82.9	51.2	31.3	77.4	82.6	48.8	30.8	75.2
05/29/93	20:00	1347.3	62.3	71.6	41.8	71.2	81.5	44.6	30.7	96.8	76.1	48.0	32.4	59.3	37.5	26.7	30.3	65.2	41.7	61.2	76.0	48.0	30.5	81.2	83.3	51.4	31.4	77.5	83.1	48.7	30.9	73.7
05/30/93	00 00	1351.3	62.2	71.9	41.9	71.2	81.7	45.0	30.9	97.3	76.3	48.3	32.8	59.6	38.0	27.2	30.2	65.4	41.9	61.1	76.1	48.3	30.7	81.4	83.3	51.8	31.7	77.4	83.5	49.2	31.2	73.2
05/30/93	04.00	1355.3	62.2	71.6	41.9	71.1	81.6	45.0	30.9	98.0	76.4	48.4	32.8	59.5	38.2	27.2	30.3	65.2	41.9	61.6	75.9	48.3	30.7	81.4	83.2	51.8	31.7	77.1	83.2	49.3	31.3	74.3
05/30/93	08.00	1359.3	62.1	71.7	42.1	71.4	81.7	45.2	31.1	98.8	76.1	48.6	32.9	59.6	38.3	27.4	30.5	65.4	42.1	61.5	75.9	48.6	31.0	81.7	83.5	52.0	32.0	77.5	83.5	49.4	31.5	72.9
05/30/93	12.00	1363.3	61.9	71.3	41.7	70.6	81.5	45.1	31.0	99.0	75.9	48.5	32.7	59.2	38.4	27.4	30.1	65.0	41.8	60.4	75.2	48.5	30.8	81.1	82.8	51.9	31.9	76.2	82.4	49.3	31.4	72.5
05/30/93	16 00	1367.3	61.5	70.8	41.3	70.1	81.0	44.7	30.8	99.5	75.1	48.1	32.8	58.6	38.0	27.0	29.9	64.4	41.6	59.9	74.9	48.0	30.6	80.6	82.2	51.3	31.7	76.2	82.7	48.8	31.1	70.5
05/30/93	20 00	1371.3	61.7	70.9	41.9	70.4	81.0	44.7	31.0	100.4	75.0	47.9	32.8	58.7	37.7	26.9	30.2	64.6	42.1	60.6	75.4	48.0	30.8	80.4	82.5	51.1	31.7	75.8	82.7	48.6	31.2	68.1
05/31/93	00 00	1375.3	61.8	71.2	42.1	70.8	81.2	45.1	31.2	101.4	75.8	48.4	33.0	59.0	38.2	27.2	30.3	64.9	42.4	61.0	75.4	48.4	31.0	80.7	82.7	51.5	31.9	76.6	83.5	49.1	31.4	73.0
05/31/93	04.00	1379.3	62.1	71.1	42.1	70.7	81.2	45.2	31.2	102.2	76.0	48.4	33.1	59.1	38.5	27.3	30.4	64.8	42.4	61.3	75.4	48.4	31.1	80.8	82.8	51.6	32.0	76.3	83.3	49.2	31.6	72.7
05/31/93	08 00	1383.3	62.4	71.2	42.2	70.8	81.3	45.3	31.4	103.1	76.3	48.7	33.1	59.0	38.5	27.4	30.2	64.9	42.6	61.8	75.3	48.7	31.3	80.9	82.7	51.8	32.2	76.2	80.6	49.3	31.5	73.4
05/31/93	12.00	1387.3	62.0	70.4	41.6	70.4	80.7	44.8	31.2	103.4	76.4	48.2	33.0	58.5	38.3	27.2	30.2	64.2	42.0	61.5	74.5	48.2	31.0	80.3	82.2	51.4	32.1	76.1	82.9	48.8	31.3	77.0
05/31/93	16.00	1391.3	62.2	70.3	41.8	71.0	80.8	45.0	31.4	104.8	76.2	48.3	33.3	58.6	38.6	27.4	30.4	64.2	42.0	62.2	74.5	48.1	31.1	80.3	82.1	51.3	32.1	76.5	83.2	48.9	31.5	71.0
05/31/93	20 00	1395.3	62.0	70.5	42.1	71.3	80.0	45.0	31.5	105.4	75.8	48.3	33.2	58.7	38.3	27.4	30.5	64.3	42.4	62.5	74.9	48.3	31.3	80.3	82.5	51.2	32.1	75.9	83.4	48.8	31.7	69.5
06/01/93	00.00	3	62.1	70.6	42.3	71.4	80.5	45.2	31.6	105.9	76.5	48.5	33.4	59.0	38.6	[illegible]	30.5	64.5	42.6	62.4	75.0	48.5	31.4	80.4	82.6	51.4	32.2	76.3	83.5	[illegible]	31.7	69.9

Figure B-3

Excitor Electrode B2 Temperature

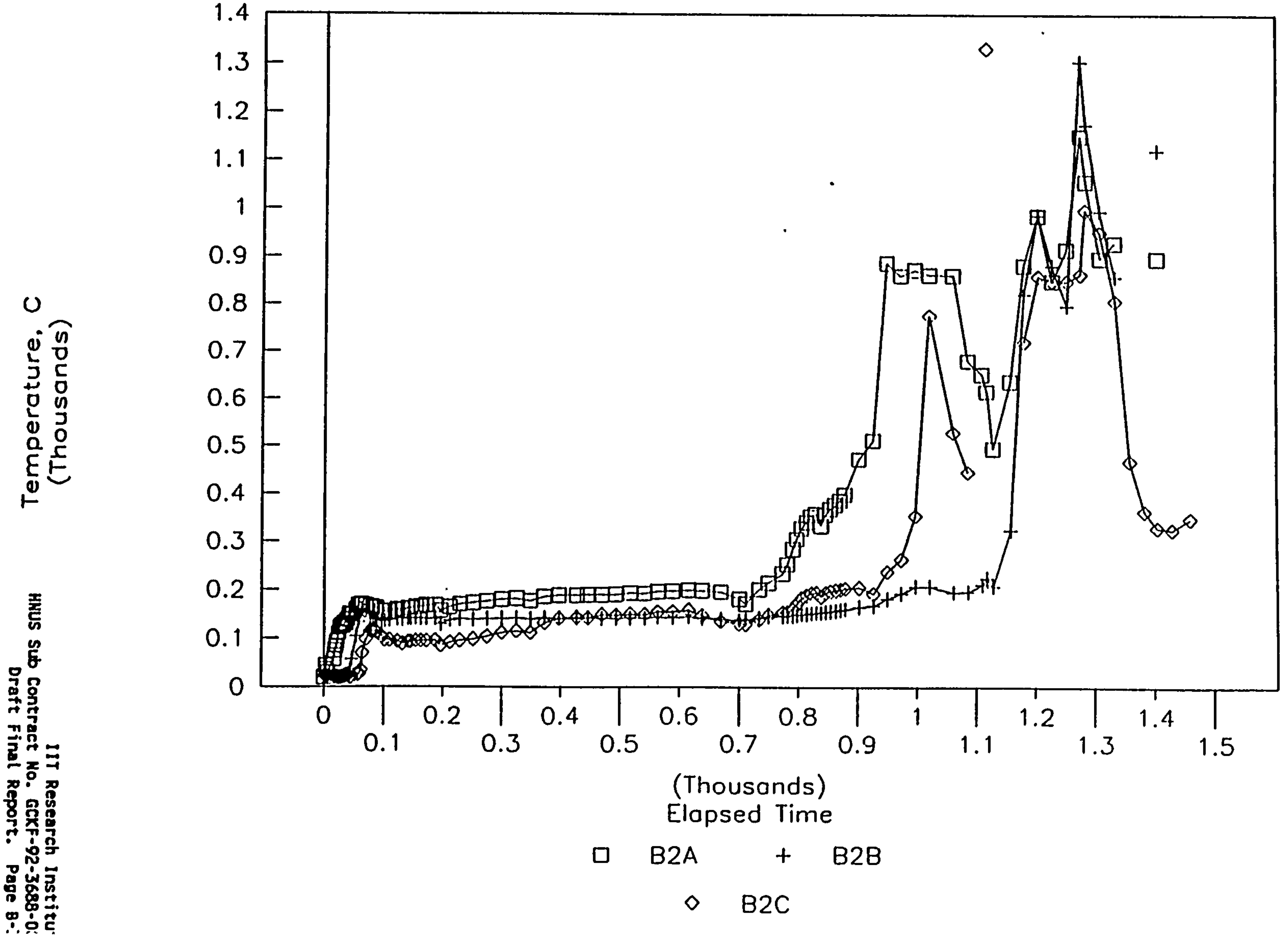


Figure B-2

Excitor Electrode B1 Temperature

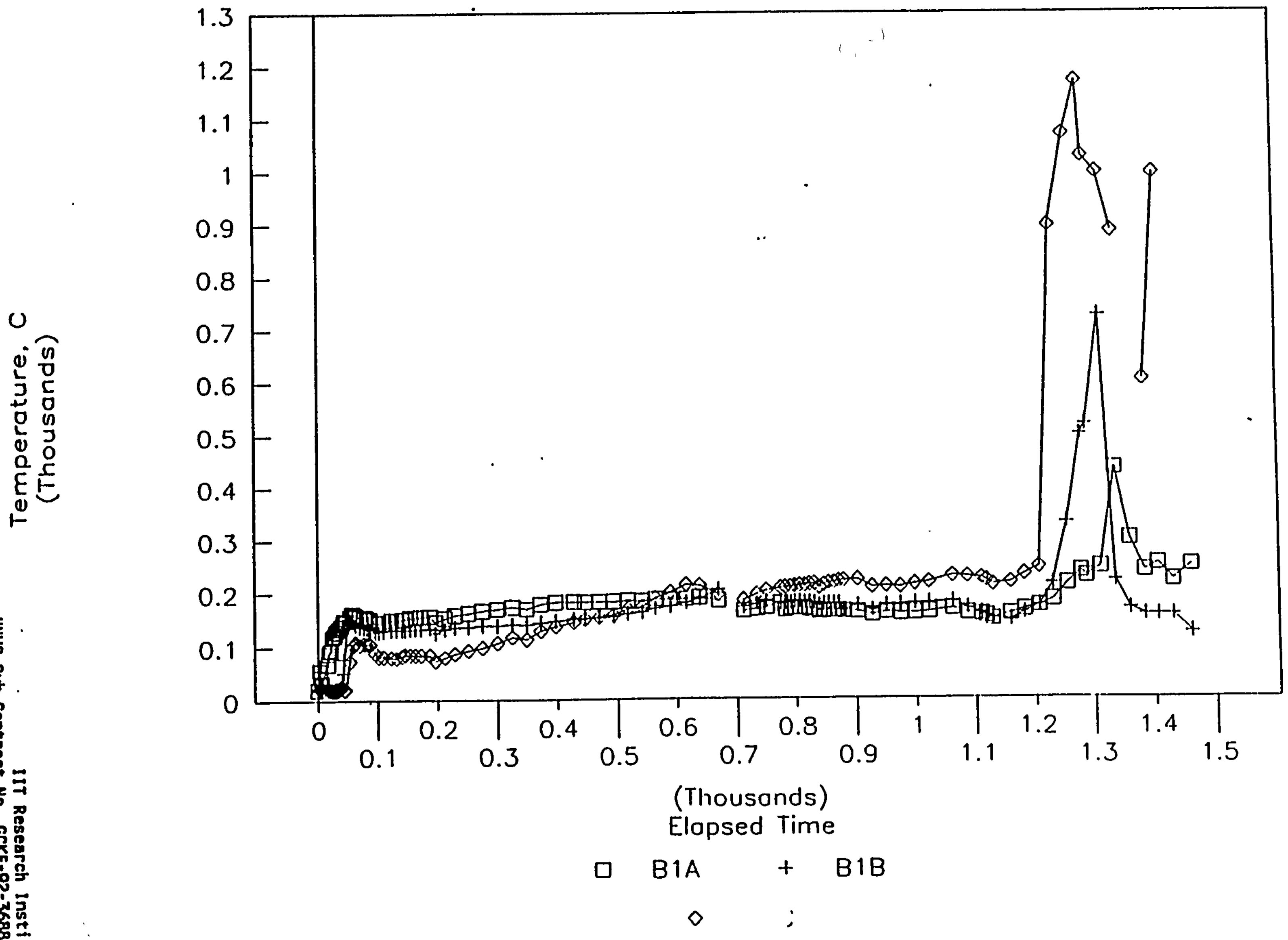


Figure B-5

Excitor Electrode B4 Temperature

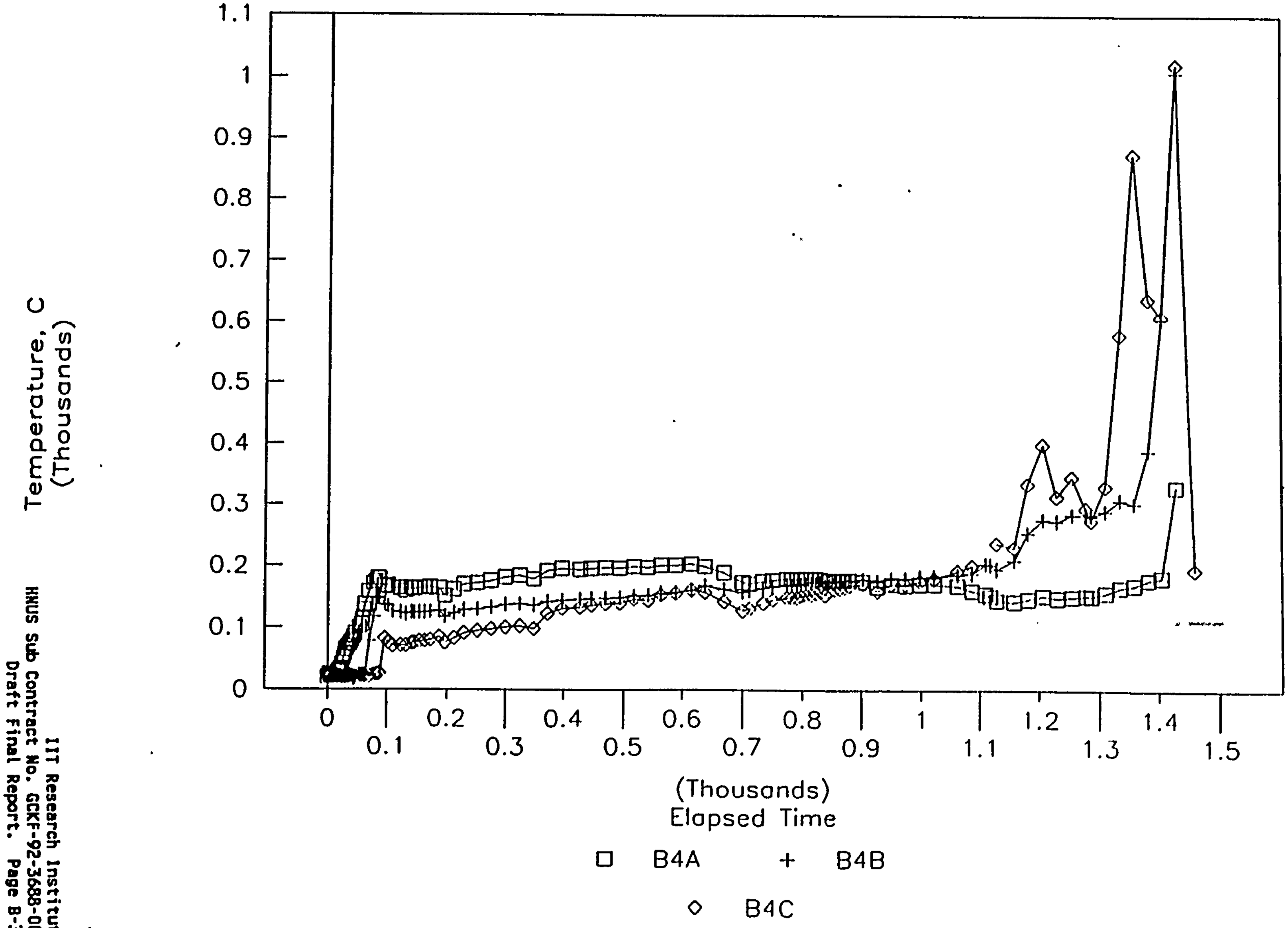


Figure B-4

Excitor Electrode B3 Temperature

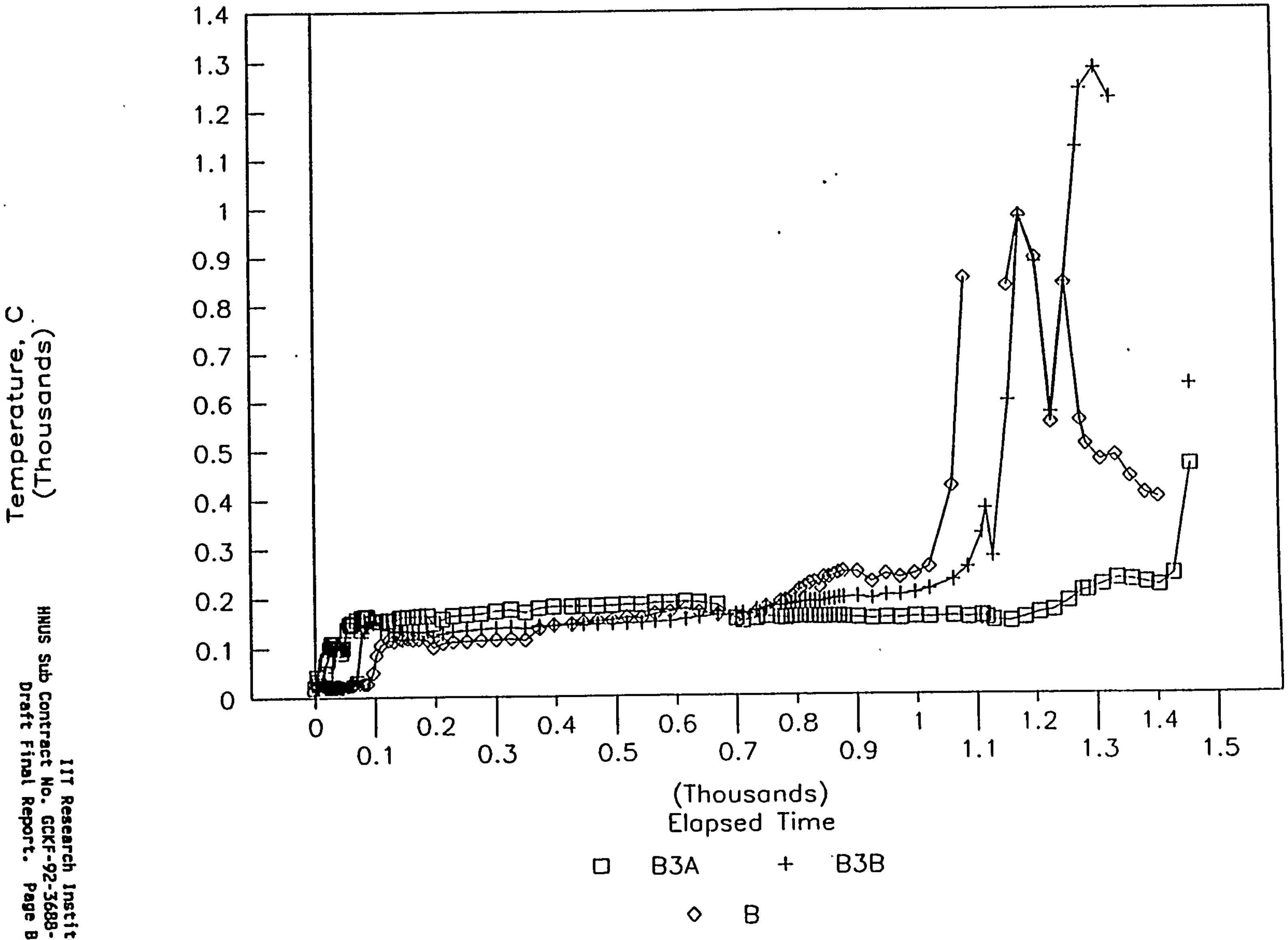


Figure B-7

GROUND ROW A (EAST ROW) TEMPERATURES

(12–ft Depth)

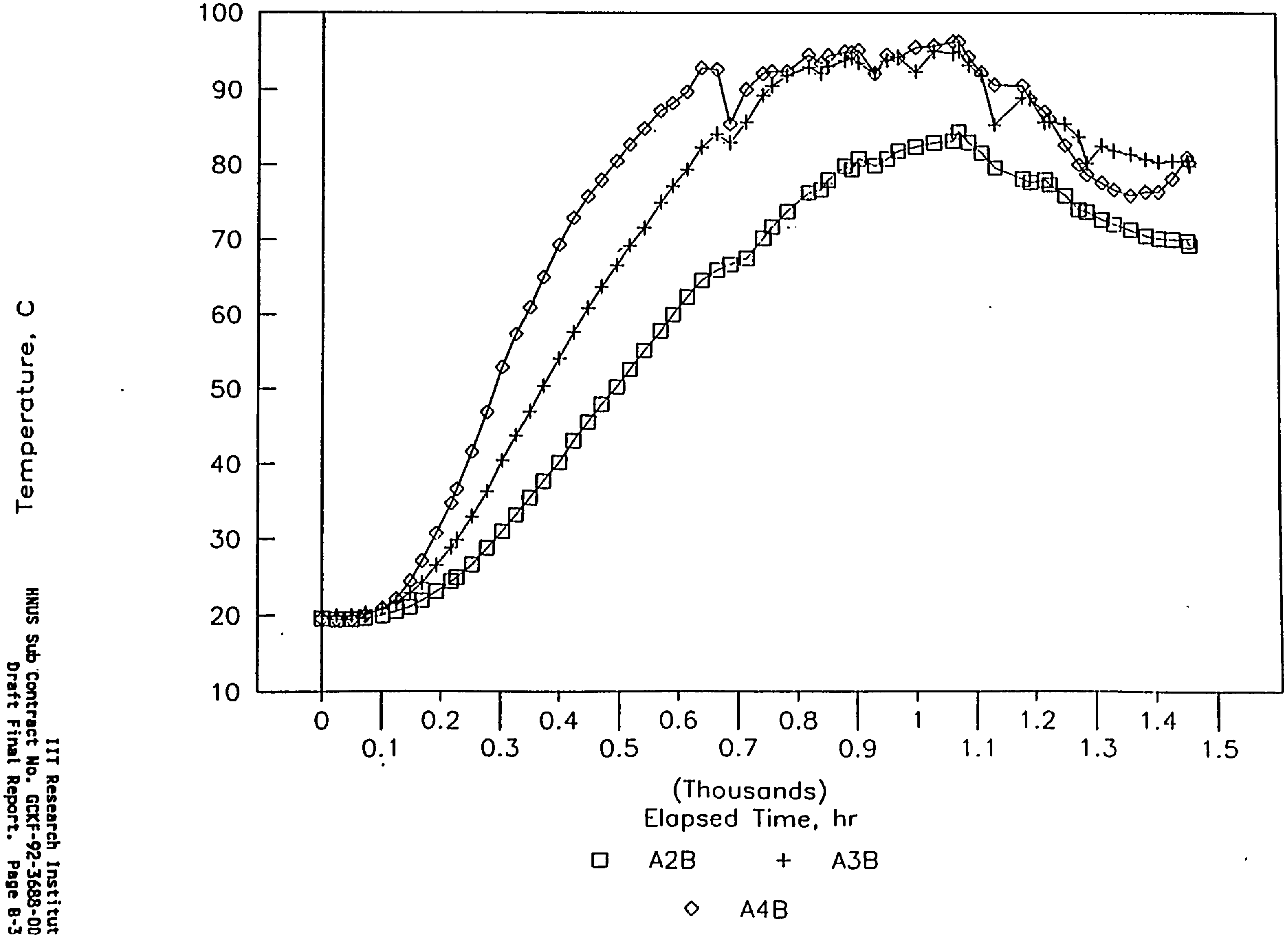


Figure B-6

GROUND ROW A (EAST ROW) TEMPERATURES

(1-ft Depth)

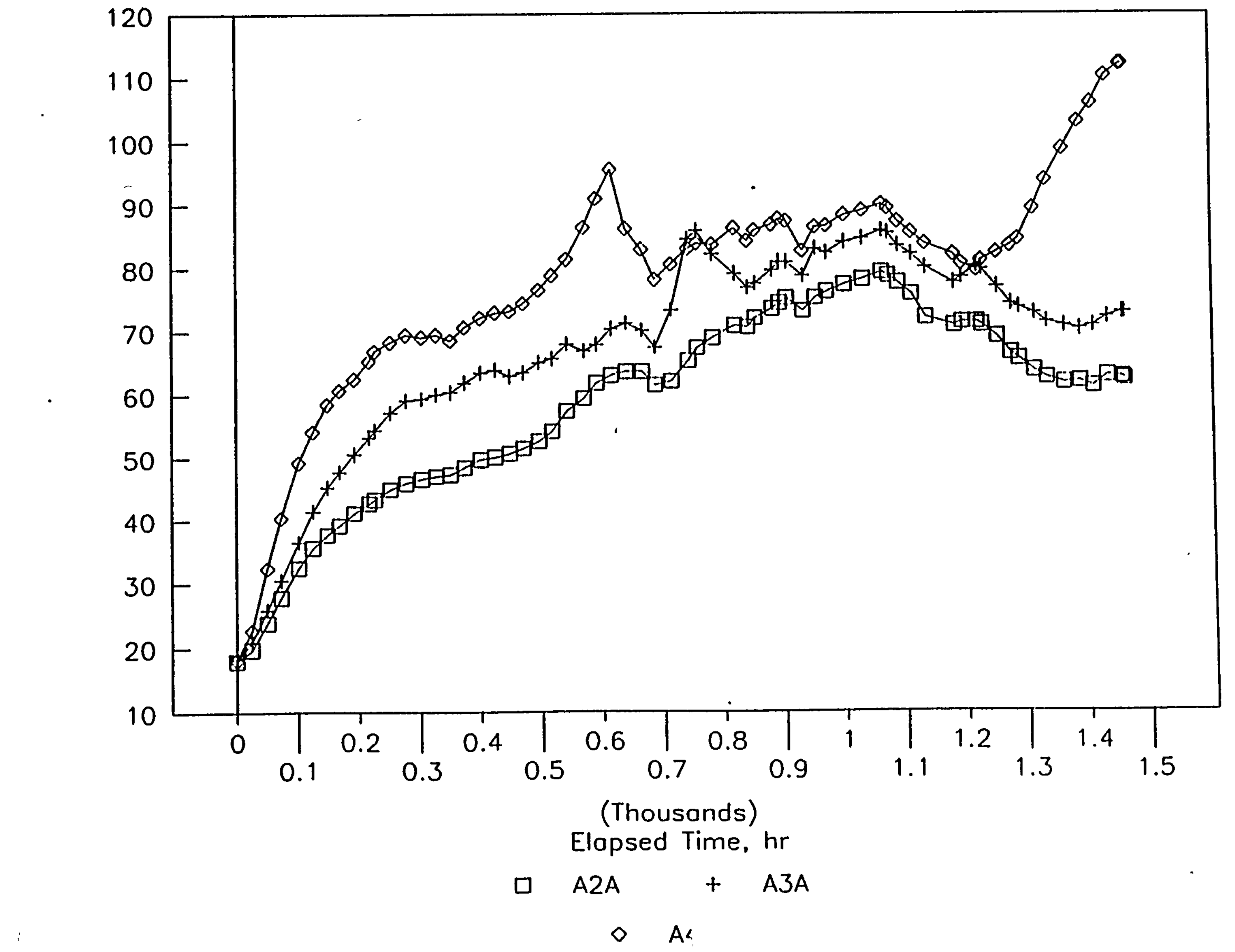


Figure B-9

GROUND ROW A (EAST ROW) TEMPERATURES

(29-ft Depth)

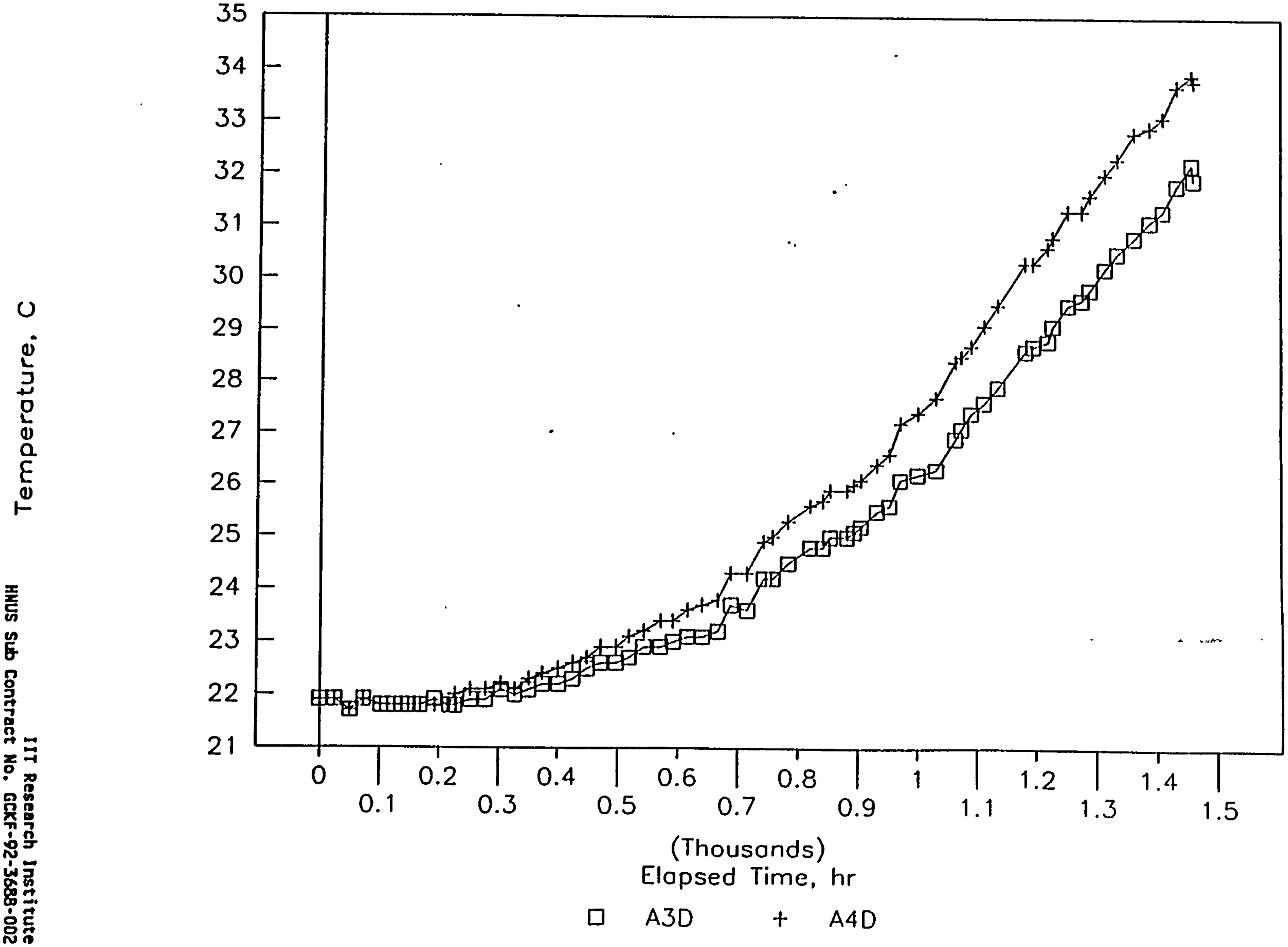


Figure B-8

GROUND ROW A (EAST ROW) TEMPERATURES

(24-ft Depth)

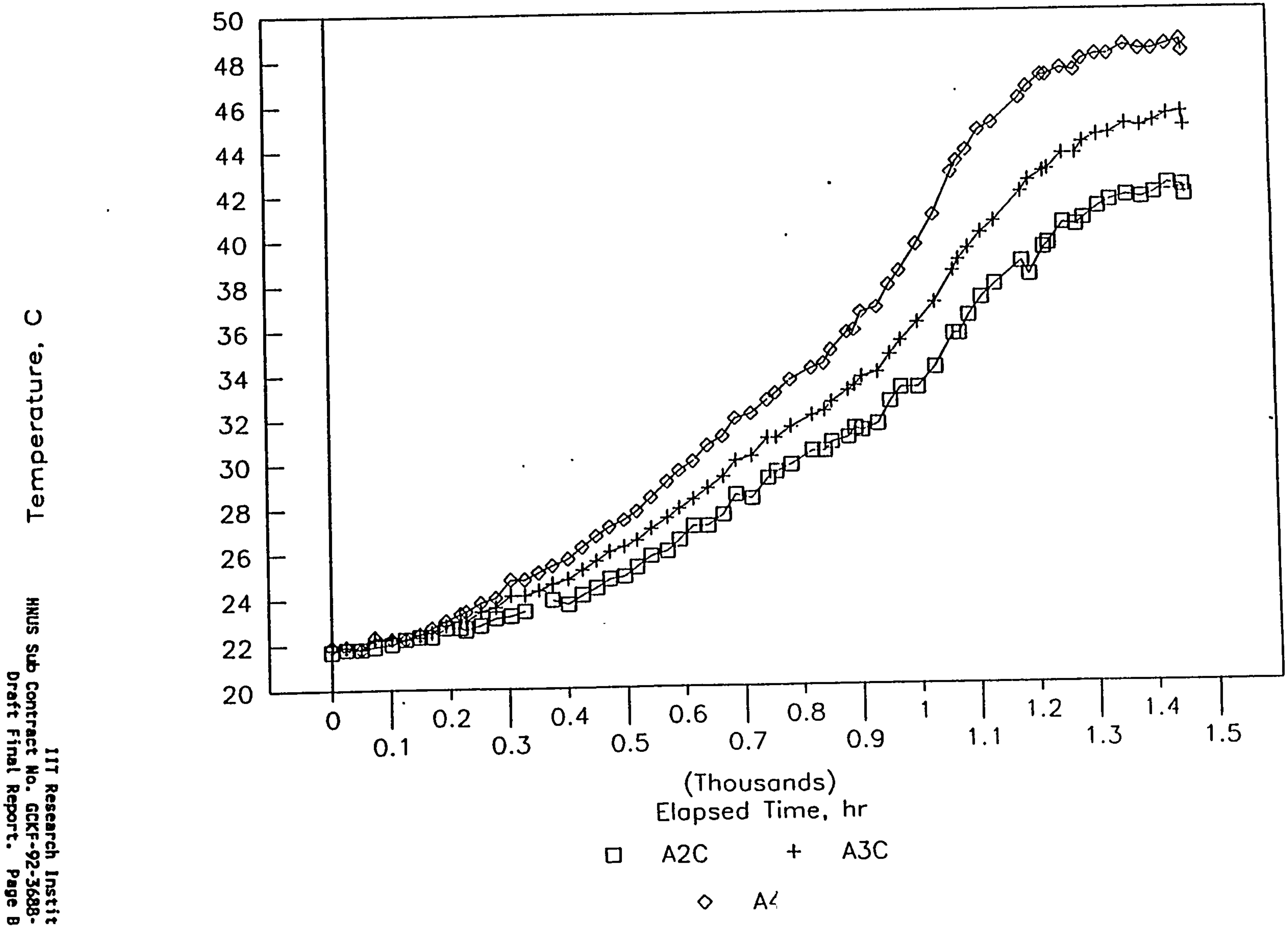


Figure B-11

GROUND ROW C (WEST ROW) TEMPERATURES

(12-ft Depth)

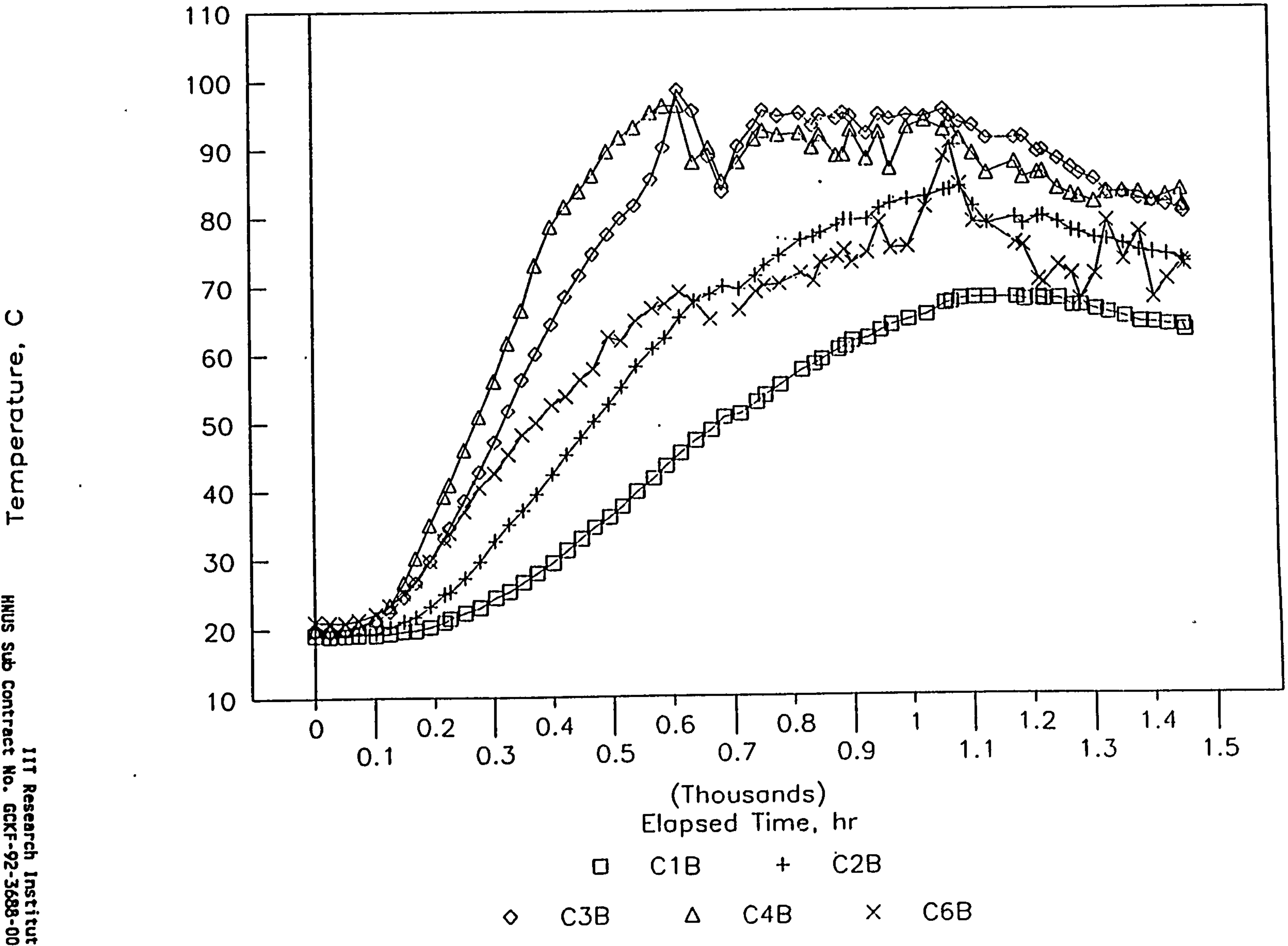


Figure B-10

GROUND ROW C (WEST ROW) TEMPERATURES

(1-ft Depth)

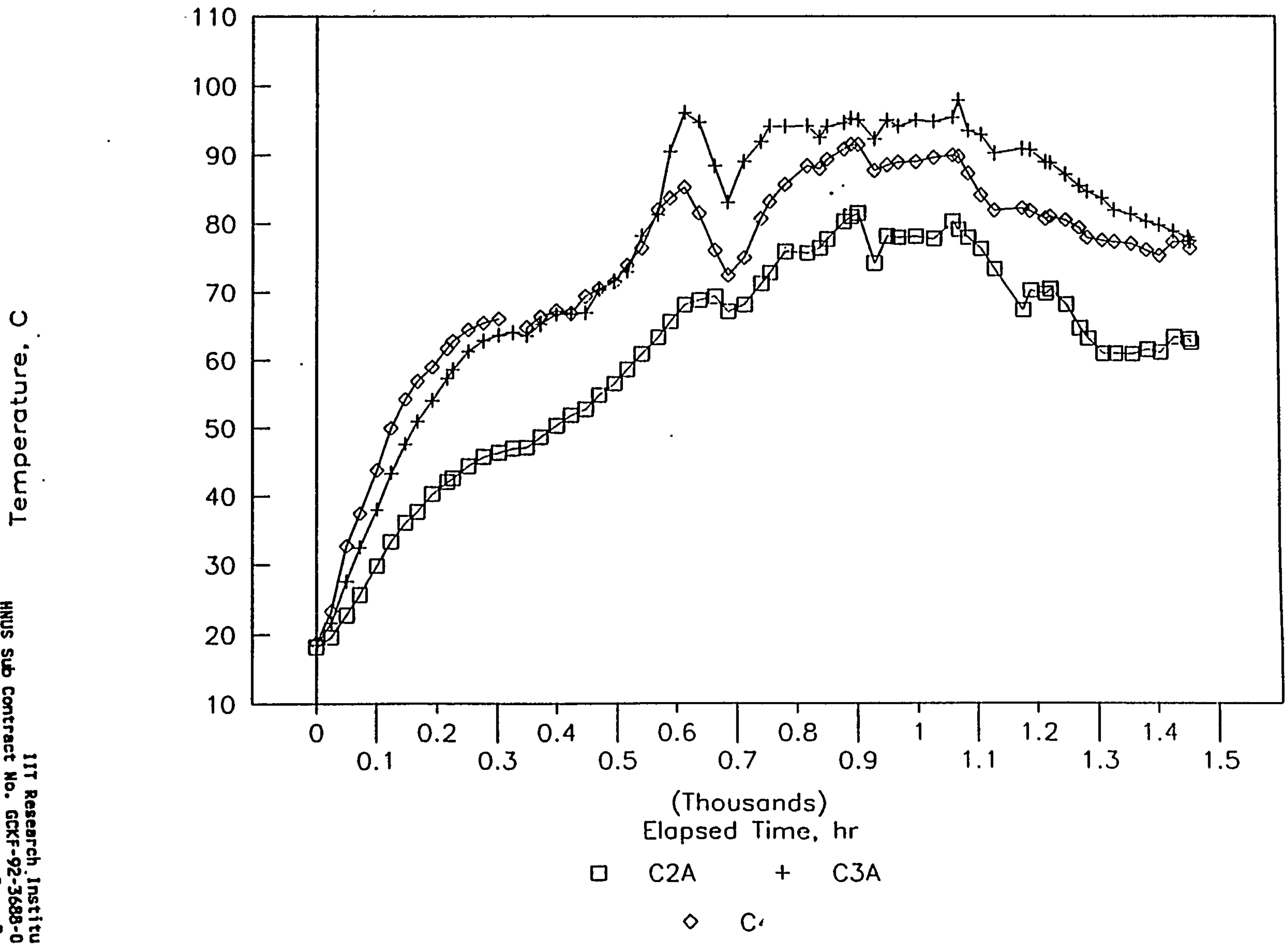


Figure B-12

GROUND ROW C (WEST ROW) TEMPERATURES

(24-ft Depth)

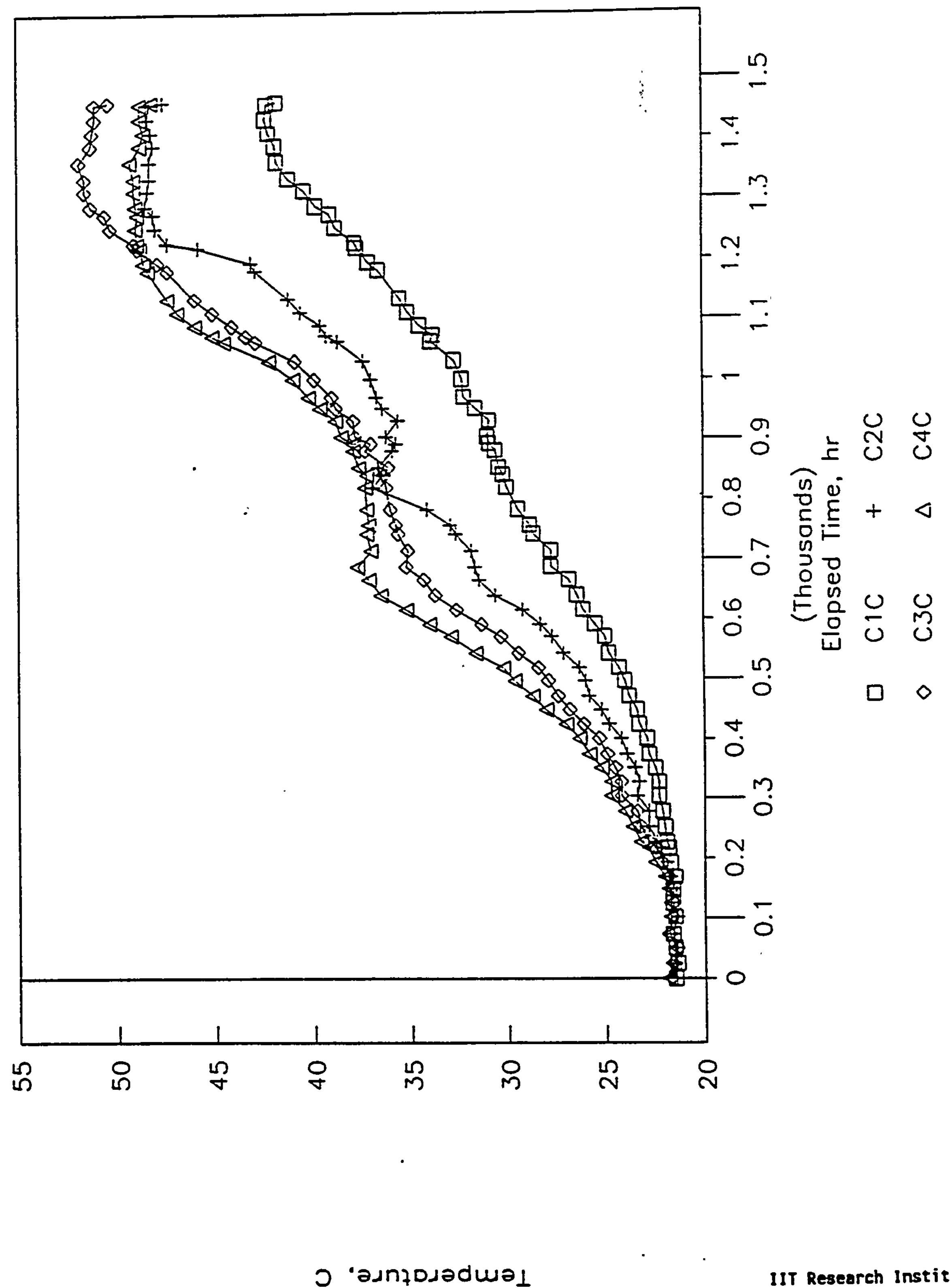


Figure B-13

GROUND ROW C (WEST ROW) TEMPERATURES

(29-ft Depth)

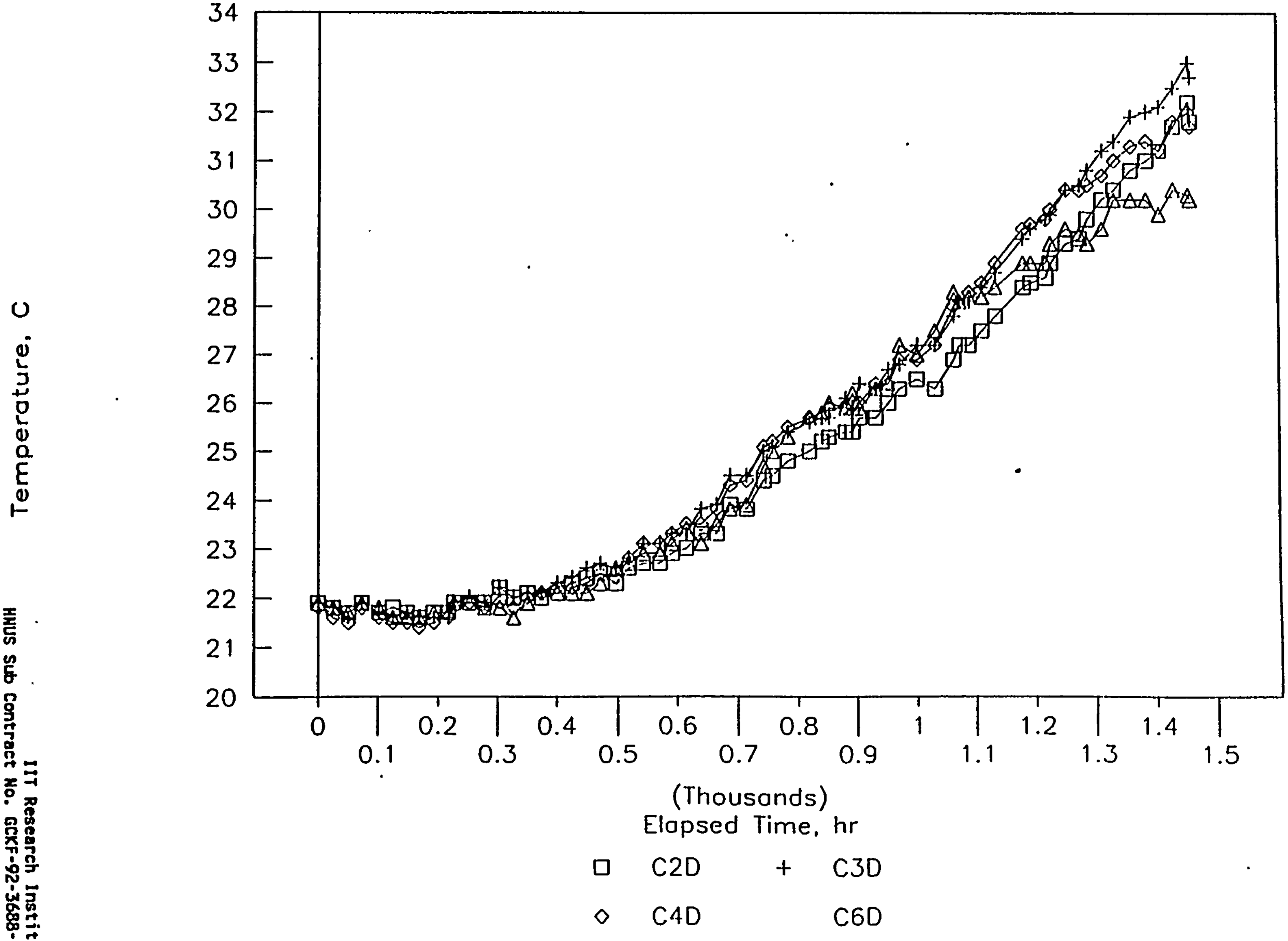


Figure B-14

Thermowell Temperature vs. Time

(1-foot depth)

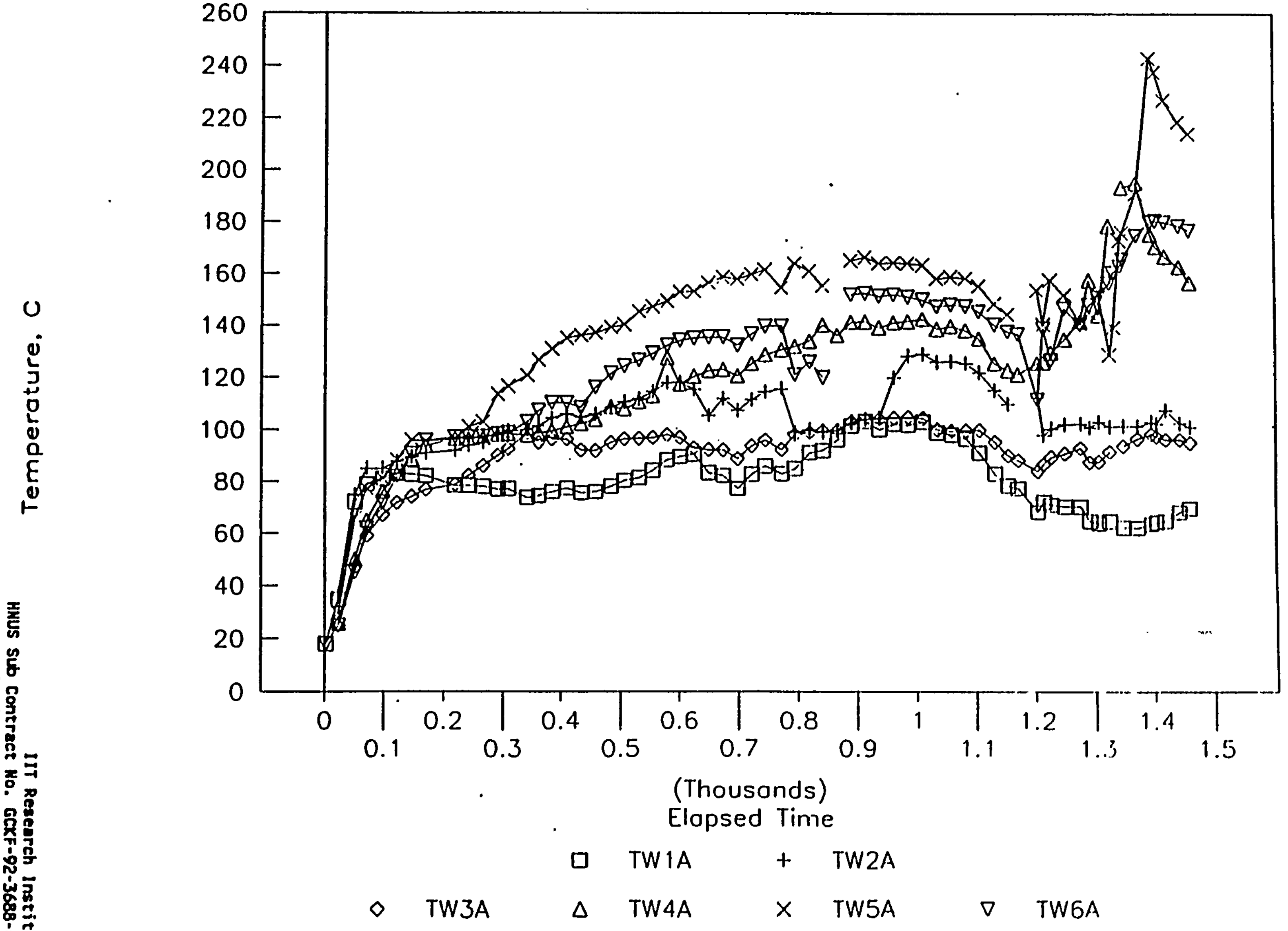


Figure B-15

Thermowell Temperature vs. Time

(12–foot depth)

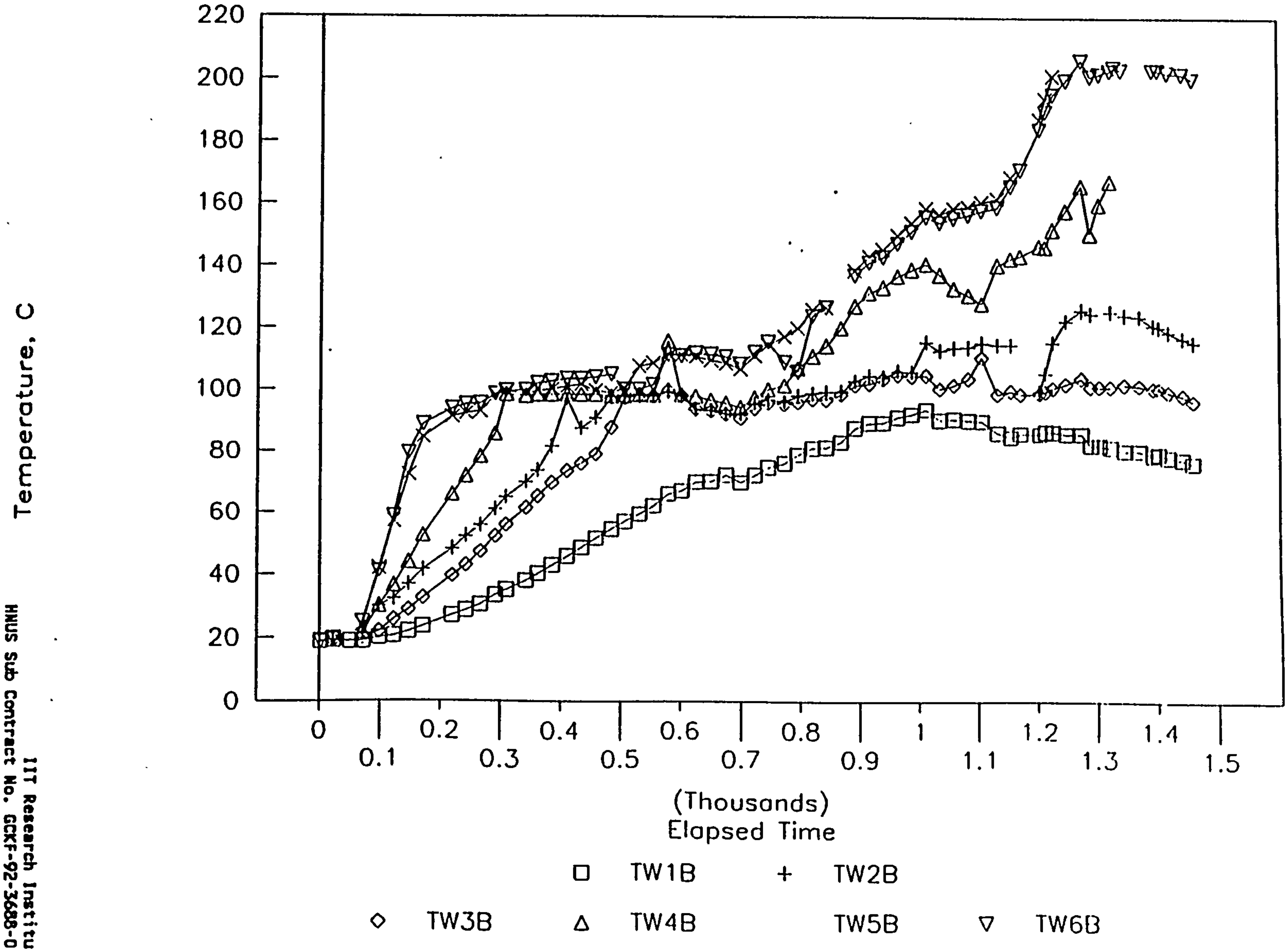


Figure B-16

Thermowell Temperature vs. Time

(24–foot depth)

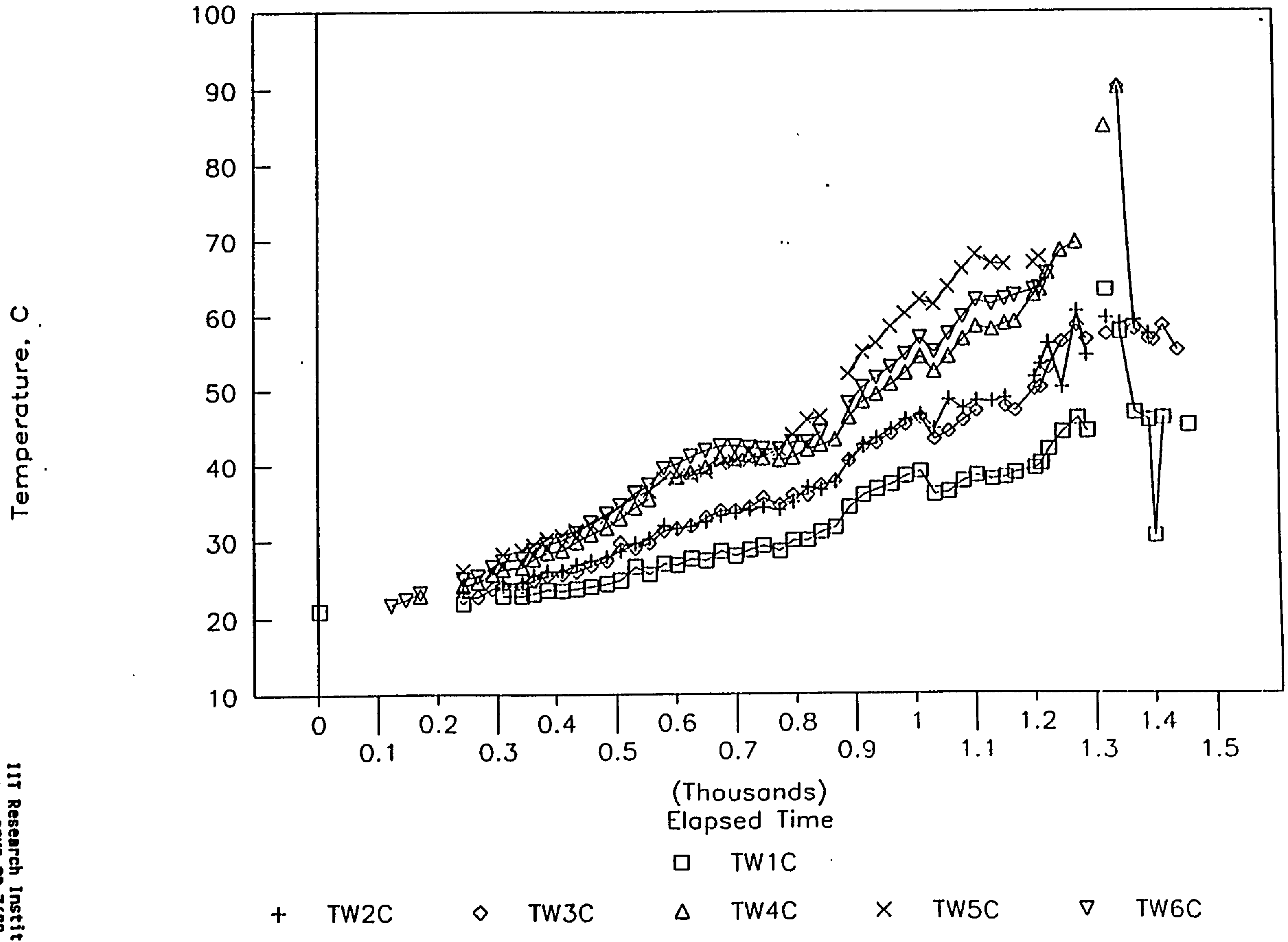


Figure B-17

Temperature Outside the Heated Array

(Depth of 12 ft)

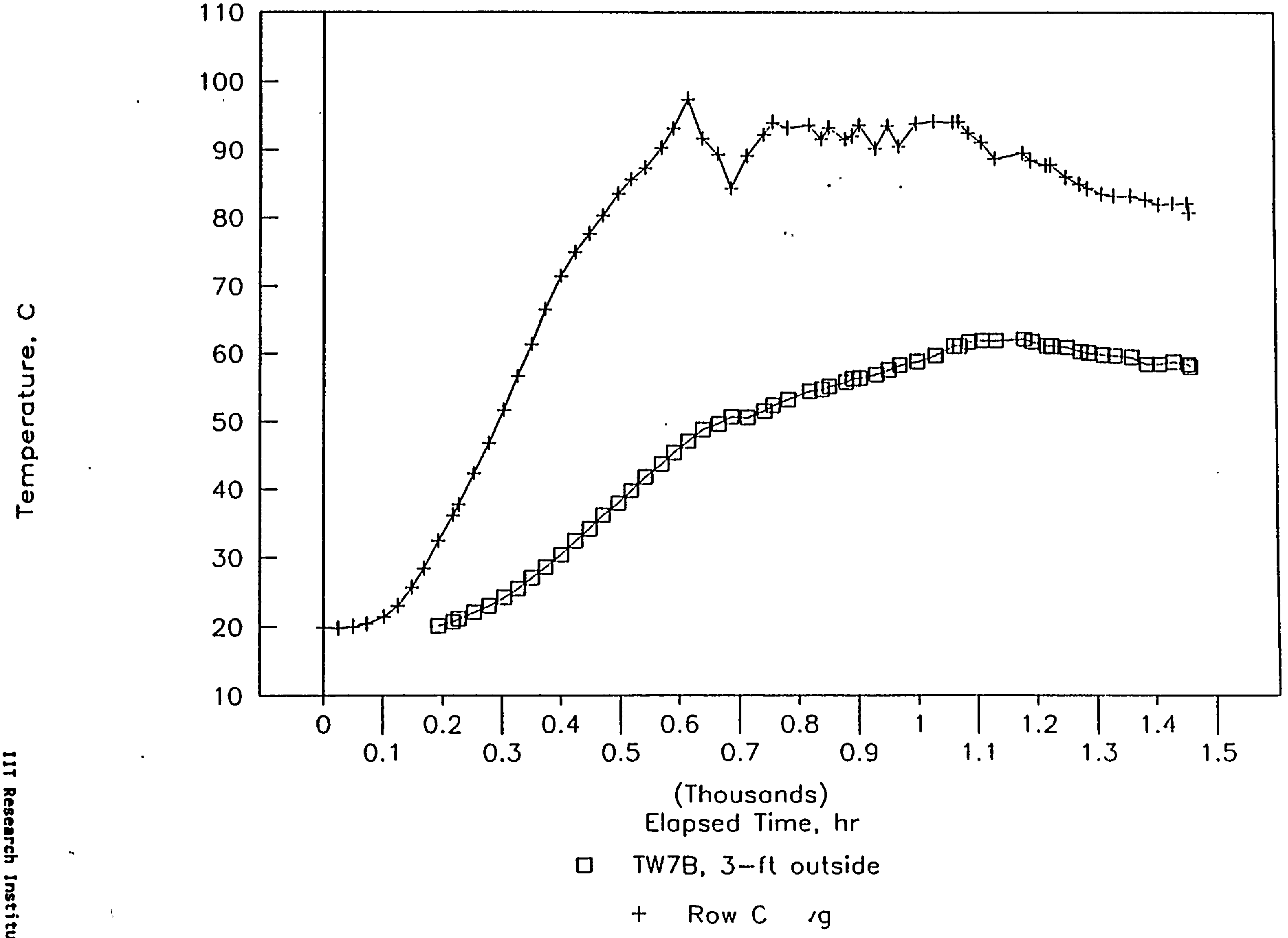


Figure B-18

Temperature Outside the Heated Array

(Depth of 24 ft)

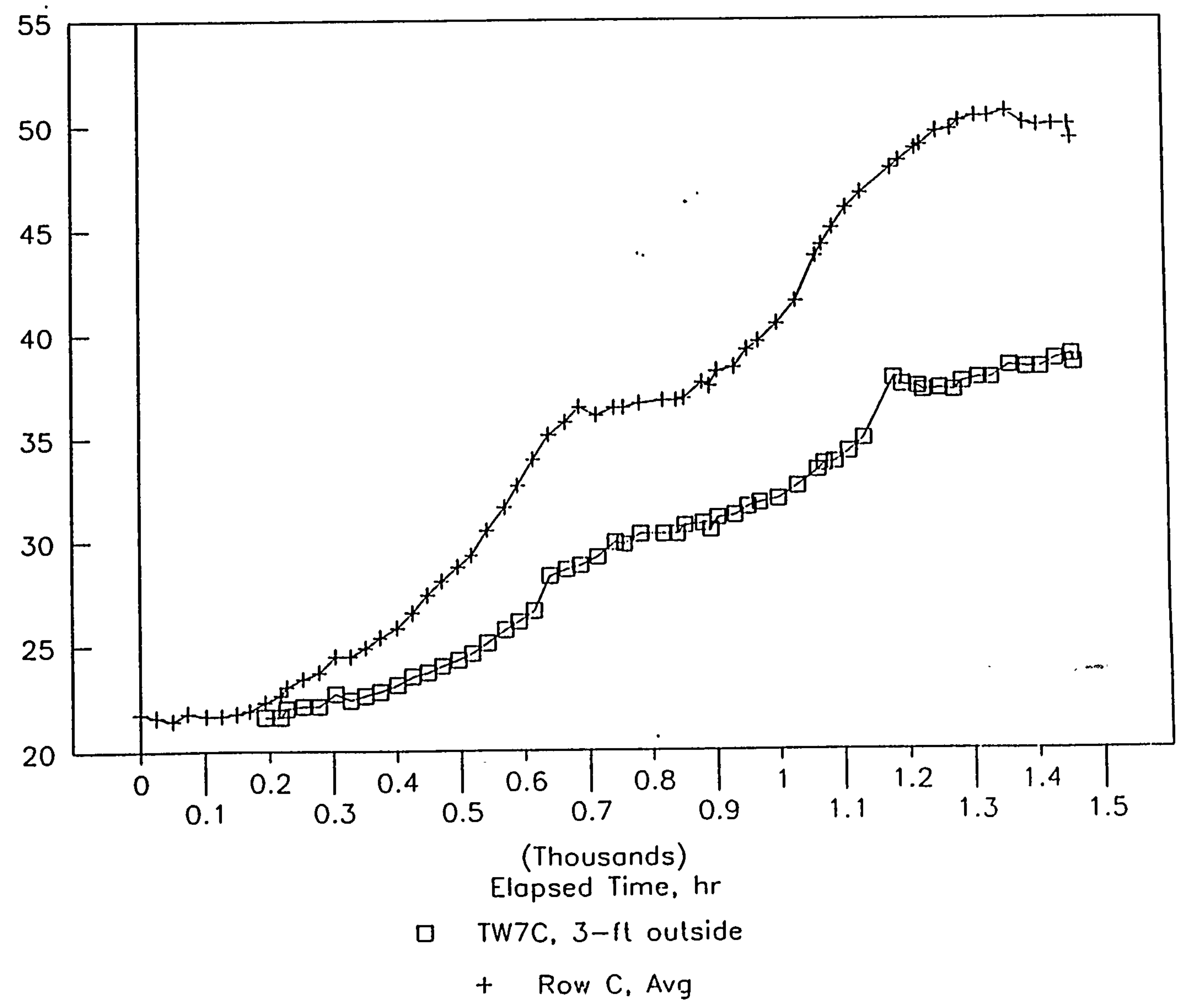


Figure B-19

Temperature Outside the Heated Array

(Depth of 29 ft, Near Ambient Temp.)

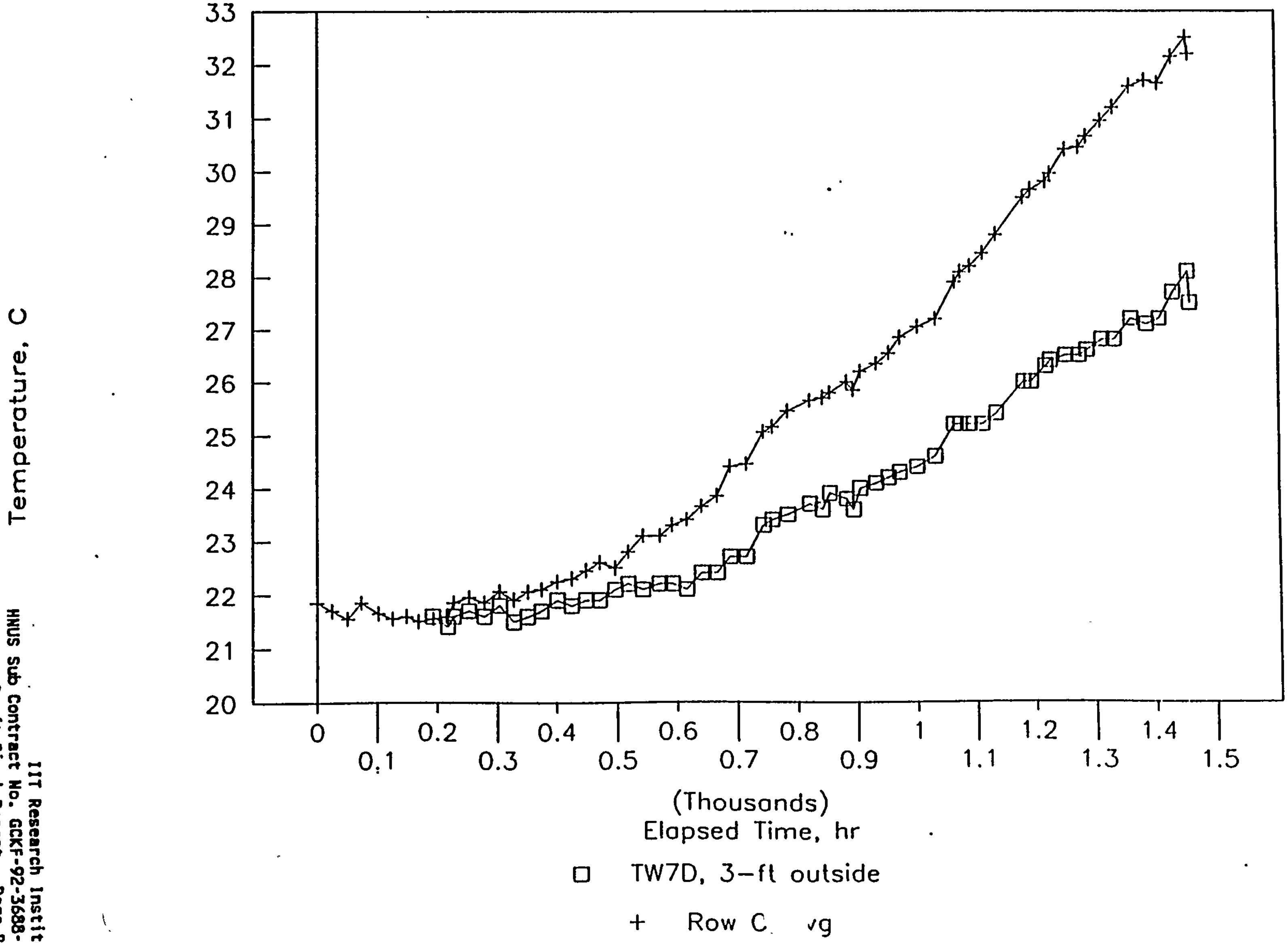


Figure B-20. Longitudinal Temperature Distribution in Plane LONG
(Depth: 1 ft)

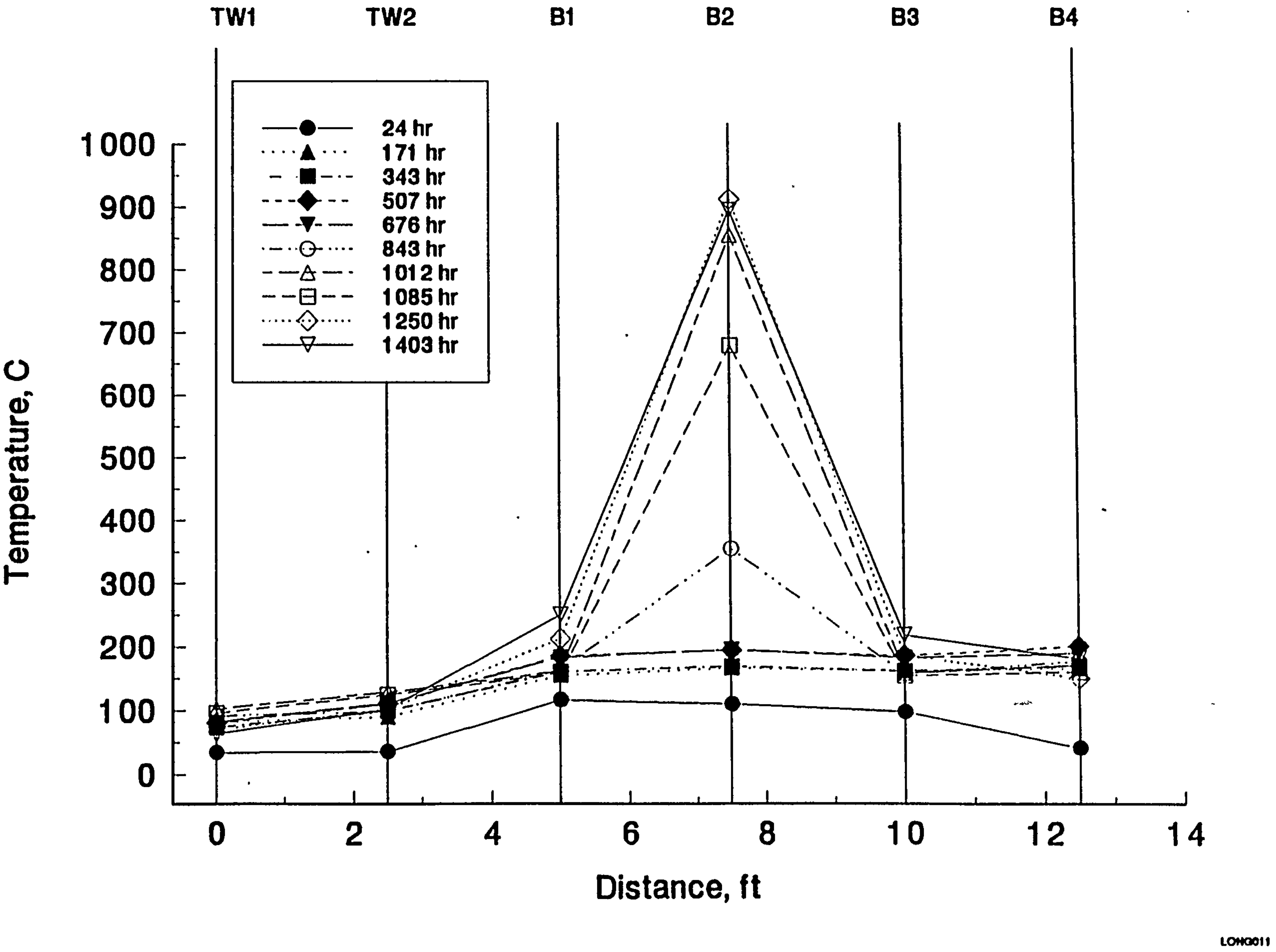
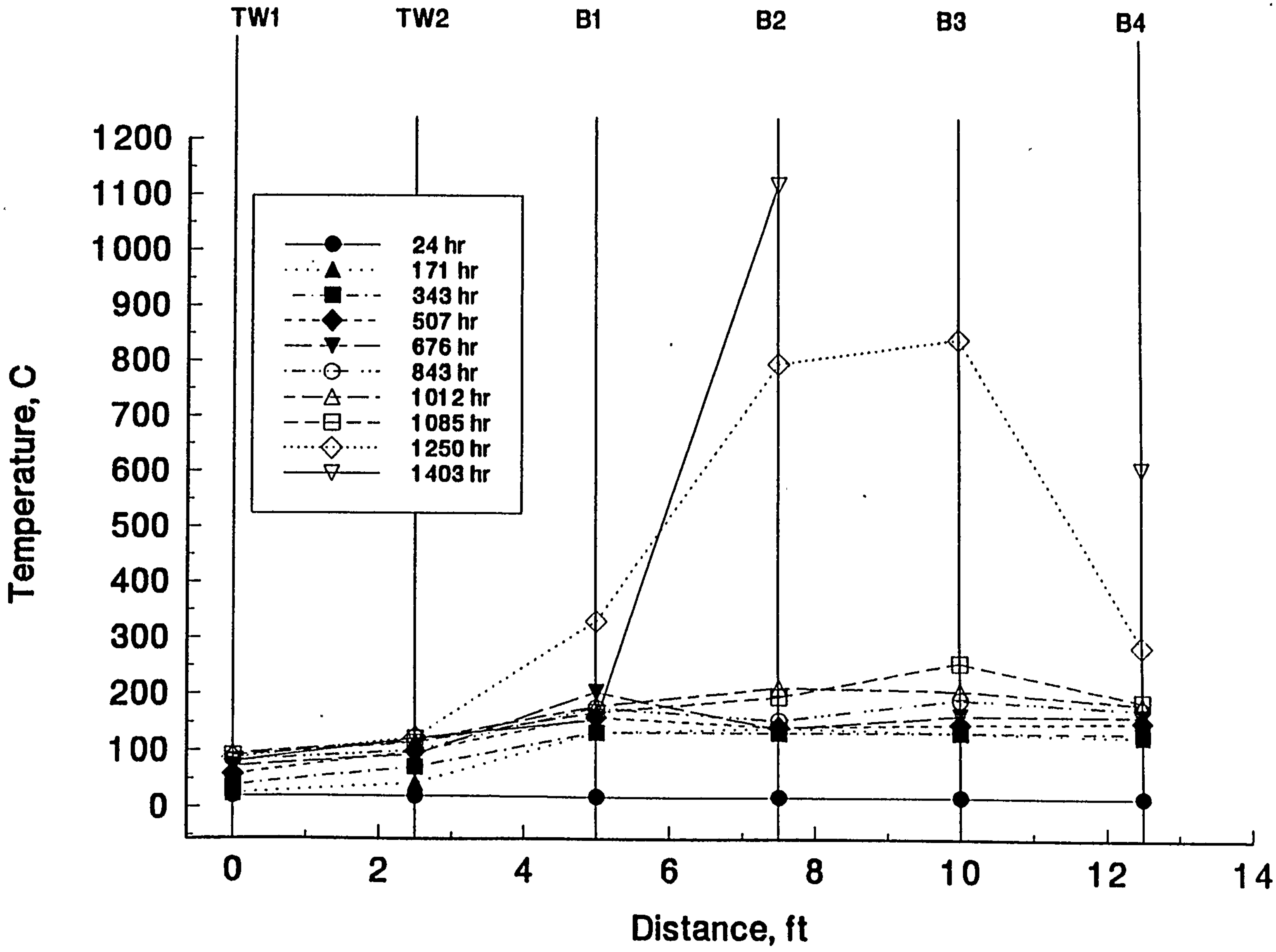


Figure B-21. Longitudinal Temperature Distribution in Plane LONG

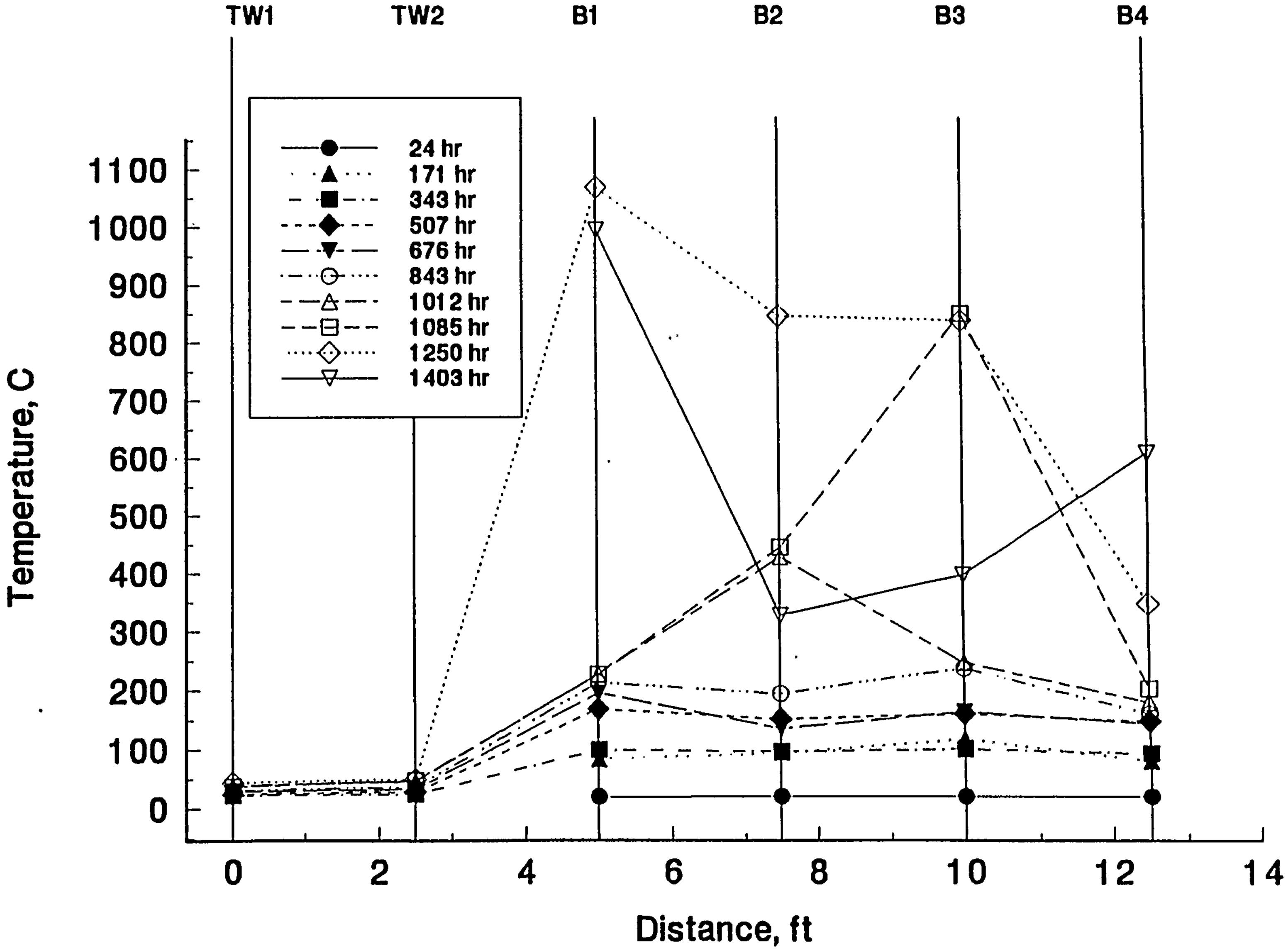
(Depth: 10-12 ft)



LONG121

Figure B-22. Longitudinal Temperature Distribution in Plane LONG

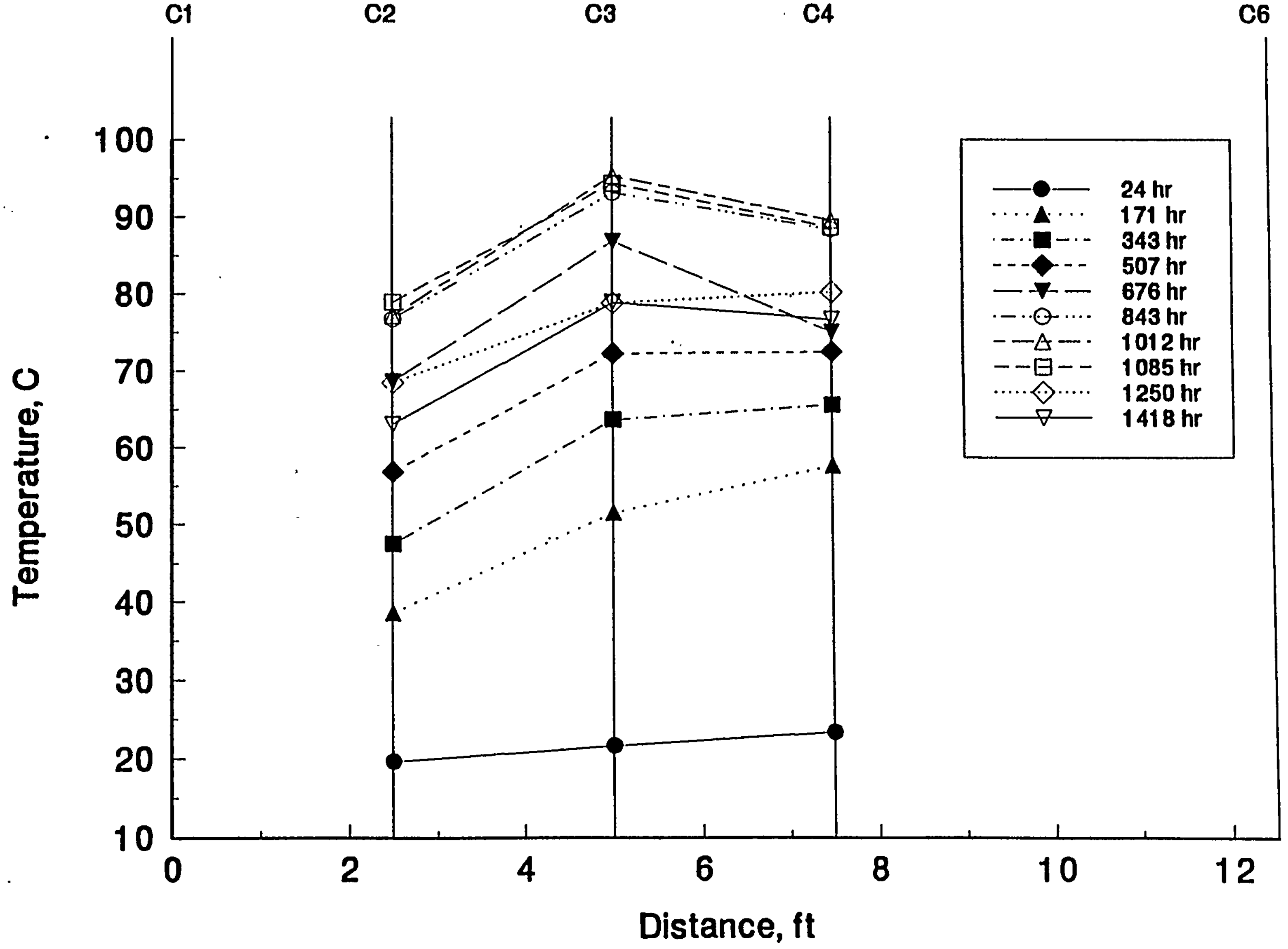
(Depth: 20-24 ft)



LONG201

Figure B-23. Longitudinal Temperature Distribution in Plane LNGU

(Depth: 1 ft)



LNGU011

Figure B-24. Longitudinal Temperature Distribution in Plane LNGU

(Depth: 12 ft)

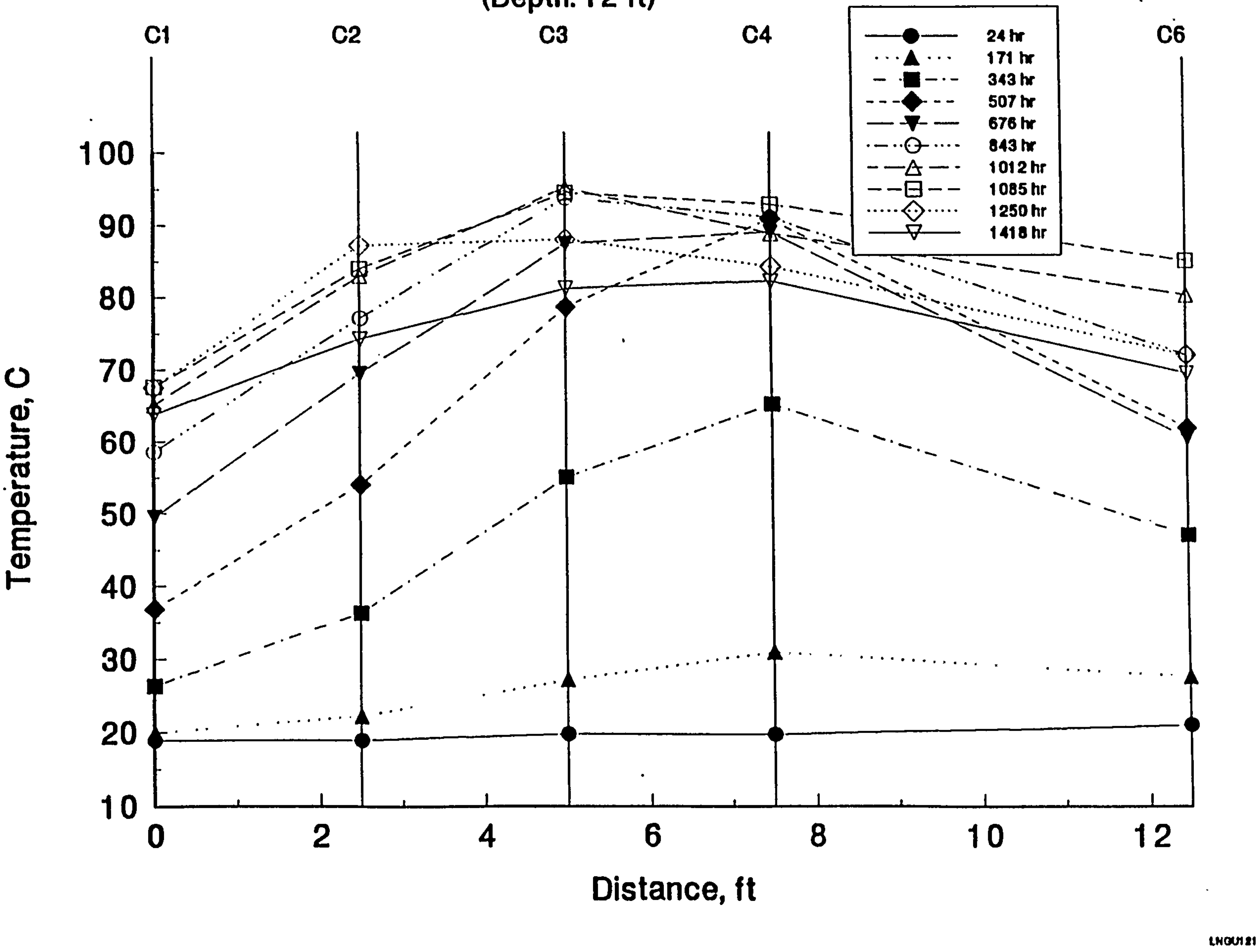


Figure B-25. Longitudinal Temperature Distribution in Plane LNGU

(Depth: 24 ft)

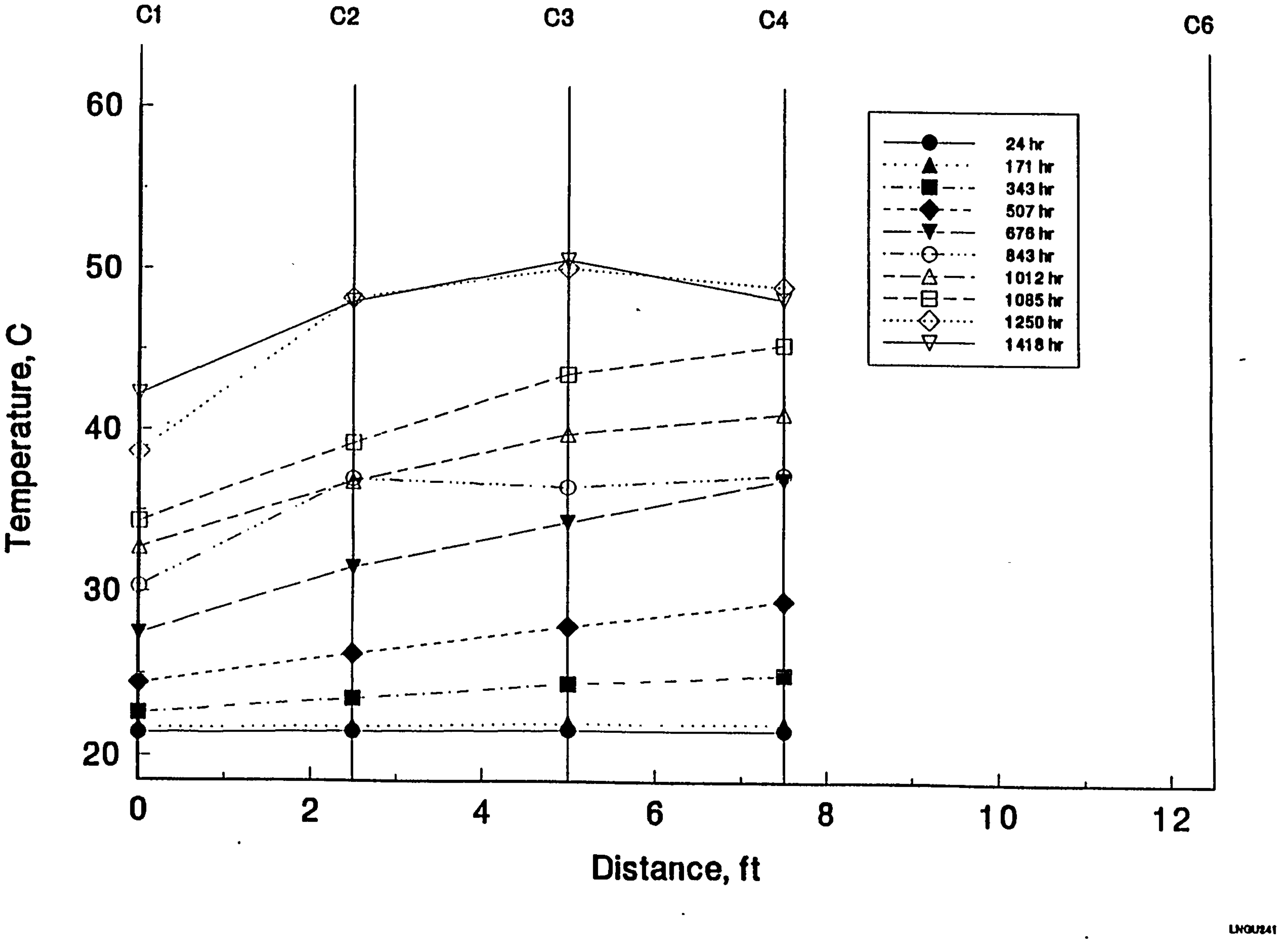


Figure B-26. Transverse Temperature Distribution in Plane TRNV

(Depth: 1 ft)

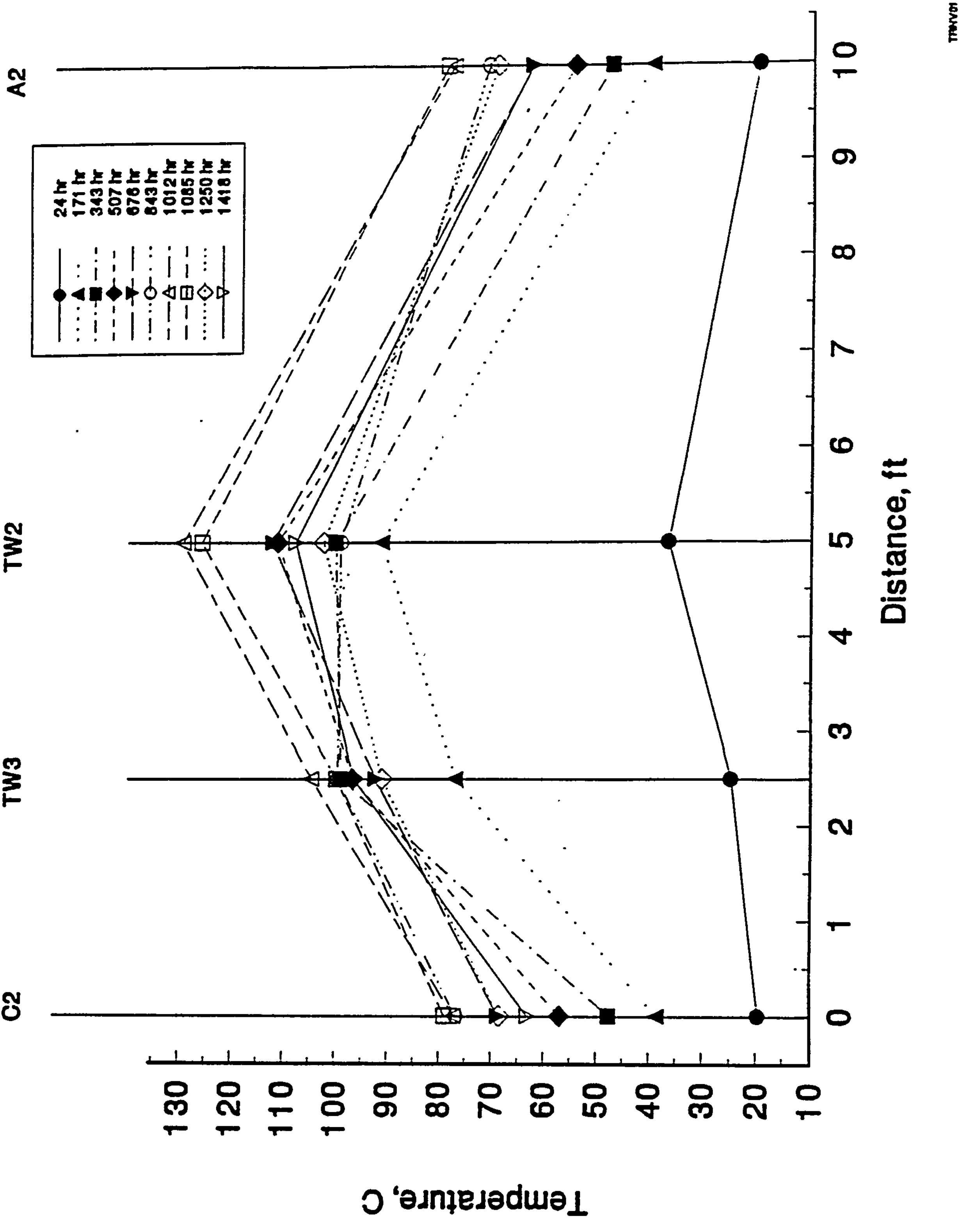
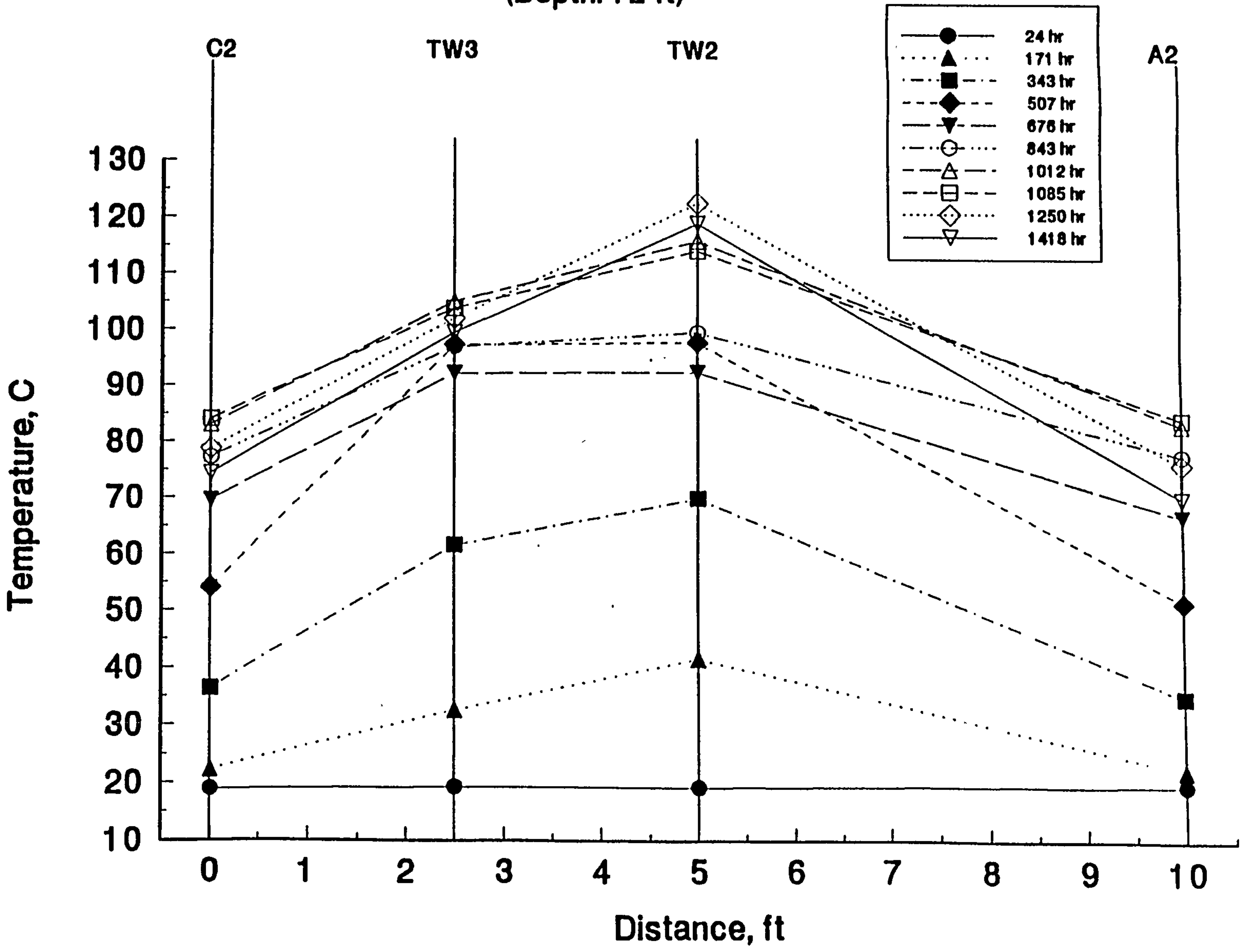


Figure B-27. Transverse Temperature Distribution in Plane TRNV

(Depth: 12 ft)



TRNV121

Figure B-28. Transverse Temperature Distribution in Plane TRNV

(Depth: 24 ft)

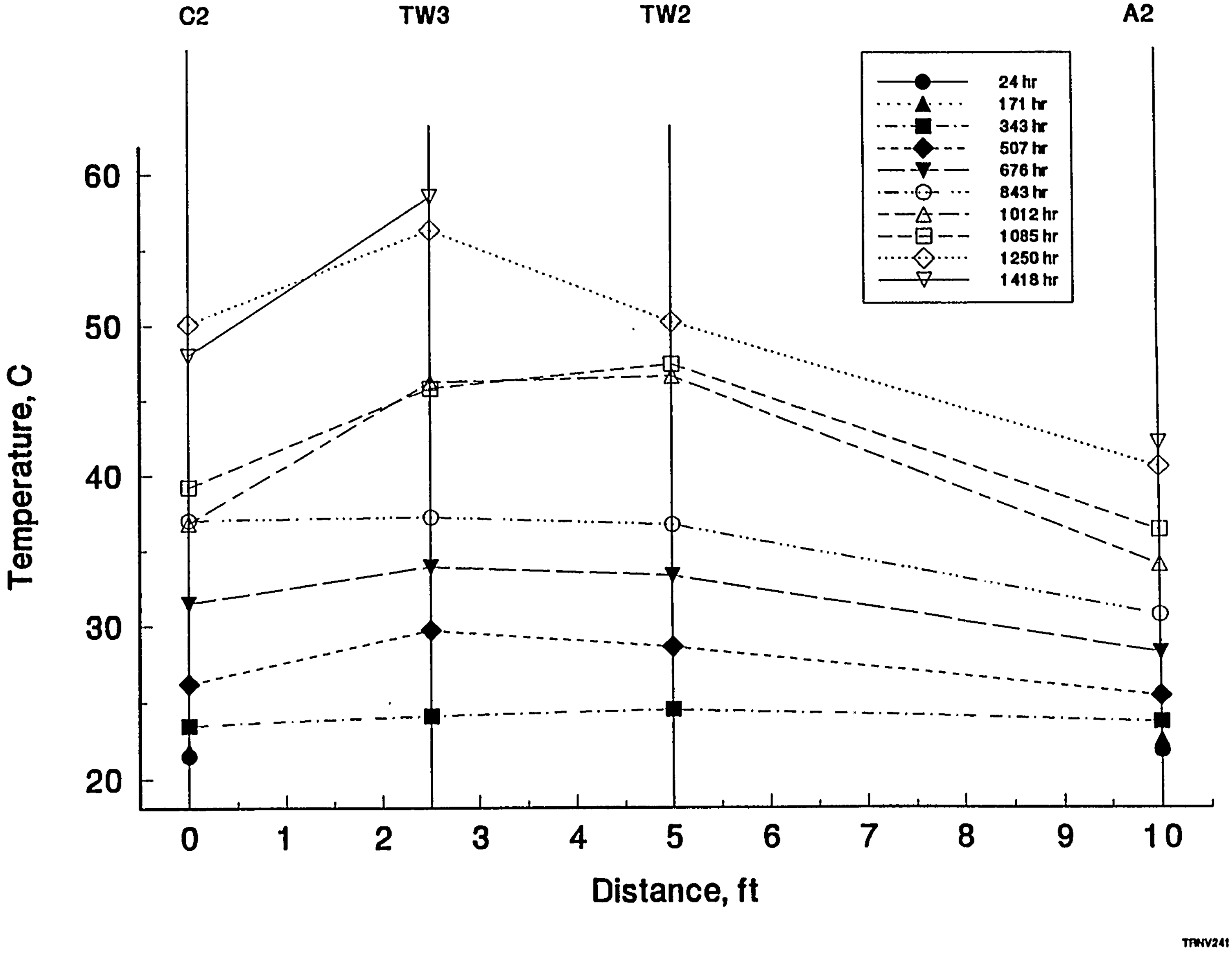


Figure B-29. Transverse Temperature Distribution in Plane TRNS

(Depth: 1 ft)

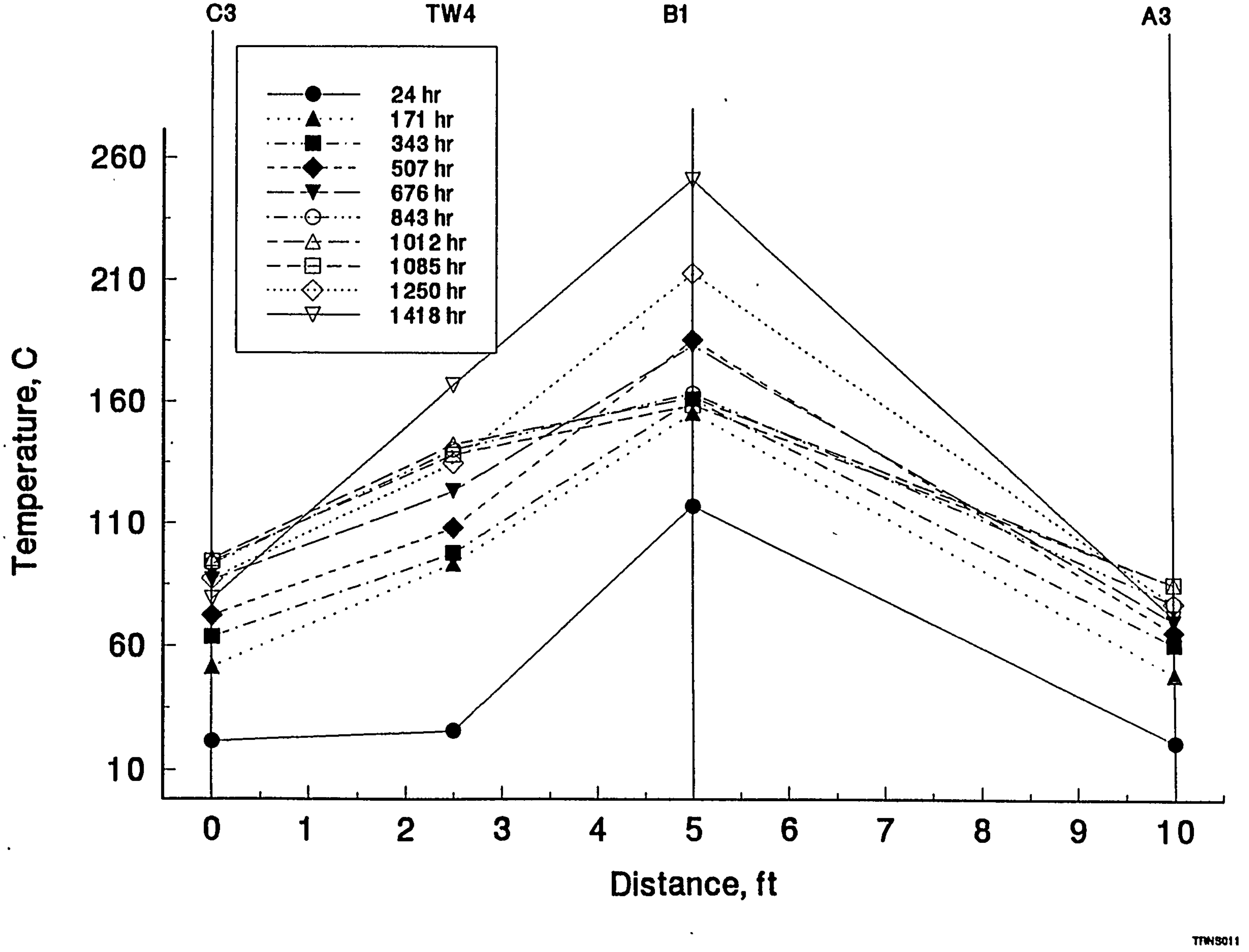
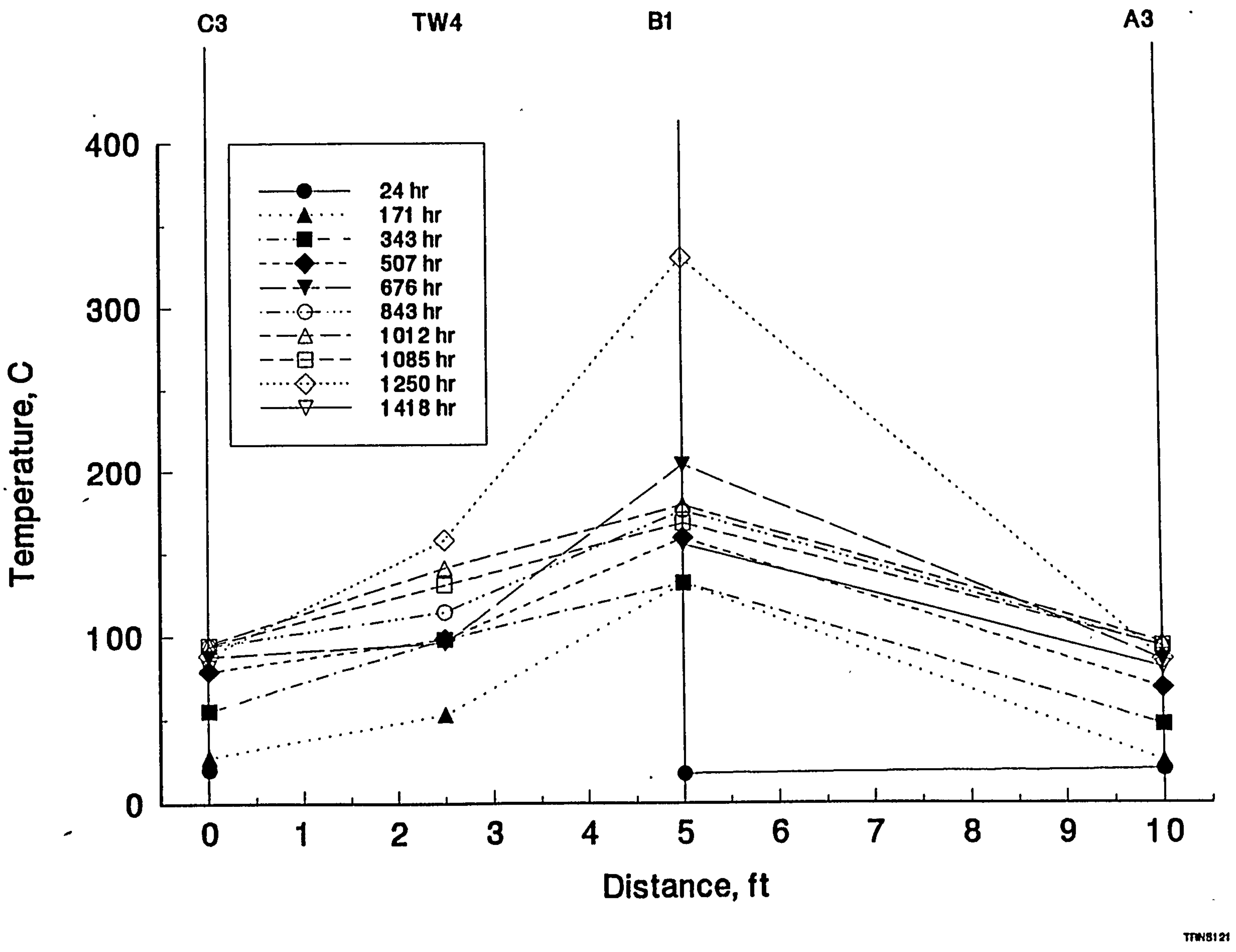


Figure B-30. Transverse Temperature Distribution in Plane TRNS

(Depth: 10-12 ft)



APPENDIX C

ELECTRICAL DATA

APPENDIX C

ELECTRICAL DATA

The electrical data and logbook entries regarding the performance of the RF power source and other observations concerning the load are summarized in this memo. Detailed information is available in the log-books. There are two tables entitled: Operating Data -- Electrical and Summary of Log Book Entries.

The table entitled Operating Data -- Electrical provides the electrical operating data for the heating experiment. The following data are tabulated:

- Date and Time
- Forward and Reflected power as measured at the array
- Net input power obtained as the difference of the forward and reflected power measured at the array
- Elapsed time in hours from the beginning of the experiment
- Equivalent days of operation at 40-kW.
- Elapsed calendar days of operation
- Power source utilization factor, percent; found by dividing equivalent days at 40-kW by the calendar days.
- VSWR estimated by equation (1) below. Also see Note 1 below.
- Vector Voltmeter readings, Va and Vb in mV.
- Magnitude of impedance calculated from equation (2) below
- Phase angle as measured by the vector voltmeter
- Magnitude of real and imaginary portions of the impedance as calculated by Equations (3a) and (3b) below.

$$VSWR = \frac{1 + \sqrt{\frac{Refl}{Forward}}}{1 - \sqrt{\frac{Refl}{Forward}}} \qquad (1)$$

$$Z,\ ohms = 31.98\left(\frac{Va}{Vb}\right) \qquad (2)$$

$$Z_{real} = Z\cos\left(\frac{\pi}{180}(-\phi)\right) \qquad (3a)$$

$$Z_{img} = Z\sin\left(\frac{\pi}{180}(-\phi)\right) \qquad (3b)$$

where:

Refl: Reflected power measured at array
Forward: Forward power measured at array
ϕ: phase angle measured by Vector voltmeter
Va, Vb: Vector voltmeter readings, mV

NOTE 1: On May 22, it was observed that there was a large discrepancy between the net input power as measured at the array versus that measured at the power source. This is marked on page 22 of the table containing electrical data (between two horizontal lines). From this point onwards, the forward and reflected data tabulated in this table is from measurements made at the power source. Due to this reason, subsequent VSWR calculations are 1 or very close to 1 unless there was significant reflected power at the power source.

Table C-1 Operating Data -- Electrical

DATE	TIME		Power at Array in kW		Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter		Z ohm	Angle degree	Z Real	Z Imaginary
	hr	mi	Forw.	Refl.							Va mV	Vb mV				
03-Apr	16	40	10.5	4.5	6.00	0.0	0.0	0.0		4.8	13.0	9.2	45.2	-70.5	15.1	42.6
03-Apr	20	4	10.6	4.5	6.10	3.4	0.0	0.1	15	4.7	13.0	9.2	45.2	-70.7	14.9	42.6
03-Apr	20	5	0.0	0.0	0.00	3.4	0.0	0.1	15	ERR			ERR		ERR	ERR
03-Apr	22	45	0.0	0.0	0.00	6.1	0.0	0.3	8	ERR			ERR		ERR	ERR
03-Apr	22	46	9.9	4.2	5.70	6.1	0.0	0.3	8	4.7	12.5	8.9	44.9	-70.2	15.2	42.3
04-Apr	2	50	10.0	4.4	5.60	10.2	0.0	0.4	11	4.9			ERR		ERR	ERR
04-Apr	2	51	0.0	0.0	0.00	10.2	0.0	0.4	11	ERR			ERR		ERR	ERR
04-Apr	3	10	0.0	0.0	0.00	10.5	0.0	0.4	10	ERR			ERR		ERR	ERR
04-Apr	3	11	10.0	4.4	5.60	10.5	0.0	0.4	10	4.9			ERR		ERR	ERR
04-Apr	8	39	11.0	4.6	6.40	16.0	0.1	0.7	12	4.7	12.6	9.3	43.3	-71.9	13.5	41.2
04-Apr	8	40	0.0	0.0	0.00	16.0	0.1	0.7	12	ERR			ERR		ERR	ERR
04-Apr	8	54	0.0	0.0	0.00	16.2	0.1	0.7	12	ERR			ERR		ERR	ERR
04-Apr	8	55	19.1	8.2	10.90	16.3	0.1	0.7	12	4.8	17.1	12.5	43.7	-71.9	13.6	41.6
04-Apr	10	29	19.8	9.0	10.80	17.8	0.1	0.7	13	5.1			ERR		ERR	ERR
04-Apr	10	30	0.0	0.0	0.00	17.8	0.1	0.7	13	ERR			ERR		ERR	ERR
04-Apr	10	39	0.0	0.0	0.00	18.0	0.1	0.7	13	ERR	16.9	12.5	43.2	-71.9	13.4	41.1
04-Apr	10	40	20.0	9.0	11.00	18.0	0.1	0.8	13	5.1			ERR		ERR	ERR
04-Apr	14	29	19.8	8.8	11.00	21.8	0.1	0.9	16	5.0			ERR		ERR	ERR
04-Apr	14	30	0.0	0.0	0.00	21.8	0.1	0.9	16	ERR	17.1	12.6	43.4	-72.2	13.3	41.3
04-Apr	14	44	0.0	0.0	0.00	22.1	0.1	0.9	15	ERR			ERR		ERR	ERR
04-Apr	14	45	20.0	9.0	11.00	22.1	0.1	0.9	15	5.1			ERR		ERR	ERR
04-Apr	15	29	20.0	9.0	11.00	22.8	0.2	1.0	16	5.1			ERR		ERR	ERR
04-Apr	15	30	41.5	19.0	22.50	22.8	0.2	1.0	16	5.2	25.7	18.8	43.7	-71.8	13.7	41.5
04-Apr	16	59	43.0	19.0	24.00	24.3	0.2	1.0	18	5.0			ERR		ERR	ERR
04-Apr	17	0	0.0	0.0	0.00	24.3	0.2	1.0	18	ERR			ERR		ERR	ERR
04-Apr	17	5	0.0	0.0	0.00	24.4	0.2	1.0	18	ERR	25.8	18.9	43.7	-71.6	13.8	41.4
04-Apr	17	6	43.0	19.0	24.00	24.4	0.2	1.0	18	5.0			ERR		ERR	ERR
04-Apr	18	59	41.0	17.5	23.50	26.3	0.2	1.1	21	4.8	25.6	18.2	45.0	-70.4	15.1	42.4

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
04–Apr	19	0	0.0	0.0	0.00	26.3	0.2	1.1	21	ERR			ERR		ERR	ERR
04–Apr	19	5	0.0	0.0	0.00	26.4	0.2	1.1	21	ERR	25.6	18.3	44.7	−70.5	14.9	42.2
04–Apr	19	6	41.0	17.5	23.50	26.4	0.2	1.1	21	4.8			ERR		ERR	ERR
04–Apr	20	45	38.0	16.0	22.00	28.1	0.3	1.2	23	4.7	25.1	17.6	45.6	−69.7	15.8	42.8
04–Apr	20	59	38.0	16.0	22.00	28.3	0.3	1.2	24	4.7			ERR		ERR	ERR
04–Apr	21	0	0.0	0.0	0.00	28.3	0.3	1.2	24	ERR			ERR		ERR	ERR
04–Apr	21	5	0.0	0.0	0.00	28.4	0.3	1.2	24	ERR	25.2	18.1	44.5	−70.0	15.2	41.8
04–Apr	21	6	38.0	15.0	23.00	28.4	0.3	1.2	24	4.4			ERR		ERR	ERR
04–Apr	22	59	38.0	14.5	23.50	30.3	0.3	1.3	26	4.2			ERR		ERR	ERR
04–Apr	23	0	0.0	0.0	0.00	30.3	0.3	1.3	26	ERR			ERR		ERR	ERR
04–Apr	23	9	0.0	0.0	0.00	30.5	0.3	1.3	26	ERR			ERR		ERR	ERR
04–Apr	23	10	38.0	14.2	23.80	30.5	0.3	1.3	26	4.1	25.0	17.7	45.2	−68.1	16.8	41.9
05–Apr	0	59	38.0	14.2	23.80	32.3	0.4	1.3	27	4.1			ERR		ERR	ERR
05–Apr	1	0	0.0	0.0	0.00	32.3	0.4	1.3	27	ERR			ERR		ERR	ERR
05–Apr	1	9	0.0	0.0	0.00	32.5	0.4	1.4	27	ERR			ERR		ERR	ERR
05–Apr	1	10	38.0	14.2	23.80	32.5	0.4	1.4	27	4.1	24.5	17.6	44.5	−70.5	14.9	42.0
05–Apr	2	59	38.0	14.2	23.80	34.3	0.4	1.4	29	4.1			ERR		ERR	ERR
05–Apr	3	0	0.0	0.0	0.00	34.3	0.4	1.4	29	ERR			ERR		ERR	ERR
05–Apr	3	9	0.0	0.0	0.00	34.5	0.4	1.4	29	ERR			ERR		ERR	ERR
05–Apr	3	10	37.0	13.9	23.10	34.5	0.4	1.4	29	4.2	24.5	17.2	45.6	−60.2	22.6	39.5
05–Apr	4	59	37.0	13.9	23.10	36.3	0.5	1.5	30	4.2			ERR		ERR	ERR
05–Apr	5	0	0.0	0.0	0.00	36.3	0.5	1.5	30	ERR			ERR		ERR	ERR
05–Apr	5	9	0.0	0.0	0.00	36.5	0.5	1.5	30	ERR			ERR		ERR	ERR
05–Apr	5	10	36.0	12.5	23.50	36.5	0.5	1.5	30	3.9	24.0	16.7	46.0	−50.5	29.2	35.5
05–Apr	6	59	33.0	11.0	22.00	38.3	0.5	1.6	31	3.7			ERR		ERR	ERR
05–Apr	7	0	0.0	0.0	0.00	38.3	0.5	1.6	31	ERR	23.1	15.9	46.5	−69.5	16.3	43.5
05–Apr	7	9	0.0	0.0	0.00	38.5	0.5	1.6	31	ERR			ERR		ERR	ERR
05–Apr	7	10	33.0	11.0	22.00	38.5	0.5	1.6	31	3.7			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
05–Apr	8	59	33.0	10.8	22.20	40.3	0.5	1.7	32	3.7			ERR		ERR	ERR
05–Apr	9	0	0.0	0.0	0.00	40.3	0.5	1.7	32	ERR	22.1	15.5	45.6	−68.8	16.5	42.5
05–Apr	9	9	0.0	0.0	0.00	40.5	0.5	1.7	32	ERR			ERR		ERR	ERR
05–Apr	9	10	33.0	10.8	22.20	40.5	0.5	1.7	32	3.7			ERR		ERR	ERR
05–Apr	10	5	33.0	10.8	22.20	41.4	0.6	1.7	33	3.7			ERR		ERR	ERR
05–Apr	10	15	49.0	15.0	34.00	41.6	0.6	1.7	33	3.5	27.5	18.5	47.5	−67.6	18.1	44.0
05–Apr	10	59	49.0	15.0	34.00	42.3	0.6	1.8	34	3.5			ERR		ERR	ERR
05–Apr	11	0	0.0	0.0	0.00	42.3	0.6	1.8	34	ERR	27.6	18.3	48.2	−67.1	18.8	44.4
05–Apr	11	21	0.0	0.0	0.00	42.7	0.6	1.8	34	ERR			ERR		ERR	ERR
05–Apr	11	22	52.0	16.2	35.80	42.7	0.6	1.8	34	3.5	27.8	18.7	47.5	67.9	17.9	−44.0
05–Apr	12	59	50.0	14.0	36.00	44.3	0.7	1.8	36	3.2			ERR		ERR	ERR
05–Apr	13	0	0.0	0.0	0.00	44.3	0.7	1.8	36	ERR	27.2	17.8	48.9	−66.1	19.8	44.7
05–Apr	13	9	0.0	0.0	0.00	44.5	0.7	1.9	36	ERR			ERR		ERR	ERR
05–Apr	13	10	50.0	14.0	36.00	44.5	0.7	1.9	36	3.2			ERR		ERR	ERR
05–Apr	14	59	44.8	11.9	32.90	46.3	0.7	1.9	38	3.1			ERR		ERR	ERR
05–Apr	15	0	0.0	0.0	0.00	46.3	0.7	1.9	38	ERR	26.2	17.2	48.7	−63.0	22.1	43.4
05–Apr	15	9	0.0	0.0	0.00	46.5	0.7	1.9	37	ERR			ERR		ERR	ERR
05–Apr	15	10	44.8	11.9	32.90	46.5	0.7	1.9	37	3.1			ERR		ERR	ERR
05–Apr	15	59	44.8	11.9	32.90	47.3	0.8	2.0	38	3.1			ERR		ERR	ERR
05–Apr	16	0	0.0	0.0	0.00	47.3	0.8	2.0	38	ERR			ERR		ERR	ERR
05–Apr	16	19	0.0	0.0	0.00	47.7	0.8	2.0	38	ERR			ERR		ERR	ERR
05–Apr	16	20	46.0	12.0	34.00	47.7	0.8	2.0	38	3.1	26.0	17.5	47.5	−63.3	21.3	42.4
05–Apr	17	59	46.0	12.0	34.00	49.3	0.8	2.1	40	3.1			ERR		ERR	ERR
05–Apr	18	0	0.0	0.0	0.00	49.3	0.8	2.1	40	ERR	24.9	15.7	50.7	−52.6	30.8	40.3
05–Apr	18	5	0.0	0.0	0.00	49.4	0.8	2.1	39	ERR			ERR		ERR	ERR
05–Apr	18	6	42.0	8.5	33.50	49.4	0.8	2.1	39	2.6			ERR		ERR	ERR
05–Apr	19	59	42.0	8.5	33.50	51.3	0.9	2.1	41	2.6			ERR		ERR	ERR
05–Apr	20	0	0.0	0.0	0.00	51.3	0.9	2.1	41	ERR			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
05-Apr	20	5	0.0	0.0	0.00	51.4	0.9	2.1	41	ERR			ERR		ERR	ERR
05-Apr	20	6	42.0	8.5	33.50	51.4	0.9	2.1	41	2.6			ERR		ERR	ERR
05-Apr	21	59	42.0	8.5	33.50	53.3	0.9	2.2	43	2.6			ERR		ERR	ERR
05-Apr	22	0	0.0	0.0	0.00	53.3	0.9	2.2	43	ERR			ERR		ERR	ERR
05-Apr	22	49	0.0	0.0	0.00	54.2	0.9	2.3	42	ERR			ERR		ERR	ERR
05-Apr	22	50	52.0	10.0	42.00	54.2	0.9	2.3	42	2.6	28.6	18.2	50.3	−52.7	30.5	40.0
05-Apr	23	59	52.0	10.0	42.00	55.3	1.0	2.3	43	2.6	28.7	18.0	51.0	−53.0	30.7	40.7
06-Apr	0	0	0.0	0.0	0.00	55.3	1.0	2.3	43	ERR			ERR		ERR	ERR
06-Apr	0	15	0.0	0.0	0.00	55.6	1.0	2.3	43	ERR			ERR		ERR	ERR
06-Apr	0	16	52.0	10.0	42.00	55.6	1.0	2.3	43	2.6			ERR		ERR	ERR
06-Apr	1	59	52.0	10.0	42.00	57.3	1.1	2.4	45	2.6			ERR		ERR	ERR
06-Apr	2	0	0.0	0.0	0.00	57.3	1.1	2.4	45	ERR	28.6	17.7	51.7	−52.0	31.8	40.7
06-Apr	2	10	0.0	0.0	0.00	57.5	1.1	2.4	45	ERR			ERR		ERR	ERR
06-Apr	2	11	52.0	10.0	42.00	57.5	1.1	2.4	45	2.6			ERR		ERR	ERR
06-Apr	3	59	50.0	9.0	41.00	59.3	1.1	2.5	47	2.5			ERR		ERR	ERR
06-Apr	4	0	0.0	0.0	0.00	59.3	1.2	2.5	47	ERR	27.8	17.5	50.8	−50.5	32.3	39.2
06-Apr	4	15	0.0	0.0	0.00	59.6	1.2	2.5	46	ERR			ERR		ERR	ERR
06-Apr	4	16	50.0	9.0	41.00	59.6	1.2	2.5	46	2.5			ERR		ERR	ERR
06-Apr	5	59	50.0	8.2	41.80	61.3	1.2	2.6	48	2.4			ERR		ERR	ERR
06-Apr	6	0	0.0	0.0	0.00	61.3	1.2	2.6	48	ERR	27.5	17.5	50.3	−49.2	32.8	38.0
06-Apr	6	15	0.0	0.0	0.00	61.6	1.2	2.6	48	ERR			ERR		ERR	ERR
06-Apr	6	16	50.0	8.2	41.80	61.6	1.2	2.6	48	2.4			ERR		ERR	ERR
06-Apr	7	59	48.0	8.2	39.80	63.3	1.3	2.6	49	2.4			ERR		ERR	ERR
06-Apr	8	0	0.0	0.0	0.00	63.3	1.3	2.6	49	ERR	26.5	17.3	49.0	−47.5	33.1	36.1
06-Apr	8	10	0.0	0.0	0.00	63.5	1.3	2.6	49	ERR			ERR		ERR	ERR
06-Apr	8	11	48.0	8.2	39.80	63.5	1.3	2.6	49	2.4			ERR		ERR	ERR
06-Apr	9	59	48.0	7.2	40.80	65.3	1.4	2.7	51	2.3			ERR		ERR	ERR
06-Apr	10	0	0.0	0.0	0.00	65.3	1.4	2.7	51	ERR	25.7	17.0	48.3	−46.4	33.3	35.0

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
06–Apr	10	8	0.0	0.0	0.00	65.5	1.4	2.7	50	ERR			ERR		ERR	ERR
06–Apr	10	9	48.0	7.2	40.80	65.5	1.4	2.7	50	2.3			ERR		ERR	ERR
06–Apr	11	59	46.5	6.5	40.00	67.3	1.5	2.8	52	2.2			ERR		ERR	ERR
06–Apr	12	0	0.0	0.0	0.00	67.3	1.5	2.8	52	ERR	25.5	16.2	50.3	–45.4	35.3	35.8
06–Apr	12	9	0.0	0.0	0.00	67.5	1.5	2.8	52	ERR			ERR		ERR	ERR
06–Apr	12	10	46.5	6.5	40.00	67.5	1.5	2.8	52	2.2			ERR		ERR	ERR
06–Apr	14	39	46.5	6.5	40.00	70.0	1.6	2.9	53	2.2			ERR		ERR	ERR
06–Apr	14	40	0.0	0.0	0.00	70.0	1.6	2.9	53	ERR			ERR		ERR	ERR
06–Apr	14	50	0.0	0.0	0.00	70.2	1.6	2.9	53	ERR			ERR		ERR	ERR
06–Apr	14	51	46.0	6.8	39.20	70.2	1.6	2.9	53	2.2	24.3	16.5	47.1	–44.9	33.4	33.2
06–Apr	15	30	45.0	6.5	38.50	70.8	1.6	3.0	54	2.2	25.3	16.3	49.6	–43.7	35.9	34.3
06–Apr	17	59	45.0	6.5	38.50	73.3	1.7	3.1	55	2.2			ERR		ERR	ERR
06–Apr	18	0	0.0	0.0	0.00	73.3	1.7	3.1	55	ERR			ERR		ERR	ERR
06–Apr	18	5	0.0	0.0	0.00	73.4	1.7	3.1	55	ERR			ERR		ERR	ERR
06–Apr	18	6	45.0	6.5	38.50	73.4	1.7	3.1	55	2.2			ERR		ERR	ERR
06–Apr	21	59	45.0	6.5	38.50	77.3	1.8	3.2	57	2.2	25.2	16.4	49.1	–44.5	35.0	34.4
06–Apr	22	0	0.0	0.0	0.00	77.3	1.8	3.2	57	ERR			ERR		ERR	ERR
06–Apr	22	5	0.0	0.0	0.00	77.4	1.8	3.2	57	ERR			ERR		ERR	ERR
06–Apr	22	6	45.0	6.5	38.50	77.4	1.8	3.2	57	2.2			ERR		ERR	ERR
07–Apr	1	59	45.0	6.5	38.50	81.3	2.0	3.4	59	2.2			ERR		ERR	ERR
07–Apr	2	0	0.0	0.0	0.00	81.3	2.0	3.4	59	ERR	25.2	16.6	48.5	–44.5	34.6	34.0
07–Apr	2	10	0.0	0.0	0.00	81.5	2.0	3.4	59	ERR			ERR		ERR	ERR
07–Apr	2	11	46.0	6.5	39.50	81.5	2.0	3.4	59	2.2			ERR		ERR	ERR
07–Apr	5	59	46.0	6.4	39.60	85.3	2.2	3.6	61	2.2			ERR		ERR	ERR
07–Apr	6	0	0.0	0.0	0.00	85.3	2.2	3.6	61	ERR	25.0	16.7	47.9	944.2	–34.3	33.4
07–Apr	6	7	0.0	0.0	0.00	85.5	2.2	3.6	60	ERR			ERR		ERR	ERR
07–Apr	6	8	46.0	6.5	39.50	85.5	2.2	3.6	60	2.2			ERR		ERR	ERR
07–Apr	8	29	46.0	6.6	39.40	87.8	2.3	3.7	61	2.2			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME		Power at Array in kW		Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter		Z ohm	Angle degree	Z Real	Z Imaginary
	hr	mi	Forw.	Refl.							Va mV	Vb mV				
07–Apr	8	30	0.0	0.0	0.00	87.8	2.3	3.7	61	ERR			ERR		ERR	ERR
07–Apr	8	36	0.0	0.0	0.00	87.9	2.3	3.7	61	ERR			ERR		ERR	ERR
07–Apr	8	37	46.0	6.6	39.40	88.0	2.3	3.7	61	2.2	24.7	16.7	47.3	–44.9	33.5	33.4
07–Apr	13	4	46.0	6.6	39.40	92.4	2.4	3.9	63	2.2			ERR		ERR	ERR
07–Apr	13	5	0.0	0.0	0.00	92.4	2.4	3.9	63	ERR			ERR		ERR	ERR
07–Apr	13	14	0.0	0.0	0.00	92.6	2.4	3.9	63	ERR			ERR		ERR	ERR
07–Apr	13	15	48.2	7.5	40.70	92.6	2.4	3.9	63	2.3	25.7	16.8	48.9	–47.6	33.0	36.1
07–Apr	14	35	47.2	7.5	39.70	93.9	2.5	3.9	64	2.3	25.4	16.5	49.2	–47.9	33.0	36.5
07–Apr	16	59	45.0	7.5	37.50	96.3	2.6	4.0	64	2.4			ERR		ERR	ERR
07–Apr	17	0	0.0	0.0	0.00	96.3	2.6	4.0	64	ERR			ERR		ERR	ERR
07–Apr	17	7	0.0	0.0	0.00	96.5	2.6	4.0	64	ERR	25.4	16.4	49.5	–47.3	33.6	36.4
07–Apr	17	8	45.0	7.5	37.50	96.5	2.6	4.0	64	2.4			ERR		ERR	ERR
07–Apr	19	15	45.9	7.2	38.70	98.6	2.7	4.1	65	2.3	25.6	16.2	50.5	–46.7	34.7	36.8
07–Apr	21	52	46.2	7.0	39.20	101.2	2.8	4.2	66	2.3	25.9	16.2	51.1	–46.1	35.5	36.8
07–Apr	21	57	46.2	7.0	39.20	101.3	2.8	4.2	66	2.3			ERR		ERR	ERR
07–Apr	21	58	0.0	0.0	0.00	101.3	2.8	4.2	66	ERR			ERR		ERR	ERR
07–Apr	22	2	0.0	0.0	0.00	101.4	2.8	4.2	66	ERR			ERR		ERR	ERR
07–Apr	22	3	46.2	7.0	39.20	101.4	2.8	4.2	66	2.3	26.0	16.2	51.3	–46.6	35.3	37.3
08–Apr	2	44	46.2	7.0	39.20	106.1	3.0	4.4	67	2.3			ERR		ERR	ERR
08–Apr	2	45	0.0	0.0	0.00	106.1	3.0	4.4	67	ERR			ERR		ERR	ERR
08–Apr	3	29	0.0	0.0	0.00	106.8	3.0	4.5	67	ERR			ERR		ERR	ERR
08–Apr	3	30	46.0	6.5	39.50	106.8	3.0	4.5	67	2.2			ERR		ERR	ERR
08–Apr	5	59	46.0	6.5	39.50	109.3	3.1	4.6	68	2.2			ERR		ERR	ERR
08–Apr	6	0	0.0	0.0	0.00	109.3	3.1	4.6	68	ERR			ERR		ERR	ERR
08–Apr	6	7	0.0	0.0	0.00	109.5	3.1	4.6	67	ERR	28.0	15.5	57.8	–47.0	39.4	42.3
08–Apr	6	8	46.0	6.5	39.50	109.5	3.1	4.6	67	2.2			ERR		ERR	ERR
08–Apr	8	10	46.4	6.9	39.50	111.5	3.2	4.6	68	2.3	27.3	15.5	56.3	–48.4	37.4	42.1
08–Apr	11	0	47.0	7.0	40.00	114.3	3.3	4.8	69	2.3	27.1	15.3	56.6	–47.5	38.3	41.8

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME		Power at Array in kW		Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter		Z ohm	Angle degree	Z Real	Z Imaginary
	hr	mi	Forw.	Refl.							Va mV	Vb mV				
08-Apr	11	26	47.0	7.0	40.00	114.8	3.3	4.8	69	2.3			ERR		ERR	ERR
08-Apr	11	27	0.0	0.0	0.00	114.8	3.3	4.8	69	ERR			ERR		ERR	ERR
08-Apr	11	41	0.0	0.0	0.00	115.0	3.3	4.8	69	ERR			ERR		ERR	ERR
08-Apr	11	42	44.2	7.0	37.20	115.0	3.3	4.8	69	2.3	26.8	15.0	57.1	−48.1	38.2	42.5
08-Apr	13	30	46.5	7.0	39.50	116.8	3.4	4.9	69	2.3	27.3	15.2	57.4	−48.1	38.4	42.8
08-Apr	14	25	46.0	7.0	39.00	117.8	3.4	4.9	69	2.3	27.3	15.1	57.8	−48.1	38.6	43.0
08-Apr	15	44	46.0	7.0	39.00	119.1	3.5	5.0	70	2.3			ERR		ERR	ERR
08-Apr	15	45	0.0	0.0	0.00	119.1	3.5	5.0	70	ERR			ERR		ERR	ERR
08-Apr	15	59	0.0	0.0	0.00	119.3	3.5	5.0	70	ERR			ERR		ERR	ERR
08-Apr	16	0	45.0	7.2	37.80	119.3	3.5	5.0	70	2.3	27.6	15.2	58.1	−47.2	39.5	42.6
08-Apr	18	59	45.0	7.2	37.80	122.3	3.6	5.1	70	2.3			ERR		ERR	ERR
08-Apr	19	0	0	0	0	122.3	3.5	5.1	69	ERR			ERR		ERR	ERR
08-Apr	19	4	0	0	0	122.4	3.5	5.1	69	ERR			ERR		ERR	ERR
08-Apr	19	5	45.0	7.0	38.00	122.4	3.6	5.1	70	2.3	27.6	15.0	58.8	−47.2	40.0	43.2
09-Apr	0	29	45.0	7.0	38.00	127.8	3.8	5.3	71	2.3			ERR		ERR	ERR
09-Apr	0	30	0.0	0.0	0.00	127.8	3.7	5.3	69	ERR			ERR		ERR	ERR
09-Apr	2	0	0.0	0.0	0.00	129.3	3.5	5.4	65	ERR			ERR		ERR	ERR
09-Apr	2	1	48.0	7.0	41.00	129.4	3.7	5.4	68	2.2			ERR		ERR	ERR
09-Apr	4	0	48.0	7.0	41.00	131.3	3.9	5.5	72	2.2	28.7	15.2	60.4	−47.8	40.6	44.7
09-Apr	4	1	0.0	0.0	0.00	131.4	3.9	5.5	71	ERR			ERR		ERR	ERR
09-Apr	4	6	0.0	0.0	0.00	131.4	3.7	5.5	67	ERR			ERR		ERR	ERR
09-Apr	4	7	48.0	7.0	41.00	131.5	3.6	5.5	65	2.2			ERR		ERR	ERR
09-Apr	9	0	50.0	7.0	43.00	136.3	4.2	5.7	73	2.2	28.0	14.7	60.9	−48.4	40.4	45.6
09-Apr	10	55	48.0	7.0	41.00	138.3	4.3	5.8	74	2.2	27.5	14.4	61.1	−48.2	40.7	45.5
09-Apr	13	43	48.0	7.0	41.00	141.1	4.4	5.9	74	2.2			ERR		ERR	ERR
09-Apr	10	44	0.0	0.0	0.00	138.1	4.3	5.8	75	ERR	27.8	14.4	61.7	−48.4	41.0	46.2
09-Apr	10	53	0.0	0.0	0.00	138.2	4.3	5.8	75	ERR			ERR		ERR	ERR
09-Apr	10	55	48.0	7.0	41.00	138.3	4.3	5.8	75	2.2			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	 mi	Power at Array in kW Forw.	 Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	 Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
09–Apr	14	14	48.0	7.0	41.00	141.6	4.4	5.9	74	2.2			ERR		ERR	ERR
09–Apr	14	15	0.0	0.0	0.00	141.6	4.3	5.9	73	ERR			ERR		ERR	ERR
09–Apr	14	29	0.0	0.0	0.00	141.8	4.4	5.9	74	ERR			ERR		ERR	ERR
09–Apr	14	30	48.0	6.9	41.10	141.8	4.3	5.9	73	2.2			ERR		ERR	ERR
09–Apr	17	33	46.5	6.8	39.70	144.9	4.5	6.0	74	2.2	27.4	14.4	60.9	−48.4	40.4	45.5
09–Apr	18	29	46.5	6.8	39.70	145.8	4.5	6.1	74	2.2			ERR		ERR	ERR
09–Apr	18	30	0.0	0.0	0.00	145.8	4.5	6.1	74	ERR			ERR		ERR	ERR
09–Apr	18	34	0.0	0.0	0.00	145.9	4.5	6.1	74	ERR			ERR		ERR	ERR
09–Apr	18	35	46.5	6.8	39.70	145.9	4.5	6.1	74	2.2			ERR		ERR	ERR
09–Apr	21	7	46.2	6.2	40.00	148.5	4.6	6.2	74	2.2	28.1	14.5	62.0	−47.7	41.7	45.8
09–Apr	23	0	46.2	6.2	40.00	150.3	4.7	6.3	75	2.2	28.4	14.5	62.6	−45.4	44.0	44.6
10–Apr	1	30	46.0	6.2	39.80	152.8	4.8	6.4	75	2.2	28.5	14.5	62.9	−44.6	44.8	44.1
10–Apr	3	0	46.0	6.2	39.80	154.3	4.8	6.4	75	2.2			ERR		ERR	ERR
10–Apr	3	1	0.0	0.0	0.00	154.4	4.8	6.4	75	ERR			ERR		ERR	ERR
10–Apr	3	11	0.0	0.0	0.00	154.5	4.8	6.4	75	ERR	28.8	14.7	62.7	−40.0	48.0	40.3
10–Apr	3	12	46.0	6.2	39.80	154.5	4.8	6.4	75	2.2			ERR		ERR	ERR
10–Apr	5	0	46.0	6.0	40.00	156.3	4.9	6.5	76	2.1			ERR		ERR	ERR
10–Apr	10	5	49.5	6.5	43.00	161.4	5.2	6.7	77	2.1	28.3	15.0	60.3	−42.1	44.8	40.5
10–Apr	11	39	49.5	6.5	43.00	163.0	5.2	6.8	77	2.1			ERR		ERR	ERR
10–Apr	11	40	0.0	0.0	0.00	163.0	5.2	6.8	77	ERR			ERR		ERR	ERR
10–Apr	11	54	0.0	0.0	0.00	163.2	5.2	6.8	77	ERR			ERR		ERR	ERR
10–Apr	11	55	49.0	6.5	42.50	163.3	5.2	6.8	77	2.1	28.4	14.0	64.9	−42.4	47.9	43.7
10–Apr	14	20	48.0	6.5	41.50	165.7	5.3	6.9	77	2.2	28.3	14.7	61.6	−42.0	45.8	41.2
10–Apr	15	38	48.0	6.5	41.50	167.0	5.4	7.0	78	2.2			ERR		ERR	ERR
10–Apr	15	39	0.0	0.0	0.00	167.0	5.4	7.0	78	ERR			ERR		ERR	ERR
10–Apr	15	44	0.0	0.0	0.00	167.1	5.4	7.0	78	ERR			ERR		ERR	ERR
10–Apr	15	45	48.0	6.5	41.50	167.1	5.4	7.0	78	2.2			ERR		ERR	ERR
10–Apr	17	36	47.0	6.5	40.50	168.9	5.5	7.0	78	2.2	28.0	14.5	61.8	−42.1	45.8	41.4

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
10–Apr	19	23	47.0	6.2	40.80	170.7	5.6	7.1	78	2.1	28.6	14.4	63.5	–44.4	45.4	44.4
10–Apr	20	32	46.5	6.2	40.30	171.9	5.6	7.2	78	2.2			ERR		ERR	ERR
10–Apr	20	33	0.0	0.0	0.00	171.9	5.6	7.2	78	ERR			ERR		ERR	ERR
10–Apr	20	37	0.0	0.0	0.00	172.0	5.6	7.2	78	ERR			ERR		ERR	ERR
10–Apr	20	38	46.5	6.2	40.30	172.0	5.6	7.2	78	2.2			ERR		ERR	ERR
10–Apr	22	13	46.5	6.2	40.30	173.6	5.7	7.2	78	2.2	29.0	14.3	64.9	–42.6	47.7	43.9
11–Apr	0	0	47.0	6.2	40.80	175.3	5.7	7.3	79	2.1	29.1	14.3	65.1	–41.6	48.7	43.2
11–Apr	0	9	46.0	5.9	40.10	175.5	5.8	7.3	79	2.1			ERR		ERR	ERR
11–Apr	0	10	0.0	0.0	0.00	175.5	5.8	7.3	79	ERR			ERR		ERR	ERR
11–Apr	0	14	0.0	0.0	0.00	175.6	5.8	7.3	79	ERR			ERR		ERR	ERR
11–Apr	0	15	46.0	5.9	40.10	175.6	5.8	7.3	79	2.1			ERR		ERR	ERR
11–Apr	2	0	47.0	5.8	41.20	177.3	5.8	7.4	78	2.1	29.4	14.4	65.3	–41.7	48.7	43.4
11–Apr	3	0	48.0	5.8	42.20	178.3	5.8	7.4	79	2.1	29.5	14.4	65.5	–42.5	48.3	44.3
11–Apr	4	0	48.0	6.0	42.00	179.3	5.9	7.5	79	2.1	29.6	14.4	65.7	–43.5	47.7	45.3
11–Apr	5	0	48.0	6.2	41.80	180.3	5.9	7.5	79	2.1	29.6	14.3	66.2	–43.4	48.1	45.5
11–Apr	5	54	48.0	6.2	41.80	181.2	6.0	7.6	79	2.1			ERR		ERR	ERR
11–Apr	5	55	0.0	0.0	0.00	181.3	6.0	7.6	79	ERR			ERR		ERR	ERR
11–Apr	5	59	0.0	0.0	0.00	181.3	6.0	7.6	79	ERR			ERR		ERR	ERR
11–Apr	6	0	48.0	6.2	41.80	181.3	6.0	7.6	79	2.1	29.8	14.4	66.2	–43.2	48.2	45.3
11–Apr	9	53	48.0	6.2	41.80	185.2	6.1	7.7	79	2.1	29.7	13.7	69.3	–41.6	51.8	46.0
11–Apr	11	30	49.0	6.5	42.50	186.8	6.2	7.8	80	2.1	29.3	13.5	69.4	–41.4	52.1	45.9
11–Apr	12	36	49.0	6.5	42.50	187.9	6.3	7.8	80	2.1			ERR		ERR	ERR
11–Apr	12	37	0.0	0.0	0.00	188.0	6.3	7.8	80	ERR			ERR		ERR	ERR
11–Apr	16	13	0.0	0.0	0.00	191.6	6.3	8.0	78	ERR			ERR		ERR	ERR
11–Apr	16	14	47.8	6.0	41.80	191.6	6.3	8.0	78	2.1			ERR		ERR	ERR
11–Apr	16	39	47.8	6.0	41.80	192.0	6.3	8.0	78	2.1	28.3	13.3	68.0	–41.7	50.8	45.3
11–Apr	19	43	47.8	6.0	41.80	195.1	6.4	8.1	79	2.1			ERR		ERR	ERR
11–Apr	19	44	0.0	0.0	0.00	195.1	6.4	8.1	79	ERR			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME		Power at Array in kW		Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter		Z ohm	Angle degree	Z Real	Z Imaginary
	hr	mi	Forw.	Refl.							Va mV	Vb mV				
11-Apr	19	33	47.5	6.1	41.40	194.9	6.4	8.1	79	2.1			ERR		ERR	ERR
11-Apr	21	59	47.5	6.1	41.40	197.3	6.5	8.2	79	2.1			ERR		ERR	ERR
11-Apr	22	0	0.0	0.0	0.00	197.3	6.5	8.2	79	ERR			ERR		ERR	ERR
11-Apr	22	10	0.0	0.0	0.00	197.5	6.5	8.2	78	ERR			ERR		ERR	ERR
11-Apr	22	11	47.5	6.1	41.40	197.5	6.5	8.2	78	2.1			ERR		ERR	ERR
11-Apr	22	20	47.5	6.1	41.40	197.7	6.5	8.2	78	2.1			ERR		ERR	ERR
11-Apr	22	11	0.0	0.0	0.00	197.5	6.5	8.2	78	ERR			ERR		ERR	ERR
11-Apr	22	43	0.0	0.0	0.00	198.1	6.5	8.3	78	ERR			ERR		ERR	ERR
11-Apr	22	44	47.8	6.0	41.80	198.1	6.5	8.3	78	2.1			ERR		ERR	ERR
11-Apr	23	10	47.8	6.0	41.80	198.5	6.5	8.3	78	2.1	29.6	13.2	71.7	−40.8	54.3	46.9
12-Apr	0	30	47.8	6.0	41.80	199.8	6.5	8.3	79	2.1	29.7	13.3	13.3	−41.4	10.0	8.8
12-Apr	1	40	48.0	6.2	41.80	201.0	6.6	8.4	79	2.1	29.7	13.4	70.9	−41.9	52.8	47.3
12-Apr	3	0	48.0	6.2	41.80	202.3	6.6	8.4	79	2.1	29.7	13.3	71.4	−42.2	52.9	48.0
12-Apr	4	0	48.0	6.2	41.80	203.3	6.7	8.5	79	2.1	29.7	13.2	72.0	−42.1	53.4	48.2
12-Apr	4	19	48.0	6.2	41.80	203.7	6.7	8.5	79	2.1			ERR		ERR	ERR
12-Apr	4	20	0.0	0.0	0.00	203.7	6.7	8.5	79	ERR			ERR		ERR	ERR
12-Apr	4	27	0.0	0.0	0.00	203.8	6.7	8.5	79	ERR			ERR		ERR	ERR
12-Apr	4	28	48.0	6.2	41.80	203.8	6.7	8.5	79	2.1			ERR		ERR	ERR
12-Apr	5	0	48.0	6.2	41.80	204.3	6.7	8.5	79	2.1	30.0	13.3	72.1	−41.1	54.4	47.4
12-Apr	6	0	48.0	6.2	41.80	205.3	6.8	8.6	79	2.1	29.9	13.1	73.0	−41.0	55.1	47.9
12-Apr	7	0	46.0	6.0	40.00	206.3	6.8	8.6	79	2.1	29.5	13.0	72.6	−42.2	53.8	48.7
12-Apr	8	0	48.0	6.2	41.80	207.3	6.9	8.6	79	2.1	29.8	13.2	72.2	−42.0	53.7	48.3
12-Apr	9	25	48.0	6.2	41.80	208.8	6.9	8.7	80	2.1	30.0	12.9	74.4	−40.9	56.2	48.7
12-Apr	9	32	48.0	6.2	41.80	208.9	6.9	8.7	80	2.1			ERR		ERR	ERR
12-Apr	9	33	0.0	0.0	0.00	208.9	6.9	8.7	80	ERR			ERR		ERR	ERR
12-Apr	10	29	0.0	0.0	0.00	209.8	6.9	8.7	79	ERR	30.0	13.1	73.2	−40.2	55.9	47.3
12-Apr	10	30	48.0	6.2	41.80	209.8	6.9	8.7	79	2.1			ERR		ERR	ERR
12-Apr	13	14	47.5	6.0	41.50	212.6	7.0	8.9	80	2.1			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
12–Apr	13	15	0.0	0.0	0.00	212.6	7.0	8.9	80	ERR			ERR		ERR	ERR
12–Apr	13	27	0.0	0.0	0.00	212.8	7.0	8.9	79	ERR			ERR		ERR	ERR
12–Apr	13	28	47.5	6.0	41.50	212.8	7.0	8.9	79	2.1	29.3	13.0	72.1	−39.0	56.0	45.4
12–Apr	15	47	47.5	6.2	41.30	215.1	7.1	9.0	80	2.1	29.1	12.9	72.1	−39.5	55.7	45.9
12–Apr	18	10	46.5	6.2	40.30	217.5	7.2	9.1	80	2.2	29.5	12.8	73.7	−39.6	56.8	47.0
12–Apr	19	42	46.0	6.0	40.00	219.0	7.3	9.1	80	2.1			ERR		ERR	ERR
12–Apr	19	43	0.0	0.0	0.00	219.1	7.3	9.1	80	ERR			ERR		ERR	ERR
12–Apr	19	46	0.0	0.0	0.00	219.1	7.3	9.1	80	ERR			ERR		ERR	ERR
12–Apr	19	47	47.0	6.2	40.80	219.1	7.3	9.1	80	2.1			ERR		ERR	ERR
12–Apr	22	0	47.0	6.2	40.80	221.3	7.4	9.2	80	2.1	30.2	12.8	75.5	−40.0	57.8	48.5
12–Apr	23	47	48.0	6.5	41.50	223.1	7.5	9.3	80	2.2	30.5	12.8	76.2	−39.8	58.5	48.8
13–Apr	2	0	48.0	6.2	41.80	225.3	7.6	9.4	81	2.1	30.5	12.8	76.2	−39.9	58.5	48.9
13–Apr	4	0	48.0	6.2	41.80	227.3	7.7	9.5	81	2.1	30.5	12.7	76.8	−39.8	59.0	49.2
13–Apr	5	59	48.0	6.2	41.80	229.3	7.7	9.6	81	2.1			ERR		ERR	ERR
13–Apr	6	0	0.0	0.0	0.00	229.3	7.6	9.6	79	ERR			ERR		ERR	ERR
13–Apr	6	5	0.0	0.0	0.00	229.4	7.6	9.6	80	ERR			ERR		ERR	ERR
13–Apr	6	6	48.0	6.2	41.80	229.4	7.8	9.6	81	2.1			ERR		ERR	ERR
13–Apr	6	10	48.0	6.2	41.80	229.5	7.8	9.6	81	2.1	30.5	12.7	76.8	−39.5	59.3	48.9
13–Apr	14	4	48.0	6.5	41.50	237.4	8.1	9.9	82	2.2	30.0	12.2	78.6	−39.6	60.6	50.1
13–Apr	14	5	0.0	0.0	0.00	237.4	8.1	9.9	82	ERR			ERR		ERR	ERR
13–Apr	14	11	0.0	0.0	0.00	237.5	8.1	9.9	82	ERR			ERR		ERR	ERR
13–Apr	14	12	48.0	6.5	41.50	237.5	8.1	9.9	82	2.2			ERR		ERR	ERR
13–Apr	16	2	47.0	6.5	40.50	239.4	8.2	10.0	82	2.2	30.5	12.3	79.3	−38.4	62.1	49.3
13–Apr	20	52	46.5	6.5	40.00	244.2	8.4	10.2	82	2.2	30.5	12.1	80.6	−38.4	63.2	50.1
13–Apr	20	53	0.0	0.0	0.00	244.2	8.4	10.2	82	ERR			ERR		ERR	ERR
13–Apr	20	57	0.0	0.0	0.00	244.3	8.4	10.2	82	ERR			ERR		ERR	ERR
13–Apr	20	58	46.5	6.5	40.00	244.3	8.4	10.2	82	2.2			ERR		ERR	ERR
14–Apr	0	0	46.5	6.5	40.00	247.3	8.4	10.3	82	2.2	30.8	12.0	82.1	−38.3	64.4	50.9

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
14–Apr	2	0	46.5	6.5	40.00	249.3	8.6	10.4	83	2.2	31.0	12.0	82.6	−38.2	64.9	51.1
14–Apr	2	1	0.0	0.0	0.00	249.4	8.5	10.4	82	ERR			ERR		ERR	ERR
14–Apr	2	8	0.0	0.0	0.00	249.5	8.6	10.4	83	ERR			ERR		ERR	ERR
14–Apr	2	9	46.5	6.5	40.00	249.5	8.5	10.4	82	2.2			ERR		ERR	ERR
14–Apr	4	59	46.5	6.5	40.00	252.3	8.7	10.5	82	2.2			ERR		ERR	ERR
14–Apr	5	0	0.0	0.0	0.00	252.3	8.5	10.5	81	ERR			ERR		ERR	ERR
14–Apr	5	6	0.0	0.0	0.00	252.4	8.7	10.5	82	ERR			ERR		ERR	ERR
14–Apr	5	7	46.5	6.5	40.00	252.5	8.6	10.5	81	2.2	30.9	12.0	82.3	−37.4	65.4	50.0
14–Apr	9	49	47.0	6.3	40.70	257.2	8.8	10.7	82	2.2			ERR		ERR	ERR
14–Apr	9	50	0.0	0.0	0.00	257.2	8.7	10.7	81	ERR			ERR		ERR	ERR
14–Apr	9	57	0.0	0.0	0.00	257.3	8.8	10.7	82	ERR			ERR		ERR	ERR
14–Apr	9	58	47.0	6.3	40.70	257.3	8.7	10.7	81	2.2			ERR		ERR	ERR
14–Apr	19	20	47.0	6.3	40.70	266.7	9.0	11.1	81	2.2			ERR		ERR	ERR
14–Apr	19	21	0.0	0.0	0.00	266.7	8.9	11.1	80	ERR			ERR		ERR	ERR
14–Apr	19	25	0.0	0.0	0.00	266.8	9.0	11.1	81	ERR			ERR		ERR	ERR
14–Apr	19	26	47.0	6.3	40.70	266.8	8.9	11.1	80	2.2			ERR		ERR	ERR
15–Apr	0	0	48.0	7.0	41.00	271.3	9.1	11.3	80	2.2	32.2	12.0	85.8	−35.6	69.8	50.0
15–Apr	3	59	48.0	7.0	41.00	275.3	9.4	11.5	82	2.2			ERR		ERR	ERR
15–Apr	4	0	0.0	0.0	0.00	275.3	9.1	11.5	80	ERR	32.1	12.0	85.5	−35.4	69.7	49.6
15–Apr	4	4	0.0	0.0	0.00	275.4	9.4	11.5	82	ERR			ERR		ERR	ERR
15–Apr	4	5	48.0	7.0	41.00	275.4	9.1	11.5	80	2.2			ERR		ERR	ERR
15–Apr	10	15	52.0	7.3	44.70	281.6	9.6	11.7	82	2.2	32.0	11.5	89.0	−36.3	71.7	52.7
15–Apr	11	2	52.0	7.3	44.70	282.4	9.5	11.8	80	2.2			ERR		ERR	ERR
15–Apr	11	3	0.0	0.0	0.00	282.4	9.6	11.8	81	ERR			ERR		ERR	ERR
15–Apr	11	10	0.0	0.0	0.00	282.5	9.5	11.8	80	ERR			ERR		ERR	ERR
15–Apr	11	11	50.0	7.3	42.70	282.5	9.6	11.8	81	2.2	32.0	11.4	89.8	−35.6	73.0	52.3
15–Apr	20	18	49.0	7.4	41.60	291.6	9.7	12.2	79	2.3	32.1	11.2	91.7	−34.9	75.2	52.4
15–Apr	20	19	0.0	0.0	0.00	291.7	9.8	12.2	81	ERR			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME		Power at Array in kW		Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter		Z ohm	Angle degree	Z Real	Z Imaginary
	hr	mi	Forw.	Refl.							Va mV	Vb mV				
15–Apr	20	22	0.0	0.0	0.00	291.7	9.7	12.2	79	ERR			ERR		ERR	ERR
15–Apr	20	23	49.0	7.4	41.60	291.7	9.8	12.2	81	2.3			ERR		ERR	ERR
15–Apr	21	40	49.0	7.4	41.60	293.0	9.7	12.2	79	2.3	32.5	11.3	92.0	–34.7	75.6	52.4
16–Apr	0	0	48.0	7.5	40.50	295.3	9.9	12.3	81	2.3	33.0	11.7	90.2	–34.7	74.2	51.3
16–Apr	2	0	48.5	7.5	41.00	297.3	9.9	12.4	80	2.3	33.2	11.7	90.7	–34.6	74.7	51.5
16–Apr	4	0	48.0	7.5	40.50	299.3	10.1	12.5	81	2.3	33.2	11.7	90.7	–34.2	75.1	51.0
16–Apr	6	0	50.0	7.5	42.50	301.3	10.1	12.6	80	2.3	33.3	11.7	91.0	–34.3	75.2	51.3
16–Apr	7	10	49.5	7.6	41.90	302.5	10.3	12.6	81	2.3	33.8	11.5	94.0	–34.0	77.9	52.6
16–Apr	10	0	51.5	7.9	43.60	305.3	10.2	12.7	80	2.3			ERR		ERR	ERR
16–Apr	13	3	0.0	0.0	0.00	308.4	10.4	12.8	81	ERR			ERR		ERR	ERR
16–Apr	13	14	0.0	0.0	0.00	308.6	10.3	12.9	80	ERR			ERR		ERR	ERR
16–Apr	13	15	50.0	8.0	42.00	308.6	10.4	12.9	81	2.3	33.0	11.0	95.9	–34.0	79.5	53.6
16–Apr	19	4	0.0	0.0	0.00	314.4	10.3	13.1	79	ERR			ERR		ERR	ERR
16–Apr	19	13	0.0	0.0	0.00	314.6	10.5	13.1	80	ERR			ERR		ERR	ERR
16–Apr	19	14	51.0	8.1	42.90	314.6	10.3	13.1	79	2.3	33.9	11.2	96.8	–34.7	79.6	55.1
16–Apr	21	35	50.0	8.0	42.00	316.9	10.6	13.2	80	2.3	34.0	11.0	98.8	–34.8	81.2	56.4
16–Apr	23	2	0.0	0.0	0.00	318.4	10.4	13.3	78	ERR			ERR		ERR	ERR
17–Apr	0	14	0.0	0.0	0.00	319.6	10.6	13.3	80	ERR			ERR		ERR	ERR
17–Apr	0	15	50.0	8.5	41.50	319.6	10.4	13.3	78	2.4			ERR		ERR	ERR
17–Apr	2	0	50.0	8.5	41.50	321.3	10.7	13.4	80	2.4	33.2	11.7	90.7	–34.6	74.7	51.5
17–Apr	8	20	52.0	8.8	43.20	327.7	10.8	13.7	79	2.4			ERR		ERR	ERR
17–Apr	14	20	52.5	9.0	43.50	333.7	11.2	13.9	81	2.4			ERR		ERR	ERR
17–Apr	16	5	52.0	9.0	43.00	335.4	11.1	14.0	80	2.4			ERR		ERR	ERR
17–Apr	17	4	52.0	9.0	43.00	336.4	11.3	14.0	81	2.4			ERR		ERR	ERR
17–Apr	17	5	0.0	0.0	0.00	336.4	11.1	14.0	80	ERR			ERR		ERR	ERR
17–Apr	21	39	0.0	0.0	0.00	341.0	11.4	14.2	80	ERR			ERR		ERR	ERR
17–Apr	21	40	52.0	9.0	43.00	341.0	11.2	14.2	79	2.4	35.0	11.1	100.8	–31.2	86.3	52.2
18–Apr	0	5	52.0	9.0	43.00	343.4	11.5	14.3	80	2.4	35.0	11.0	101.8	–31.2	87.0	52.7

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
18–Apr	0	6	0.0	0.0	0.00	343.4	11.3	14.3	79	ERR			ERR		ERR	ERR
18–Apr	1	38	0.0	0.0	0.00	345.0	11.5	14.4	80	ERR			ERR		ERR	ERR
18–Apr	1	39	52.0	9.0	43.00	345.0	11.3	14.4	79	2.4	35.0	11.0	101.8	–31.2	87.0	52.7
18–Apr	10	10	52.5	9.5	43.00	353.5	11.7	14.7	80	2.5	35.0	11.1	100.8	–31.7	85.8	53.0
18–Apr	12	25	54.0	9.9	44.10	355.8	11.8	14.8	80	2.5	34.6	11.2	98.8	–32.0	83.8	52.4
18–Apr	20	1	53.0	10.0	43.00	363.4	12.2	15.1	80	2.5	35.5	11.0	103.2	–33.2	86.4	56.5
18–Apr	22	36	52.0	10.0	42.00	365.9	12.3	15.2	81	2.6	36.0	11.0	–33.2		–33.2	0.0
19–Apr	1	20	52.0	10.0	42.00	368.7	12.4	15.4	81	2.6	36.0	11.0	104.7	–33.4	87.4	57.6
19–Apr	6	30	54.0	10.0	44.00	373.8	12.6	15.6	81	2.5	36.0	11.0	104.7	–33.0	87.8	57.0
19–Apr	13	15	56.0	11.0	45.00	380.6	12.9	15.9	82	2.6	35.9	10.4	110.4	–34.8	90.6	63.0
19–Apr	13	16	0.0	0.0	0.00	380.6	12.8	15.9	81	ERR			ERR		ERR	ERR
19–Apr	14	34	0.0	0.0	0.00	381.9	13.0	15.9	81	ERR			ERR		ERR	ERR
19–Apr	14	35	54.0	11.0	43.00	381.9	12.8	15.9	81	2.6			ERR		ERR	ERR
19–Apr	18	23	55.0	11.0	44.00	385.7	13.0	16.1	81	2.6	35.5	10.4	109.2	–34.8	89.6	62.3
19–Apr	19	13	55.0	11.0	44.00	386.6	13.0	16.1	81	2.6			ERR		ERR	ERR
19–Apr	19	14	0.0	0.0	0.00	386.6	13.1	16.1	81	ERR			ERR		ERR	ERR
19–Apr	19	25	0.0	0.0	0.00	386.8	13.0	16.1	81	ERR			ERR		ERR	ERR
19–Apr	19	26	55.0	11.2	43.80	386.8	13.1	16.1	81	2.6	36.1	10.4	111.0	–35.1	90.8	63.8
19–Apr	22	27	54.0	11.2	42.80	389.8	13.1	16.2	81	2.7	37.1	10.4	114.1	–35.5	92.9	66.2
20–Apr	8	30	56.0	12.0	44.00	399.8	13.7	16.7	82	2.7	37.5	10.0	119.9	–37.5	95.1	73.0
20–Apr	13	34	57.0	12.3	44.70	404.9	13.8	16.9	82	2.7			ERR		ERR	ERR
20–Apr	13	35	0.0	0.0	0.00	404.9	13.8	16.9	82	ERR			ERR		ERR	ERR
20–Apr	13	44	0.0	0.0	0.00	405.1	13.8	16.9	82	ERR			ERR		ERR	ERR
20–Apr	13	45	57.0	12.5	44.50	405.1	13.8	16.9	82	2.8	37.9	11.1	109.2	–35.6	88.8	63.6
20–Apr	19	50	56.0	12.8	43.20	411.2	13.9	17.1	81	2.8	38.3	11.0	111.3	–32.0	94.4	59.0
20–Apr	19	51	0.0	0.0	0.00	411.2	13.9	17.1	81	ERR			ERR		ERR	ERR
20–Apr	20	29	0.0	0.0	0.00	411.8	13.9	17.2	81	ERR			ERR		ERR	ERR
20–Apr	20	30	57.0	13.0	44.00	411.8	13.9	17.2	81	2.8	38.5	11.0	111.9	–31.9	95.0	59.1

Table C-1 Operating Data -- Electrical (Continued)

	TIME		Power at Array in kW		Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter		Z ohm	Angle degree	Z Real	Z Imaginary
DATE	hr	mi	Forw.	Refl.							Va mV	Vb mV				
20-Apr	21	39	57.0	13.0	44.00	413.0	14.0	17.2	81	2.8			ERR		ERR	ERR
20-Apr	21	40	0.0	0.0	0.00	413.0	14.0	17.2	81	ERR			ERR		ERR	ERR
21-Apr	0	54	0.0	0.0	0.00	416.2	14.0	17.3	81	ERR			ERR		ERR	ERR
21-Apr	0	55	58.0	13.0	45.00	416.3	14.1	17.3	81	2.8	39.1	10.0	125.0	−32.7	105.2	67.6
21-Apr	6	0	58.6	13.0	45.60	421.3	14.2	17.6	81	2.8	39.0	11.0	113.4	−38.1	89.2	70.0
21-Apr	11	19	58.0	13.0	45.00	426.7	14.5	17.8	82	2.8			ERR		ERR	ERR
21-Apr	11	20	0.0	0.0	0.00	426.7	14.3	17.8	80	ERR			ERR		ERR	ERR
21-Apr	16	29	0.0	0.0	0.00	431.8	14.7	18.0	81	ERR			ERR		ERR	ERR
21-Apr	16	30	56.0	13.0	43.00	431.8	14.4	18.0	80	2.9	38.1	9.7	125.6	−38.5	98.3	78.2
21-Apr	19	43	57.5	13.5	44.00	435.1	14.7	18.1	81	2.9	39.0	9.9	126.0	−38.8	98.2	78.9
21-Apr	19	59	57.5	13.5	44.00	435.3	14.6	18.1	80	2.9			ERR		ERR	ERR
21-Apr	20	0	0.0	0.0	0.00	435.3	14.7	18.1	81	ERR			ERR		ERR	ERR
21-Apr	23	59	0.0	0.0	0.00	439.3	14.7	18.3	80	ERR			ERR		ERR	ERR
21-Apr	0	0	60.0	14.0	46.00	415.3	14.3	17.3	82	2.9	40.0	10.0	127.9	−38.5	100.1	79.6
22-Apr	9	15	56.0	13.5	42.50	448.6	14.9	18.7	80	2.9	38.0	9.6	126.6	−40.7	96.0	82.5
22-Apr	10	40	55.0	13.4	41.60	450.0	15.8	18.8	84	2.9	37.5	9.4	127.6	−41.0	96.3	83.7
22-Apr	13	27	55.0	13.4	41.60	452.8	15.1	18.9	80	2.9			ERR		ERR	ERR
22-Apr	13	28	0.0	0.0	0.00	452.8	15.9	18.9	84	ERR			ERR		ERR	ERR
22-Apr	18	9	0.0	0.0	0.00	457.5	15.2	19.1	79	ERR			ERR		ERR	ERR
22-Apr	18	10	60.0	15.0	45.00	457.5	16.0	19.1	84	3.0	39.5	9.7	130.2	−40.8	98.6	85.1
23-Apr	1	30	60.0	15.0	45.00	464.8	15.3	19.4	79	3.0	41.0	10.0	131.1	−41.6	98.0	87.1
23-Apr	9	40	65.0	16.6	48.40	473.0	16.8	19.7	85	3.0	40.0	10.0	127.9	−42.7	94.0	86.8
23-Apr	12	19	65.0	16.6	48.40	475.7	15.9	19.8	80	3.0			ERR		ERR	ERR
23-Apr	12	20	0.0	0.0	0.00	475.7	16.8	19.8	85	ERR			ERR		ERR	ERR
23-Apr	13	19	0.0	0.0	0.00	476.7	15.9	19.9	80	ERR			ERR		ERR	ERR
23-Apr	13	20	61.0	16.0	45.00	476.7	16.9	19.9	85	3.1	39.5	9.6	131.6	−44.6	93.7	92.4
24-Apr	0	10	64.0	17.5	46.50	487.5	16.1	20.3	79	3.2	41.9	10.0	134.0	−44.0	96.4	93.1
24-Apr	0	59	64.0	17.5	46.50	488.3	17.4	20.3	86	3.2			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME		Power at Array in kW		Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter		Z ohm	Angle degree	Z Real	Z Imaginary
	hr	mi	Forw.	Refl.							Va mV	Vb mV				
24–Apr	1	0	0.0	0.0	0.00	488.3	16.2	20.3	79	ERR			ERR		ERR	ERR
24–Apr	1	54	0.0	0.0	0.00	489.2	17.4	20.4	86	ERR			ERR		ERR	ERR
24–Apr	1	55	64.0	17.5	46.50	489.3	16.2	20.4	79	3.2			ERR		ERR	ERR
24–Apr	13	4	64.0	17.9	46.10	500.4	17.7	20.9	85	3.2			ERR		ERR	ERR
24–Apr	13	5	0.0	0.0	0.00	500.4	16.5	20.9	79	ERR			ERR		ERR	ERR
24–Apr	13	29	0.0	0.0	0.00	500.8	17.7	20.9	85	ERR			ERR		ERR	ERR
24–Apr	13	30	66.0	18.5	47.50	500.8	16.5	20.9	79	3.3	41.2	9.8	134.4	–46.1	93.2	96.9
24–Apr	22	34	64.0	18.2	45.80	509.9	17.9	21.2	84	3.3	42.0	9.8	137.1	–47.2	93.1	100.6
25–Apr	2	39	64.0	18.5	45.50	514.0	17.1	21.4	80	3.3			ERR		ERR	ERR
25–Apr	2	40	0.0	0.0	0.00	514.0	18.0	21.4	84	ERR			ERR		ERR	ERR
25–Apr	2	49	0.0	0.0	0.00	514.2	17.1	21.4	80	ERR			ERR		ERR	ERR
25–Apr	2	50	62.0	18.5	43.50	514.2	18.0	21.4	84	3.4			ERR		ERR	ERR
25–Apr	9	34	64.0	19.0	45.00	520.9	17.3	21.7	80	3.4	41.8	9.9	135.0	–47.5	91.2	99.6
25–Apr	9	35	0.0	0.0	0.00	520.9	18.2	21.7	84	ERR			ERR		ERR	ERR
25–Apr	11	54	0.0	0.0	0.00	523.2	17.3	21.8	79	ERR			ERR		ERR	ERR
25–Apr	11	55	65.0	19.1	45.90	523.3	18.2	21.8	84	3.4	41.9	10.0	134.0	–47.5	90.5	98.8
25–Apr	20	44	65.0	19.2	45.80	532.1	17.5	22.2	79	3.4	41.0	10.0	131.1	–48.5	86.9	98.2
25–Apr	20	45	0.0	0.0	0.00	532.1	18.5	22.2	83	ERR			ERR		ERR	ERR
25–Apr	21	33	0.0	0.0	0.00	532.9	17.5	22.2	79	ERR			ERR		ERR	ERR
25–Apr	21	34	65.0	19.2	45.80	532.9	18.5	22.2	83	3.4			ERR		ERR	ERR
26–Apr	0	9	66.0	20.0	46.00	535.5	17.6	22.3	79	3.4			ERR		ERR	ERR
26–Apr	0	10	0.0	0.0	0.00	535.5	18.5	22.3	83	ERR			ERR		ERR	ERR
26–Apr	1	29	0.0	0.0	0.00	536.8	17.6	22.4	79	ERR			ERR		ERR	ERR
26–Apr	1	30	66.0	20.0	46.00	536.8	18.6	22.4	83	3.4			ERR		ERR	ERR
26–Apr	12	55	69.0	21.0	48.00	548.3	17.9	22.8	78	3.5	43.5	14.1	98.7	–39.5	76.1	62.8
26–Apr	14	11	69.0	21.0	48.00	549.5	19.2	22.9	84	3.5			ERR		ERR	ERR
26–Apr	14	12	0.0	0.0	0.00	549.5	18.0	22.9	78	ERR			ERR		ERR	ERR
26–Apr	14	21	0.0	0.0	0.00	549.7	19.2	22.9	84	ERR			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
26-Apr	14	22	67.0	21.0	46.00	549.7	18.0	22.9	78	3.5	42.5	14.2	95.7	-39.0	74.4	60.2
26-Apr	20	0	67.0	21.0	46.00	555.3	19.3	23.1	84	3.5	42.8	13.7	99.9	-40.4	76.1	64.8
26-Apr	20	1	0.0	0.0	0.00	555.4	18.1	23.1	78	ERR			ERR		ERR	ERR
26-Apr	21	4	0.0	0.0	0.00	556.4	19.4	23.2	83	ERR			ERR		ERR	ERR
26-Apr	21	5	67.0	21.0	46.00	556.4	18.1	23.2	78	3.5			ERR		ERR	ERR
26-Apr	21	45	68.0	22.0	46.00	557.1	19.4	23.2	83	3.6	42.8	13.5	101.4	-42.0	75.3	67.8
27-Apr	3	0	67.0	22.0	45.00	562.3	18.4	23.4	79	3.7	44.0	14.0	100.5	-42.6	74.0	68.0
27-Apr	12	30	70.0	23.6	46.40	571.8	20.1	23.8	84	3.8	45.5	10.5	138.6	-53.5	82.4	111.4
27-Apr	14	29	70.0	23.6	46.40	573.8	18.9	23.9	79	3.8			ERR		ERR	ERR
27-Apr	14	30	0.0	0.0	0.00	573.8	20.1	23.9	84	ERR			ERR		ERR	ERR
27-Apr	14	39	0.0	0.0	0.00	574.0	19.0	23.9	79	ERR			ERR		ERR	ERR
27-Apr	14	40	70.0	29.0	41.00	574.0	20.1	23.9	84	4.6	45.1	10.5	137.4	-53.6	81.5	110.6
27-Apr	20	25	70.0	29.0	41.00	579.8	19.1	24.2	79	4.6	45.0	10.5	137.1	-54.2	80.2	111.2
28-Apr	6	35	72.0	29.5	42.50	589.9	20.8	24.6	85	4.6	45.6	10.5	138.9	-55.0	79.7	113.8
28-Apr	11	4	72.0	29.5	42.50	594.4	19.7	24.8	80	4.6			ERR		ERR	ERR
28-Apr	11	5	0.0	0.0	0.00	594.4	20.9	24.8	84	ERR			ERR		ERR	ERR
28-Apr	11	54	0.0	0.0	0.00	595.2	19.7	24.8	80	ERR			ERR		ERR	ERR
28-Apr	11	55	72.0	29.5	42.50	595.3	20.9	24.8	84	4.6			ERR		ERR	ERR
28-Apr	22	35	76.0	32.0	44.00	605.9	20.0	25.2	79	4.7	46.3	10.9	135.8	-56.7	74.6	113.5
29-Apr	1	0	75.0	32.5	42.50	608.3	21.5	25.3	85	4.9	46.2	11.0	134.3	-56.9	73.4	112.5
29-Apr	14	30	77.0	33.0	44.00	621.8	20.7	25.9	80	4.8	46.4	11.1	133.7	-61.5	63.8	117.5
29-Apr	18	30	80.0	35.0	45.00	625.8	22.3	26.1	86	4.9	48.0	11.6	132.3	-63.2	59.7	118.1
30-Apr	0	35	80.0	35.0	45.00	631.9	21.2	26.3	80	4.9	48.0	11.9	129.0	-61.7	61.2	113.6
30-Apr	7	50	83.0	36.1	46.90	639.2	23.0	26.6	86	4.9	48.4	12.4	124.8	-64.0	54.7	112.2
30-Apr	10	59	83.0	36.1	46.90	642.3	21.7	26.8	81	4.9			ERR		ERR	ERR
30-Apr	11	0	0.0	0.0	0.00	642.3	23.0	26.8	86	ERR			ERR		ERR	ERR
30-Apr	13	34	0.0	0.0	0.00	644.9	21.7	26.9	81	ERR			ERR		ERR	ERR
30-Apr	13	35	37.0	0.4	36.60	644.9	23.1	26.9	86	1.2	21.0	14.5	46.3	0.4	46.3	-0.3

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME		Power at Array in kW		Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter		Z ohm	Angle degree	Z Real	Z Imaginary
	hr	mi	Forw.	Refl.							Va mV	Vb mV				
30–Apr	21	30	38.0	0.3	37.70	652.8	21.9	27.2	80	1.2	20.5	14.0	46.8	0.2	46.8	−0.2
1–May	1	0	37.0	0.3	36.70	656.3	23.5	27.3	86	1.2	20.0	14.0	45.7	0.2	45.7	−0.2
1–May	7	50	40.0	0.4	39.60	663.2	22.3	27.6	81	1.2	20.0	14.5	44.1	0.8	44.1	−0.6
1–May	10	49	40.0	0.4	39.60	666.2	23.9	27.8	86	1.2			ERR		ERR	ERR
1–May	10	50	0.0	0.0	0.00	666.2	22.4	27.8	81	ERR			ERR		ERR	ERR
1–May	11	9	0.0	0.0	0.00	666.5	23.9	27.8	86	ERR			ERR		ERR	ERR
1–May	11	10	39.0	0.6	38.40	666.5	22.4	27.8	81	1.3	19.6	14.6	42.9	1.0	42.9	−0.7
1–May	14	29	39.0	0.6	38.40	669.8	24.0	27.9	86	1.3	19.4	14.5	42.8	1.0	42.8	−0.7
1–May	14	30	0.0	0.0	0.00	669.8	22.4	27.9	80	ERR			ERR		ERR	ERR
1–May	16	49	0.0	0.0	0.00	672.2	24.0	28.0	86	ERR			ERR		ERR	ERR
1–May	16	50	40.0	5.0	35.00	672.2	22.5	28.0	80	2.1	20.2	15.9	40.6	30.0	35.2	−20.3
2–May	12	0	39.0	4.8	34.20	691.3	24.4	28.8	85	2.1	19.4	16.8	36.9	29.8	32.0	−18.4
2–May	21	47	43.0	5.8	37.20	701.1	23.6	29.2	81	2.2	20.2	19.2	33.6	71.8	10.5	−32.0
3–May	0	14	43.0	5.8	37.20	703.6	24.8	29.3	85	2.2			ERR		ERR	ERR
3–May	0	15	0.0	0.0	0.00	703.6	23.6	29.3	81	ERR			ERR		ERR	ERR
3–May	0	54	0.0	0.0	0.00	704.2	24.8	29.3	85	ERR			ERR		ERR	ERR
3–May	0	55	44.0	6.0	38.00	704.3	23.6	29.3	81	2.2			ERR		ERR	ERR
3–May	8	20	44.0	6.5	37.50	711.7	25.0	29.7	84	2.2	20.4	18.8	34.7	35.0	28.4	−19.9
3–May	15	4	44.0	6.3	37.75	718.4	24.2	29.9	81	2.2			ERR		ERR	ERR
3–May	15	5	0.0	0.0	0.00	718.4	25.1	29.9	84	ERR			ERR		ERR	ERR
3–May	15	19	0.0	0.0	0.00	718.7	24.2	29.9	81	ERR			ERR		ERR	ERR
3–May	15	20	41.0	6.6	34.40	718.7	25.1	29.9	84	2.3	19.6	18.3	34.3	35.6	27.9	−19.9
4–May	6	59	42.0	6.5	35.50	734.3	24.5	30.6	80	2.3			ERR		ERR	ERR
4–May	7	0	0.0	0.0	0.00	734.3	25.4	30.6	83	ERR			ERR		ERR	ERR
4–May	7	34	0.0	0.0	0.00	734.9	24.5	30.6	80	ERR			ERR		ERR	ERR
4–May	7	35	43.6	7.0	36.60	734.9	25.4	30.6	83	2.3	20.6	18.2	36.2	36.4	29.1	−21.5
4–May	18	18	44.0	7.7	36.30	745.6	24.7	31.1	80	2.4	20.9	18.5	36.1	36.0	29.2	−21.2
4–May	23	35	45.0	8.4	36.60	750.9	26.0	31.3	83	2.5	21.2	18.7	36.3	41.1	27.3	−23.8

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
5-May	11	5	48.0	8.9	39.10	762.4	25.4	31.8	80	2.5	21.0	19.0	35.3	45.0	25.0	-25.0
5-May	17	58	46.0	9.5	36.50	769.3	26.7	32.1	83	2.7	21.0	19.0	35.3	44.0	25.4	-24.6
6-May	1	30	47.0	10.8	36.20	776.8	25.9	32.4	80	2.8	21.2	20.2	33.6	47.0	22.9	-24.5
6-May	8	6	46.5	11.0	35.50	783.4	27.2	32.6	83	2.9	21.6	20.0	34.5	49.5	22.4	-26.3
6-May	22	37	48.0	12.6	35.40	798.0	26.7	33.2	80	3.1	21.9	20.6	34.0	47.0	23.2	-24.9
7-May	1	30	48.5	13.0	35.50	800.8	27.9	33.4	84	3.1	21.9	20.5	34.2	47.5	23.1	-25.2
7-May	7	6	48.5	13.0	35.50	806.4	27.0	33.6	80	3.1			ERR		ERR	ERR
7-May	7	7	0.0	0.0	0.00	806.5	28.0	33.6	83	ERR			ERR		ERR	ERR
7-May	7	29	0.0	0.0	0.00	806.8	27.0	33.6	80	ERR			ERR		ERR	ERR
7-May	7	30	53.5	13.3	40.20	806.8	28.0	33.6	83	3.0	21.8	20.5	34.0	43.0	24.9	-23.2
7-May	20	28	53.0	14.0	39.00	819.8	27.3	34.2	80	3.1	21.7	21.0	33.0	42.0	24.6	-22.1
8-May	2	30	55.0	14.9	40.10	825.8	28.8	34.4	84	3.2	22.3	21.9	32.6	43.0	23.8	-22.2
8-May	6	59	55.0	15.0	40.00	830.3	27.7	34.6	80	3.2			ERR		ERR	ERR
8-May	7	0	0.0	0.0	0.00	830.3	28.9	34.6	84	ERR			ERR		ERR	ERR
8-May	10	44	0.0	0.0	0.00	834.1	27.8	34.8	80	ERR			ERR		ERR	ERR
8-May	10	45	56.5	16.1	40.40	834.1	29.0	34.8	83	3.3	22.6	21.5	33.6	51.5	20.9	-26.3
8-May	14	54	56.5	16.1	40.40	838.2	27.9	34.9	80	3.3			ERR		ERR	ERR
8-May	14	55	0.0	0.0	0.00	838.3	29.1	34.9	83	ERR			ERR		ERR	ERR
8-May	15	36	0.0	0.0	0.00	838.9	27.9	35.0	80	ERR			ERR		ERR	ERR
8-May	15	37	55.0	16.0	39.00	839.0	29.1	35.0	83	3.3	22.5	21.5	33.5	52.0	20.6	-26.4
9-May	0	10	56.0	16.5	39.50	847.5	28.1	35.3	80	3.4	22.8	21.8	33.4	52.0	20.6	-26.4
9-May	6	24	57.0	17.0	40.00	853.7	29.7	35.6	83	3.4	23.2	22.1	33.6	52.3	20.5	-26.6
9-May	21	50	56.4	18.0	38.40	869.2	29.0	36.2	80	3.6	22.8	22.7	32.1	55.2	18.3	-26.4
10-May	1	5	58.0	19.0	39.00	872.4	30.5	36.4	84	3.7	23.3	23.2	32.1	55.7	18.1	-26.5
10-May	21	56	59.9	20.0	39.90	893.3	29.9	37.2	80	3.7	23.7	26.0	29.2	57.3	15.7	-24.5
11-May	0	30	62.0	21.0	41.00	895.8	31.4	37.3	84	3.8	24.3	26.5	29.3	56.9	16.0	-24.6
11-May	8	0	63.0	21.9	41.10	903.3	30.4	37.6	81	3.9	24.4	23.6	33.1	57.6	17.7	-27.9
11-May	16	0	54.5	18.7	35.80	911.3	32.0	38.0	84	3.8	23.9	23.8	32.1	53.3	19.2	-25.7

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME		Power at Array in kW		Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter		Z ohm	Angle degree	Z Real	Z Imaginary
	hr	mi	Forw.	Refl.							Va mV	Vb mV				
11–May	16	29	54.5	18.7	35.80	911.8	30.7	38.0	81	3.8			ERR		ERR	ERR
11–May	16	30	0.0	0.0	0.00	911.8	32.1	38.0	84	ERR			ERR		ERR	ERR
12–May	3	55	64.0	24.5	39.50	923.3	31.2	38.5	81	4.2	25.6	24.8	33.0	61.8	15.6	−29.1
12–May	12	18	59.0	20.5	38.50	931.6	32.5	38.8	84	3.9	23.1	22.8	32.4	56.0	18.1	−26.9
12–May	19	55	55.5	19.0	36.50	939.3	31.8	39.1	81	3.8	22.3	22.0	32.4	53.9	19.1	−26.2
13–May	2	0	56.5	17.5	39.00	945.3	33.0	39.4	84	3.5	22.5	22.2	32.4	52.9	19.6	−25.9
13–May	13	20	52.5	12.5	40.00	956.7	32.5	39.9	82	2.9	20.6	21.1	31.2	47.1	21.3	−22.9
13–May	21	55	51.5	14.0	37.50	965.3	33.8	40.2	84	3.2	20.7	21.0	31.5	47.3	21.4	−23.2
14–May	4	0	54.0	15.0	39.00	971.3	33.1	40.5	82	3.2	21.4	21.7	31.5	48.6	20.9	−23.7
14–May	15	55	51.5	14.3	37.20	983.3	34.5	41.0	84	3.2	20.4	21.0	31.1	46.6	21.3	−22.6
14–May	21	55	52.5	14.3	38.20	989.3	33.8	41.2	82	3.2	20.8	21.2	31.4	46.0	21.8	−22.6
15–May	0	37	52.2	13.0	39.20	992.0	34.8	41.3	84	3.0	21.2	21.5	31.5	47.2	21.4	−23.1
15–May	6	40	52.2	14.5	37.70	998.0	34.2	41.6	82	3.2	21.1	21.6	31.2	46.9	21.3	−22.8
15–May	8	30	56.0	15.2	40.80	999.8	35.2	41.7	84	3.2	20.6	21.5	30.6	46.0	21.3	−22.0
15–May	11	44	56.0	15.2	40.80	1003.1	34.4	41.8	82	3.2			ERR		ERR	ERR
15–May	11	45	0.0	0.0	0.00	1003.1	35.2	41.8	84	ERR			ERR		ERR	ERR
15–May	12	4	0.0	0.0	0.00	1003.4	34.4	41.8	82	ERR			ERR		ERR	ERR
15–May	12	5	54.0	15.1	38.90	1003.4	35.3	41.8	84	3.2	20.5	21.2	30.9	46.4	21.3	−22.4
15–May	21	43	52.0	15.0	37.00	1013.1	34.6	42.2	82	3.3	20.4	21.3	30.6	47.3	20.8	−22.5
16–May	1	5	53.0	15.2	37.80	1016.4	35.8	42.4	84	3.3	20.9	21.7	30.8	46.8	21.1	−22.5
16–May	4	2	53.0	15.2	37.80	1019.4	34.8	42.5	82	3.3	20.2	20.9	30.9	43.6	22.4	−21.3
16–May	9	55	48.0	9.4	38.60	1025.3	36.1	42.7	85	2.6	18.1	19.4	29.8	36.7	23.9	−17.8
16–May	20	2	46.0	8.5	37.50	1035.4	35.4	43.1	82	2.5	18.0	19.3	29.8	34.5	24.6	−16.9
16–May	21	40	46.0	8.5	37.50	1037.0	36.6	43.2	85	2.5	18.1	19.3	30.0	34.0	24.9	−16.8
17–May	0	28	46.0	8.3	37.70	1039.8	35.6	43.3	82	2.5	18.2	19.3	30.2	34.0	25.0	−16.9
17–May	8	40	46.2	7.4	38.80	1048.0	37.0	43.7	85	2.3	18.0	19.0	30.3	30.0	26.2	−15.1
17–May	12	0	0.0	0.0	0.00	1051.3	35.8	43.8	82	ERR			ERR		ERR	ERR
17–May	12	34	0.0	0.0	0.00	1051.9	37.1	43.8	85	ERR			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
17–May	12	35	45.6	7.9	37.70	1051.9	35.8	43.8	82	2.4			ERR		ERR	ERR
17–May	15	5	0.0	0.0	0.00	1054.4	37.1	43.9	84	ERR			ERR		ERR	ERR
17–May	15	34	0.0	0.0	0.00	1054.9	35.9	44.0	82	ERR			ERR		ERR	ERR
17–May	15	35	45.0	7.5	37.50	1054.9	37.1	44.0	84	2.4			ERR		ERR	ERR
17–May	21	0	44.0	7.5	36.50	1060.3	36.0	44.2	81	2.4	17.3	18.8	29.4	29.5	25.6	–14.5
18–May	4	35	44.0	6.5	37.50	1067.9	37.6	44.5	85	2.2	16.6	18.5	28.7	23.1	26.4	–11.3
18–May	6	0	44.0	6.0	38.00	1069.3	36.4	44.6	82	2.2	16.8	18.5	29.0	22.1	26.9	–10.9
18–May	8	45	45.5	6.5	39.00	1072.1	37.8	44.7	85	2.2	16.9	18.8	28.7	23.0	26.5	–11.2
18–May	13	30	43.0	4.9	38.10	1076.8	36.7	44.9	82	2.0	17.0	18.1	30.0	17.6	28.6	–9.1
18–May	16	0	41.8	4.0	37.80	1079.3	38.1	45.0	85	1.9	16.9	17.2	31.4	15.7	30.2	–8.5
18–May	23	40	18.0	2.5	15.50	1087.0	36.9	45.3	82	2.2	20.4	7.5	87.0	33.5	72.5	–48.0
18–May	23	55	0.0	0.0	0.00	1087.3	38.2	45.3	84	ERR			ERR		ERR	ERR
19–May	1	15	0.0	0.0	0.00	1088.6	36.9	45.4	81	ERR			ERR		ERR	ERR
19–May	1	15	21.0	0.7	20.30	1088.6	38.2	45.4	84	1.4			ERR		ERR	ERR
19–May	5	58	21.5	0.8	20.70	1093.3	37.0	45.6	81	1.5	20.3	8.0	81.1	–1.0	81.1	1.4
19–May	7	55	22.0	0.8	21.20	1095.3	38.4	45.6	84	1.5	20.0	7.8	82.0	–0.1	82.0	0.1
19–May	10	0	35.5	2.0	33.50	1097.3	37.1	45.7	81	1.6	25.1	9.4	85.4	16.0	82.1	–23.5
19–May	11	11	34.0	0.8	33.20	1098.5	38.5	45.8	84	1.4	23.4	9.9	75.6	–2.4	75.5	3.2
19–May	14	13	33.0	0.7	32.30	1101.6	37.3	45.9	81	1.3	22.3	10.0	71.3	–4.0	71.1	5.0
19–May	14	23	38.0	0.8	37.20	1101.7	38.6	45.9	84	1.3	24.0	10.8	71.1	–3.4	70.9	4.2
19–May	15	23	36.5	0.5	36.00	1102.7	37.3	45.9	81	1.3	23.0	11.4	64.5	–7.8	63.9	8.8
19–May	17	0	38.0	0.8	37.20	1104.3	38.7	46.0	84	1.3	24.0	10.0	76.8	3.5	76.6	–4.7
19–May	19	0	38.0	2.5	35.50	1106.3	37.4	46.1	81	1.7	25.0	11.8	67.8	15.0	65.4	–17.5
19–May	20	0	42.5	6.5	36.00	1107.3	38.8	46.1	84	2.3	26.5	13.3	63.7	43.0	46.6	–43.5
19–May	23	55	33.0	3.0	30.00	1111.3	37.6	46.3	81	1.9	21.5	12.7	54.1	32.0	45.9	–28.7
20–May	4	22	26.0	6.0	20.00	1115.7	39.1	46.5	84	2.8	22.0	10.5	67.0	46.0	46.5	–48.2
20–May	5	49	7.0	0.0	7.00	1117.2	37.7	46.5	81	1.0	23.0	5.7	129.0	64.0	56.6	–116.0
20–May	6	25	0.0	0.0	0.00	1117.8	39.1	46.6	84	ERR			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
20–May	7	30	31.0	15.0	16.00	1118.8	37.7	46.6	81	5.6	29.0	9.0	103.0	63.5	46.0	–92.2
20–May	7	31	0.0	0.0	0.00	1118.9	39.1	46.6	84	ERR			ERR		ERR	ERR
20–May	18	29	0.0	0.0	0.00	1129.8	37.8	47.1	80	ERR			ERR		ERR	ERR
20–May	18	30	12.0	2.0	10.00	1129.8	39.1	47.1	83	2.4	16.0	5.5	93.0	30.5	80.2	–47.2
20–May	18	53	24.0	3.6	20.40	1130.2	37.8	47.1	80	2.3	22.3	7.9	90.3	30.1	78.1	–45.3
21–May	0	25	22.5	3.0	19.50	1135.8	39.2	47.3	83	2.2	21.7	8.4	82.6	29.5	71.9	–40.7
21–May	1	18	10.0	0.0	10.00	1136.6	37.9	47.4	80	1.0	11.5	6.0	61.3	0.0	61.3	0.0
21–May	3	31	11.0	1.1	9.90	1138.9	39.3	47.5	83	1.9	15.5	5.6	88.5	24.7	80.4	–37.0
21–May	5	23	11.0	1.0	10.00	1140.7	38.0	47.5	80	1.9	14.7	6.0	78.4	23.0	72.1	–30.6
21–May	5	30	16.0	1.5	14.50	1140.8	39.3	47.5	83	1.9	17.6	7.2	78.2	23.5	71.7	–31.2
21–May	8	15	23.0	2.1	20.90	1143.6	38.0	47.6	80	1.9	20.4	8.4	77.7	25.3	70.2	–33.2
21–May	8	55	10.0	0.0	10.00	1144.3	39.3	47.7	83	1.0	11.3	6.6	54.8	–5.0	54.5	4.8
21–May	9	28	17.0	1.9	15.10	1144.8	38.0	47.7	80	2.0	18.0	10.0	57.6	25.9	51.8	–25.1
21–May	13	15	16.0	0.3	15.70	1148.6	39.4	47.9	82	1.3	13.0	8.6	48.3	4.0	48.2	–3.4
21–May	23	6	22.0	2.5	19.50	1158.4	38.3	48.3	79	2.0	17.1	11.0	49.7	–40.0	38.1	32.0
22–May	0	49	32	7.3	24.70	1160.2	39.6	48.3	82	2.8	29.5	5.9	159.9	–33.3	133.6	87.8
22–May	1	57	46.0	16.0	30.00	1161.3	38.4	48.4	79	3.9	38.0	6.0	202.5	–51.8	125.3	159.2
22–May	4	18	66.0	22.0	44.00	1163.6	39.8	48.5	82	3.7	45.0	8.0	179.9	–56.4	99.5	149.8
22–May	7	40	35.0	0.0	35.00	1167.0	38.6	48.6	79	1.0	48.0	8.2	187.2	–54.5	108.7	152.4
22–May	12	20	30.0	0.0	30.00	1171.7	40.1	48.8	82	1.0	46.0	9.7	151.7	–54.3	88.5	123.2
22–May	16	25	35.0	0.0	35.00	1175.8	38.9	49.0	79	1.0	49.5	8.4	188.2	–53.7	111.4	151.7
22–May	21	24	35.0	0.1	34.90	1180.7	40.4	49.2	82	1.1	51.8	8.3	199.6	–54.5	115.9	162.5
22–May	23	29	38.0	0.1	37.90	1182.8	39.1	49.3	79	1.1	51.0	8.6	189.6	–50.6	120.4	146.5
23–May	1	14	39.8	0.1	39.70	1184.6	40.5	49.4	82	1.1	54.2	8.8	197.0	–53.9	116.1	159.1
23–May	5	29	37.0	0.1	36.90	1188.8	39.4	49.5	79	1.1	51.0	8.0	203.9	–48.2	135.9	152.0
23–May	20	8	36.0	0.0	36.00	1203.5	41.3	50.1	82	1.0	46.1	10.4	141.8	–59.0	73.0	121.5
24–May	6	0	10.0	0.1	9.90	1213.3	40.0	50.6	79	1.2			ERR		ERR	ERR
24–May	6	43	15.0	0.0	15.00	1214.1	41.6	50.6	82	1.0	8.1	13.0	19.9	–5.0	19.9	1.7

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
24–May	9	50	25.5	7.0	18.50	1217.2	40.0	50.7	79	3.2	12.9	15.0	27.5	40.3	21.0	–17.8
24–May	17	30	20.0	0.0	20.00	1224.8	41.8	51.0	82	1.0	32.8	9.4	111.6	55.8	62.7	–92.3
25–May	1	0	21.0	0.0	21.00	1232.3	40.3	51.3	79	1.0	38.0	18.0	67.5	51.5	42.0	–52.8
25–May	2	0	15.0	0.0	15.00	1233.3	41.9	51.4	82	1.0	35.6	6.7	169.9	56.0	95.0	–140.9
25–May	5	20	15.0	0.0	15.00	1236.7	40.4	51.5	78	1.0	35.0	6.7	167.1	55.0	95.8	–136.8
25–May	8	33	20.0	0.0	20.00	1239.9	42.0	51.7	81	1.0	40.0	7.8	164.0	55.0	94.1	–134.3
26–May	0	18	20.0	0.0	20.00	1255.6	40.8	52.3	78	1.0	36.5	4.5	259.4	24.5	236.0	–107.6
26–May	6	5	24.0	0.0	24.00	1261.4	42.5	52.6	81	1.0	38.2	5.5	222.1	21.0	207.4	–79.6
26–May	7	31	22.0	0.0	21.99	1262.9	40.9	52.6	78	1.0	37.0	5.3	223.3	11.5	218.8	–44.5
26–May	14	34	22.0	0.0	22.00	1269.9	42.7	52.9	81	1.0	46.0	3.9	377.2	13.3	367.1	–86.8
26–May	15	2	25.0	0.3	24.75	1270.4	41.1	52.9	78	1.2	46.0	4.4	334.3	12.8	326.0	–74.1
26–May	15	15	35.0	0.1	34.90	1270.6	42.8	52.9	81	1.1	51.0	5.5	296.5	8.2	293.5	–42.3
26–May	15	45	5.0	1.3	3.70	1271.1	41.1	53.0	78	3.1	21.1	1.1	624.8	–7.4	619.6	80.5
26–May	19	5	5.0	1.4	3.60	1274.4	42.8	53.1	81	3.2	27.5	1.3	676.5	–10.5	665.2	123.3
26–May	22	25	7.0	1.3	5.70	1277.8	41.2	53.2	77	2.5	30.4	1.4	694.4	–11.4	680.7	137.3
27–May	1	0	7.0	1.3	5.70	1280.3	42.9	53.3	80	2.5	31.6	1.5	673.7	–8.2	666.8	96.1
27–May	7	25	7.2	1.1	6.10	1286.8	41.2	53.6	77	2.3	29.9	1.6	597.6	–0.4	597.6	4.2
27–May	8	7	10.0	1.4	8.60	1287.5	42.9	53.6	80	2.2	34.5	1.9	580.7	0.2	580.7	–2.0
27–May	11	49	0.0	0.0	0.00	1291.2	41.2	53.8	77	ERR			ERR		ERR	ERR
27–May	22	9	0.0	0.0	0.00	1301.5	43.0	54.2	79	ERR			ERR		ERR	ERR
27–May	22	10	20.0	0.0	20.00	1301.5	41.3	54.2	76	1.0	64.0	2.5	818.7	–11.8	801.4	167.4
28–May	10	25	20.0	0.0	20.00	1313.8	43.1	54.7	79	1.0	59.0	2.5	754.7	–12.6	736.6	164.6
28–May	16	9	20.0	0.0	20.00	1319.5	41.7	55.0	76	1.0			ERR		ERR	ERR
28–May	16	10	0.0	0.0	0.00	1319.5	43.2	55.0	79	ERR			ERR		ERR	ERR
28–May	18	39	0.0	0.0	0.00	1322.0	41.7	55.1	76	ERR			ERR		ERR	ERR
28–May	18	40	21.0	0.0	21.00	1322.0	43.2	55.1	78	1.0	71.0	2.6	873.3	–39.2	676.8	552.0
29–May	8	0	20.0	0.0	20.00	1335.3	41.9	55.6	75	1.0			ERR		ERR	ERR
29–May	8	1	0.0	0.0	0.00	1335.4	43.3	55.6	78	ERR			ERR		ERR	ERR

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
29-May	10	25	0.0	0.0	0.00	1337.8	41.9	55.7	75	ERR	81.0	3.6	719.6	-53.4	429.0	577.7
29-May	10	25	21.5	0.0	21.50	1337.8	43.4	55.7	78	1.0			ERR		ERR	ERR
29-May	12	50	25.0	0.0	25.00	1340.2	41.9	55.8	75	1.0	79.0	3.2	789.5	-48.0	528.3	586.7
29-May	16	50	26.0	0.0	26.00	1344.2	43.5	56.0	78	1.0	48.1	4.7	327.3	32.8	275.1	-177.3
29-May	20	0	26.0	0.0	26.00	1347.3	42.1	56.1	75	1.0			ERR		ERR	ERR
29-May	20	0	0.0	0.0	0.00	1347.3	43.6	56.1	78	ERR			ERR		ERR	ERR
29-May	22	0	0.0	0.0	0.00	1349.3	42.1	56.2	75	ERR	15.0	1.0	479.7	-75.5	120.1	464.4
29-May	22	0	2.0	1.0	1.00	1349.3	43.6	56.2	77	5.8			ERR		ERR	ERR
29-May	22	40	4.2	1.1	3.10	1350.0	42.1	56.3	75	3.1	34.0	2.6	418.2	-76.5	97.6	406.6
29-May	23	37	10.0	1.4	8.60	1351.0	43.6	56.3	77	2.2	29.0	5.0	185.5	64.0	81.3	-166.7
29-May	23	55	8.0	1.4	6.60	1351.3	42.2	56.3	75	2.4	18.5	4.8	123.3	-55.2	70.3	101.2
30-May	0	36	20.0	0.0	20.00	1351.9	43.6	56.3	77	1.0	33.0	9.8	107.7	60.3	53.4	-93.5
30-May	2	0	8.0	0.0	8.00	1353.3	42.2	56.4	75	1.0	22.0	6.0	117.3	59.0	60.4	-100.5
30-May	3	0	11.0	0.0	11.00	1354.3	43.6	56.4	77	1.0	24.5	7.0	111.9	60.0	56.0	-96.9
30-May	4	30	15.0	0.0	15.00	1355.8	42.2	56.5	75	1.0	26.5	7.0	121.1	53.0	72.9	-96.7
30-May	6	45	8.0	0.0	8.00	1358.1	43.7	56.6	77	1.0	22.0	6.3	111.7	69.0	40.0	-104.3
30-May	8	25	15.0	1.0	14.00	1359.8	42.3	56.7	75	1.7	30.1	5.5	175.0	61.0	84.9	-153.1
30-May	13	5	7.2	2.7	4.50	1364.4	43.7	56.9	77	4.2	33.5	6.7	159.9	81.0	25.0	-157.9
30-May	13	45	0.0	0.0	0.00	1365.1	42.3	56.9	74	ERR			ERR		ERR	ERR
30-May	15	55	20.0	0.0	20.00	1367.3	43.7	57.0	77	1.0	9.7	14.0	22.2	0.0	22.2	0.0
30-May	18	27	20.0	1.0	19.00	1369.8	42.3	57.1	74	1.6			ERR		ERR	ERR
30-May	18	58	4.0	2.8	1.20	1370.3	43.8	57.1	77	11.2	3.8	4.1	29.6	60.0	14.8	-25.7
30-May	19	10	0.0	0.0	0.00	1370.5	42.4	57.1	74	ERR			ERR		ERR	ERR
30-May	20	55	15.0	1.0	14.00	1372.3	43.8	57.2	77	1.7	15.1	15.7	30.8	62.0	14.4	-27.2
30-May	22	15	10.0	0.0	10.00	1373.6	42.4	57.2	74	1.0	12.8	12.3	33.3	65.6	13.7	-30.3
31-May	1	33	12.0	0.0	12.00	1376.9	43.9	57.4	76	1.0	13.8	13.6	32.5	61.5	15.5	-28.5
31-May	4	33	12.5	0.0	12.50	1379.9	42.4	57.5	74	1.0	13.5	13.3	32.5	58.5	17.0	-27.7
31-May	7	45	15.0	0.0	15.00	1383.1	43.9	57.6	76	1.0	13.6	13.8	31.5	53.0	19.0	-25.2

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
31–May	9	26	21.0	0.0	21.00	1384.8	42.5	57.7	74	1.0	14.6	15.6	29.9	41.7	22.3	–19.9
31–May	11	30	30.0	0.0	30.00	1386.8	44.0	57.8	76	1.0	16.2	16.0	32.4	29.4	28.2	–15.9
31–May	12	55	25.0	0.0	25.00	1388.3	42.6	57.8	74	1.0	23.5	8.5	88.4	–1.0	88.4	1.5
31–May	14	20	20.0	1.0	19.00	1389.7	44.1	57.9	76	1.6	42.0	16.5	81.4	72.5	24.5	–77.6
31–May	16	30	0.0	0.0	0.00	1391.8	42.7	58.0	74	ERR			ERR		ERR	ERR
31–May	18	15	2.0	1.6	0.40	1393.6	44.1	58.1	76	17.9	3.4	1.2	92.1	86.0	6.4	–91.9
31–May	21	40	0.0	0.0	0.00	1397.0	42.7	58.2	73	ERR			ERR		ERR	ERR
31–May	23	45	20.0	0.0	20.00	1399.1	44.2	58.3	76	1.0	7.7	2.4	102.6	33.4	85.7	–56.5
1–Jun	0	18	10.0	0.0	10.00	1399.6	42.7	58.3	73	1.0	9.9	13.4	23.6	0.0	23.6	0.0
1–Jun	1	0	5.0	0.0	5.00	1400.3	44.2	58.3	76	1.0	6.4	6.1	33.6	–12.8	32.7	7.4
1–Jun	3	35	0.0	0.0	0.00	1402.9	42.7	58.5	73	ERR			ERR		ERR	ERR
1–Jun	7	30	10.0	0.0	10.00	1406.8	44.3	58.6	76	1.0			ERR		ERR	ERR
1–Jun	8	15	15.0	0.0	15.00	1407.6	42.7	58.6	73	1.0	9.0	13.0	22.1	40.0	17.0	–14.2
1–Jun	19	0	0.0	0.0	0.00	1418.3	44.3	59.1	75	ERR			ERR		ERR	ERR
1–Jun	20	0	0.0	0.0	0.00	1419.3	42.8	59.1	72	ERR	26.0	23.1	36.0	79.2	6.7	–35.4
1–Jun	20	0	15.0	0.0	15.00	1419.3	44.3	59.1	75	1.0			ERR		ERR	ERR
2–Jun	5	20	13.0	0.0	13.00	1428.7	42.9	59.5	72	1.0	22.0	15.7	44.8	72.0	13.8	–42.6
2–Jun	5	50	0.0	0.0	0.00	1429.2	44.4	59.5	75	ERR			ERR		ERR	ERR
2–Jun	6	25	0.0	0.0	0.00	1429.8	42.9	59.6	72	ERR			ERR		ERR	ERR
2–Jun	6	25	13.0	0.0	13.00	1429.8	44.4	59.6	75	1.0			ERR		ERR	ERR
2–Jun	8	5	15.0	0.0	15.00	1431.4	42.9	59.6	72	1.0			ERR		ERR	ERR
2–Jun	17	0	15.0	0.0	15.00	1440.3	44.6	60.0	74	1.0	21.5	14.0	49.1	61.5	23.4	–43.2
2–Jun	23	20	12.0	0.0	12.00	1446.7	43.1	60.3	72	1.0			ERR		ERR	ERR
3–Jun	3	45	5.0	5.0	0.00	1451.1	44.7	60.5	74				ERR		ERR	ERR
3–Jun	3	50	5.0	0.0	5.00	1451.2	43.2	60.5	71	1.0			ERR		ERR	ERR
3–Jun	4	0	12.0	0.0	12.00	1451.3	44.7	60.5	74	1.0			ERR		ERR	ERR
3–Jun	4	5	10.0	0.0	10.00	1451.4	43.2	60.5	71	1.0			ERR		ERR	ERR
3–Jun	5	10	10.0	0.0	10.00	1452.5	44.7	60.5	74	1.0	3.4	2.5	43.2	9494.5	–30.3	–30.8

Table C-1 Operating Data -- Electrical (Continued)

DATE	TIME hr	TIME mi	Power at Array in kW Forw.	Power at Array in kW Refl.	Input Power in kW	Elapsed Time hours	Equiv. Days at 40 kW	Elapsed Days	Source Utilization %	VSWR	Vector Voltmeter Va mV	Vector Voltmeter Vb mV	Z ohm	Angle degree	Z Real	Z Imaginary
3–Jun	6	15	0.0	0.0	0.00	1453.6	43.2	60.6	71	ERR			ERR		ERR	ERR

APPENDIX A.2.

IITRI Project No. C06754
HNUS Sub-contract No. 91-D-4011I-1018
June 8, 1992

BENCH SCALE TREATABILITY STUDY
AND
SOIL DIELECTRIC PROPERTY MEASUREMENTS

Submitted to:

HALLIBURTON NUS Environmental Corp.
800 Oak Ridge Turnpike
Jackson Plaza, C-200
Oak Ridge, Tennessee 37830

HNUS Subcontract No.
91-D-4011I-1018
IIT Research
Institute

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FOREWORD

This report documents a treatability study performed by IITRI to determine the conditions for the decontamination of soils in Site S-1, Kelly AFB. The study was performed for soil decontamination by the radio frequency in situ soil decontamination process. This treatability study was performed to support planning and design activities aimed at the demonstration of the in situ RF heating process at Site S-1, Kelly AFB.

The work reported herein was conducted under HALLIBURTON NUS Environmental Corporation Sub-contract No. 91-D-4011I-1018, IITRI Project No. C06754. This report is a companion document to two other reports currently under preparation, the demonstration system design report and the demonstration test plan.

Respectfully Submitted

Harsh Dev

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Senior Engineer
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Guggilam Sresty
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CONTENTS

APPENDICES

FIGURES

TABLES

SUMMARY

A treatability study was performed for the decontamination of soils present at site S-1, Kelly AFB, by the in situ radio frequency heating soil heating and decontamination process. Soils at site S-1 contain hydrocarbon contaminants spilled as a result of waste transfer operations performed on the site. The site was used as a storage area for wastes which were reclaimed off-base. The soils in the site are contaminated down to the saturated zone which is underlain by an impermeable clayey formation called the Navarro unit. The depth of the vadose zone at the site varies from 27 to 30 ft below the surface.

The radio frequency in situ heating process utilizes electromagnetic (EM) energy in the radio frequency band to heat the soil in situ to a temperature range of 150°C. The soil is heated by providing power to an array of electrodes placed in drilled bore holes made through the contaminated soil volume. The organic vapors and steam formed upon heating of the soil are recovered by applying a vacuum to some of the electrodes and to gas collection lines placed on the soil surface. A vapor barrier is used to assist in the collection of the hot gases and to prevent fugitive emissions from the heated soil surface.

The purpose of the work reported herein was two-fold: first to determine the time and temperature conditions necessary for the removal of the petroleum hydrocarbons spilled at site S-1; second to measure soil dielectric properties which affect the design of the in situ RF heating system. These properties are: the loss tangent, conductivity and permittivity. These were determined as a function of temperature and frequency of the applied EM field. All the work was performed on soil samples obtained from borings made at the site in October 1991.

The results of the treatability study have shown that the diesel range total petroleum hydrocarbons (TPH) can be removed by treatment of the soil at a temperature of 150°C for a period of approximately 120 hours. The residual soil concentration of total diesel range TPH was in the range of 70 to 230 ppm. This corresponds to a percentage removal of 78 to 97

percent depending upon the initial soil concentration. The chemicals present in diesel have high boiling points, ranging from approximately 150°C to greater than 500°C. Thus these are all semi-volatiles. Good removal data for such chemicals in the temperature range of 150°C implies that the lower boiling volatiles should have even better removal efficiency.

The dielectric soil properties were measured. These measurements will be used to specify the electrical components of the RF heating system and in developing the detailed design and operating procedure for the demonstration.

SECTION 1

INTRODUCTION

The purpose of this document is to present the results of a treatability study performed to determine the feasibility of the radio frequency (RF) in situ soil decontamination process for the removal of petroleum hydrocarbons spilled on Site S-1, Kelly AFB, Texas. The study is in two parts. In the first part soil decontamination experiments were performed to determine the treatment temperature and time conditions for soils obtained from site S-1. In the second part of this study, dielectric properties of the soil were measured to confirm the specifications of the RF power source and assist in the design of RF heating system.

The in situ RF heating process utilizes electromagnetic energy (EM) in the RF band to heat contaminated soil in situ thereby vaporizing, boiling or distilling off the organic contaminants present therein. The vaporized contaminants and steam along with infiltrating air are recovered from the heated soil volume by means of a vacuum gas collection system. A surface vapor barrier is utilized to facilitate collection of the vapors while at the same time preventing fugitive emissions of hot contaminant vapors from the site and controlling excessive infiltration of air into the vapor collection system. The soil is heated in situ by energizing an array of electrodes placed in bore holes drilled through the contaminated soil. These electrodes are electrically interconnected and supplied with RF energy from a power source. The hot gases and vapors are collected by means of vacuum applied to selected electrodes and to a gas collection line placed horizontally on the hot soil surface, below the vapor barrier. The gas collection electrodes and the surface pipe are perforated. These collection pipes are connected to an on site vapor treatment system which contains among other components a gas collection blower.

The process decontaminates soils by removing organic and other contaminants which exhibit a vapor pressure of at least 1 mm Hg at the elevated treatment temperature. Previously, IITRI demonstrated the technical feasibility of the process at a site of jet fuel spill located at

Volk Air National Guard Base (1). This field test was done on sandy soil and approximately 94 to 99 percent of the jet fuel spill components were removed from the soil.

This treatability study was done to support planning and design activities currently under way to perform an in situ RF heating and soil decontamination demonstration at Site S-1, Kelly AFB. The primary contaminant at this site is total petroleum hydrocarbons (TPH) along with lower concentrations of polynuclear aromatic hydrocarbons (PAHs), benzene, toluene, ethylbenzene, and xylene (BTEX) components and yet lower concentrations of polychlorinated biphenyls (PCBs) confined to near surface zones. The main objective of the demonstration is to show decontamination of organic volatile and semi-volatile components associated with TPH contamination at the site. Other objectives of the decontamination are: demonstrate under field conditions the process for clayey soils; assess the implementation requirements for commercial scale systems; demonstrate the use of selected electrodes as vapor collection wells; evaluate vertical and horizontal contaminant migration effects, if any; assess removal of higher boiling semi-volatiles such as phthalates, PAHs, etc.

There are two other related reports under preparation. These are a System Design report for the RF Demonstration at Kelly AFB, and a Demonstration Test Plan.

In Section 2 a brief description of the site and its use history is provided, in Section 3 the treatability experiments and results are discussed while in Section 4 the measurement of soil dielectric properties is described.

SECTION 2

SITE AND SOIL DESCRIPTION

2.1 SITE HISTORY AND DESCRIPTION

The site for the planned demonstration of the RF in situ soil decontamination process is located on Kelly AFB, San Antonio, Texas within a few hundred feet of the northern boundary of the base. The site has a designation of S-1. The site was used as an intermediate storage area for wastes to be reclaimed off-base. The waste was stored in tanks installed on the site. The storage area handled mixed solvents, carbon cleaning compounds, petroleum oils and lubricants (POL), etc. The western half of the site was used as a storage area for electrical transformers.

During waste transfer operations spills occurred. The spilled material flowed into a depression which contained a sump for the liquid spills and a spoil pile. The site was used in the period 1960 to 1973. After the waste transfer operations were halted at the site, the storage tanks were removed, the former depression was backfilled and the site was regraded.

Several site investigations have been conducted as described in Reference 2. These investigations have established the presence of chlorobenzenes and benzene in the ground water below the site. Several investigations have been done in which soil borings were advanced into the saturated zone and up to the underlaying Navarro unit which forms an impermeable layer for the downward migration of groundwater. The results of these investigations are summarized in Reference 2. In October 1991, HALLIBURTON NUS Environmental Corporation (HNUS) advanced three new borings in the south eastern edge of the former depression area located on Site S-1. These new borings were designated as SB-16 through SB-18. Figure 1 illustrates the approximate location of these borings on a plan view of the site (reference 3). Bore holes SB-17 and SB-18 were done at the southern extremity of the former sump, while boring SB-16 was done approximately 6 ft outside the estimated boundary of the sump. The main purpose of the two borings made inside the sump was to determine the extent of contamination in the upper half

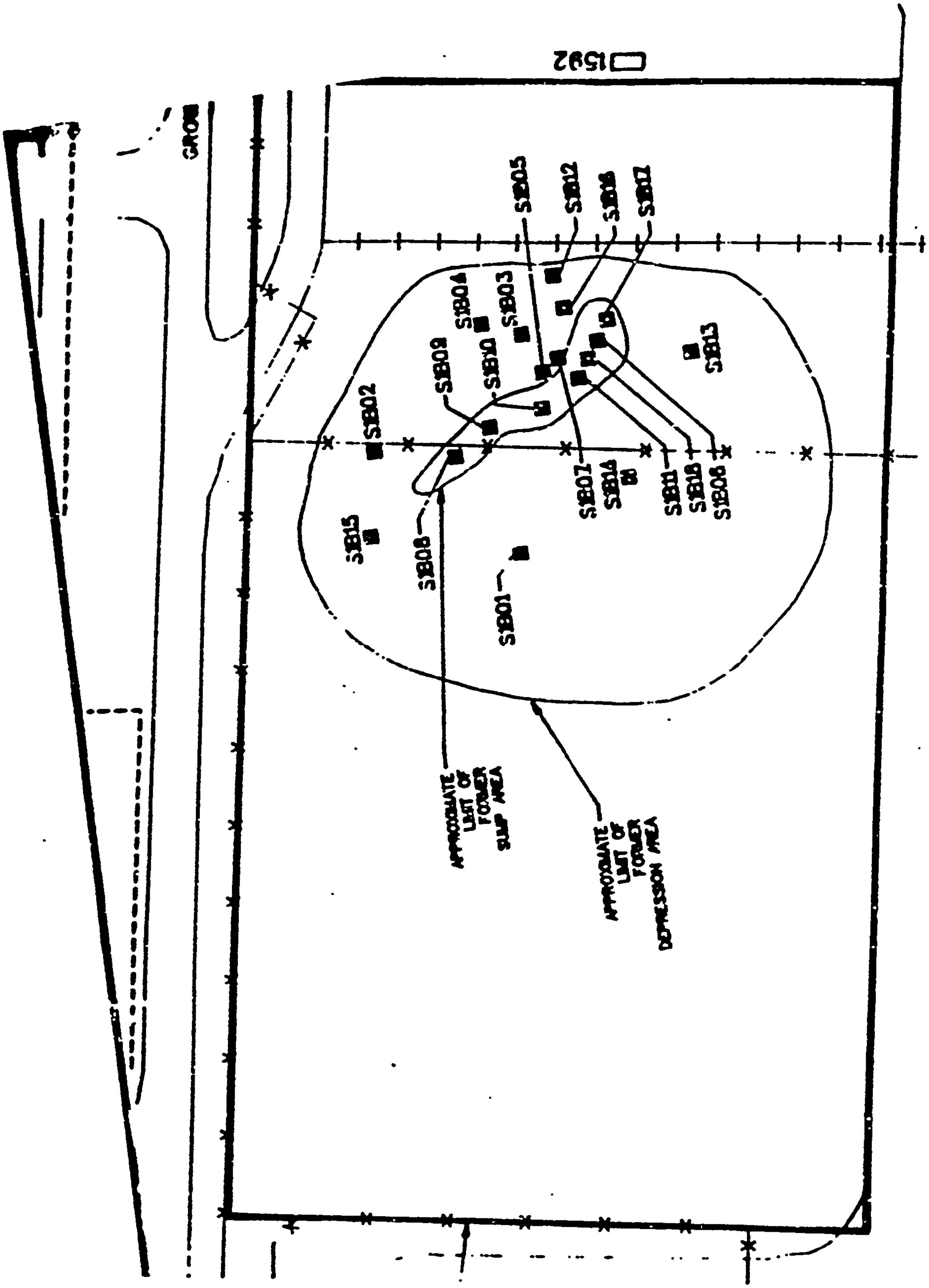

Figure 1. Location of soil borings in Site S-1.

of the vadose zone (0-12 ft below surface) and to obtain samples for this treatability study. The purpose of advancing boring SB-16 was to obtain samples to assess lateral migration of the contaminants outside the original estimated boundary of the sump.

2.2 SOIL SAMPLE DESCRIPTION

Three new bore holes were made by HNUS on October 19, 1991, at the southeastern corner of site S-1. Two of these bore holes were on the center line of the pit while one was outside. Continuous coring was done during the drilling of these bore holes by means of a hollow stem auger drill. Table 1 summarizes the core recoveries, field OVA readings, HNUS' analysis for TPH from selected core intervals, etc. Soil needed for the treatability study was selected from the samples sent to IITRI. In Table 1 the core sample used for each of the five experiments is also indicated by means of the experiment number.

Table 2 provides a list of other contaminants found in the new borings. As the data in Tables 1 and 2 show, TPH with a concentration of up to 980 ppm is by far the most abundant contaminant present in the soil samples analyzed for this study. Other contaminants listed in Table 2 are present at levels which are approximately one thousandth the concentration of TPH. The results from the samples obtained from SB-16 show that the concentrations are considerably lower 5 to 6 ft outside the original estimated location of the sump boundary. Thus SB-16 may indeed be outside the original boundary and also outside the zone of current contamination. The field demonstration should be performed in the southern edge of the sump, near the location of borings SB-17 and SB-18.

Table 1. Field Screening and Lab. Analysis of Core Samples Obtained on 10/19/91
Site S-1, Kelly AFB
(All results in ppm)

Depth Interval	SB-17				SB-18				SB-16			
	TPH ppm	Moist %	OVA ppm	Recovery ft	TPH ppm	Moist %	OVA ppm	Recovery ft	TPH ppm	Moist %	OVA ppm	Recovery ft
2-7	400	20.3	40-700	4.5	<20	19.5	300-700	4 Exp5	<20	12.2	30-80	1.9
7-12	NA	NA	20	1	<20	24.7	100-1000+	4.6 Exp4	<20	9.2	5-80	4.5
12-17	NA	NA	10-40	1.0	<20	26.7	300-1000+	5 Exp2	NA	NA	0	0.8
17-22	980	8.5	200-300	2.0 Exp1	NA	NA	200-300	1.5 Exp3	NA	NA	15	0.4
22-27	NA	NA	40	0.8	110	15.7	500-700	2.5	-	-	-	0.0
27-32	-	-	-	0.0	NA	NA	700	2	NA	NA	0-2	0.8
32-37	-	-	-	0.0	<20	22.1	10-100	3	-	-	-	0.0

TPH: Total petroleum hydrocarbons as analyzed by HNUS.
OVA: Field measurement for hydrocarbons
NA: Not Analyzed
-: No Sample Recovery

Table 2. Concentration (μg/kg) of Semi-Volatiles in Borings SB-16 to SB-18

Chemical Name	SB-16	SB-17	SB-18		
	2-7'	2-7'	2-7'	22-27'	32-37'
1,2,4-trichlorobenzene				190	
1,2-dichlorobenzene				3600	230
1,3-dichlorobenzene		200		1600	
1,4-dichlorobenzene		1100		9300	
2-methylnaphthalene		2300		4400	
Benzo(a)anthracene	170				
Benzo(b)fluoranthene	260				
bis(2-ethylhexyl)phthalate		13000	640	1800	
Di-n-butylphthalate		200	250		
Fluoranthene	430	300			
Naphthalene		140			
Phenanthrene		200			
Pyrene	350				
Solids, wt %	87.8	79.7	80.5	84.3	77.7

Blank cells indicate the contaminant was below its quantitation limit
In SB-16, 7-12 ft all were below quantitation limit
In SB-17, 17-22 ft all were below quantitation limit
In SB-18, 7-12, and 12-17 all were below quantitation limit

SECTION 3

SOIL TREATABILITY EXPERIMENTS

3.1 INTRODUCTION

Soil treatability experiments were performed to determine the required treatment conditions for the removal of petroleum hydrocarbons found in soils obtained from borings made in Site S-1, Kelly AFB. The main focus of the study was to determine the temperature and time conditions necessary to remove at least 90 percent of the total petroleum hydrocarbons (TPH) as analyzed by the California (1) DHS method for TPH.

The analytical method allows for determination of TPH as gasoline or as diesel. In this study the TPH was reported as diesel to determine the condition necessary for the removal of higher boiling components represented by diesel. Most of the hydrocarbons in diesel contain nine to 21 carbon atoms. They are primarily straight and branched chain alkanes, alkyl benzenes and PAH. The boiling point range of the straight chain alkanes is in the range of 150°-376°C; the lowest boiling branched chain alkane boils at 306°C; the alkyl benzenes boil in the range of 80° to 255°C, and the PAHs boil in the range of 218°C to greater than 500°C. Thus most of the diesel components can be classified as semi-volatiles. Based on previous treatability studies performed by IITRI on clayey soils it is anticipated that lower boiling volatile organics would have even better removal efficiency under the same conditions that give greater than 90 percent removal for diesel range TPH.

Due to scheduling constraints, the soil analysis was originally performed by an outside independent laboratory. However, problems with spike recovery were noted in the analysis of the independent laboratory. Subsequently, all the soils samples were returned to IITRI where they were reanalyzed in house by IITRI. An IITRI sponsored internal research and development program funded the installation and verification of the California DHS Method and reanalysis of the early samples from soil treatability experiments. The analytical procedure is described in Section 3.5. Results obtained by the outside independent laboratory are presented in Appendix B.

The laboratory approach to the treatability study attempts to simulate the temperature and gas flow conditions that occur in situ. This approach was developed at IITRI over the last five years and was used to develop conditions for the successful field experiment at Volk ANGB (2,3). The treatability experiments were performed by packing the clayey soils of Site S-1 into a 1.5 in. diameter pipe. The soil column was heated with externally wrapped heating tapes. Gas flow was simulated by injecting at a controlled rate either nitrogen or superheated steam at the base of the soil column.

Under in situ conditions, as soil is heated and the native moisture is removed from the soil pores, the effective permeability to gas flow increases. Thus a gas and steam sweeping action is established in the heated zone due to the vacuum imposed for the collection of the contaminant gases, vapors and steam. The gas and steam sweep thus established helps to increase the rate of contaminant removal from the soil matrix. In the laboratory this sweeping action is simulated by injection of nitrogen, air or steam at the base of the soil column.

The purpose of this document is to provide a description of the experimental set up, procedure and results of the treatability study. As described in Section 2 the soils used in this study were obtained from Site S-1, soil borings SB 17 and SB 18 which were made by HNUS in October 1991.

3.2 EXPERIMENTAL APPARATUS

The treatability experiments were performed by heating a column of soil packed into a 1.5 in diameter stainless steel pipe. The soil inside the pipe was heated by means of heating tapes wound around the pipe. Thermocouples were used to measure the temperature of the soil inside the pipe. The experimental set up is illustrated in Figure 2. The hot gases and vapors formed upon heating the soil pass through a heated vapor tube into a water cooled condenser. The outlet of the condenser is connected to a chilled condensate receiver wherein all the liquids

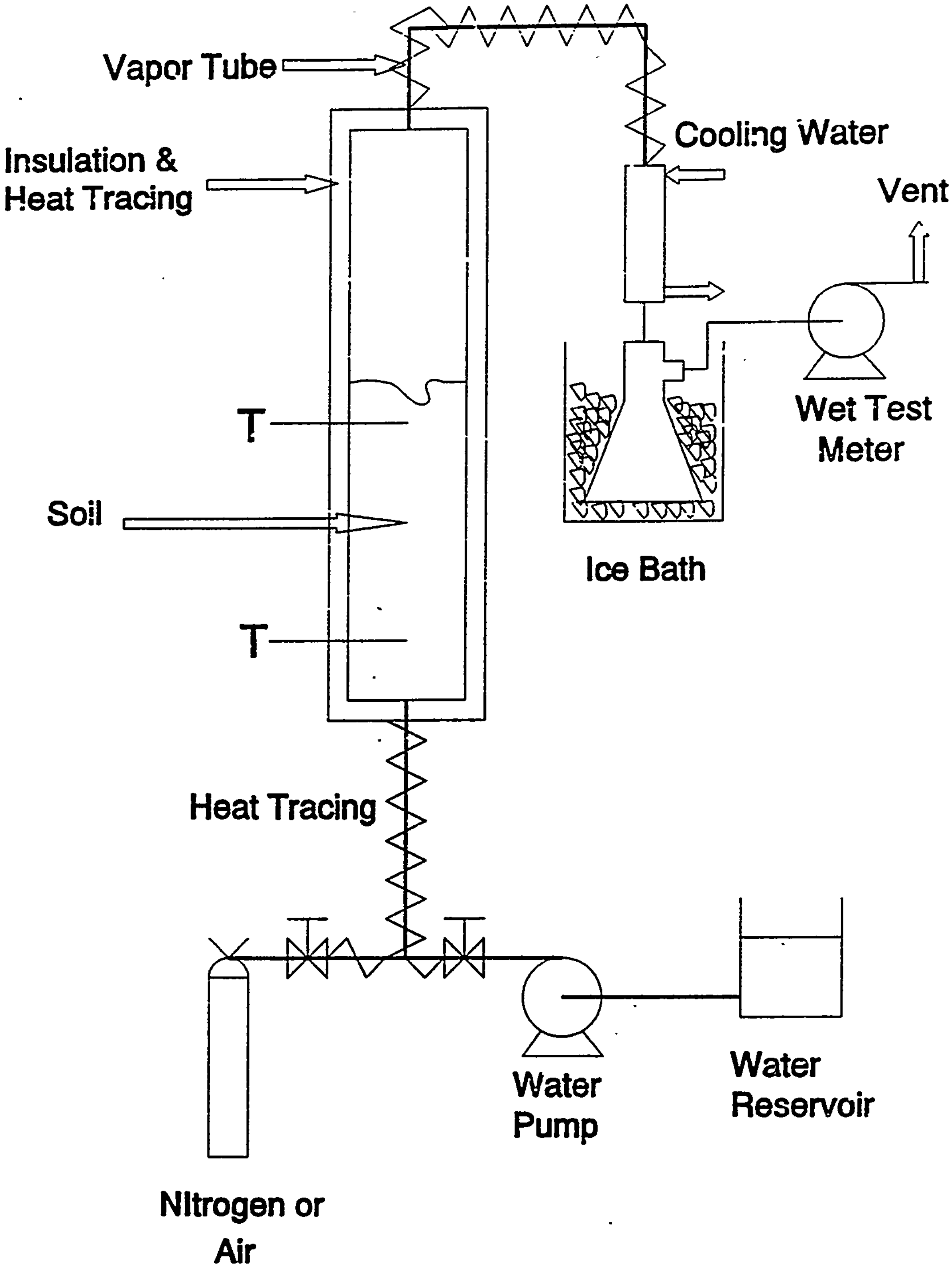

Figure 2. Experimental Setup

formed in the condenser are collected. The uncondensed gases leaving the condensate receiver were passed through a wet test meter.

The soil column was equipped with an injection port at the bottom through which a selected gas (air or nitrogen) or superheated steam was introduced into the soil column to simulate the gas sweep established in the soil upon in situ heating and collection of the produced gases and vapors. The volume of uncondensed gas leaving the chilled condensate receiver was measured by means of a wet test meter as shown in Figure 2. When nitrogen or air was injected at the base of the column it was assumed that the uncondensed gas leaving the receiver was 100% v/v air or nitrogen. Superheated steam was made by pumping deionized water at a controlled rate through a heat traced tubing. The amount of water pumped through the soil column was determined by weighing the water reservoir.

3.3 EXPERIMENTAL PROCEDURE

The cleaned stainless steel reactor was packed with soil core samples sent to IITRI by HNUS. Only core samples obtained from the two bore holes made inside the pit were used in the treatability study. In all experiments soil obtained from a single core interval (5 ft length of core) was packed into the reactor. As the reactor was being packed, soil samples were taken for TPH analysis and transferred to a clean glass jar. In some cases, the collected soil sample was split into two portions, one of which was spiked with a solution of known concentration of diesel in carbon disulfide. The jar was sealed with a teflon lined cap and refrigerated pending analysis.

After packing the reactor with soil, the column was connected to the vapor condenser, the wet test meter and the gas injection system as shown in Figure 2. The experiment was begun by heating the column of soil while passing nitrogen or air through the column. During this phase of the experiment native water present in the soil was recovered along with the condensed contaminant vapors in the chilled receiver. Once the recovery of the native soil moisture had ceased (determined by visual observation in the glass condenser) then the nitrogen or air flow was stopped, and the condensate receiver was replaced with a new one. Steam injection was now begun. The temperature of steam entering the base of the soil column was measured and adjusted to match the average temperature of the soil in the column.

Once the final soil temperature was attained, the soil was maintained at the temperature for a period of 100 to 380 hours (the soak period). During the soaking period the flow of sweep gas was maintained at a constant rate.

At the end of the soaking period steam injection was terminated and nitrogen was reinjected at the base of the column. The purpose of nitrogen injection was to remove all residual steam from the column. The experiment was then terminated and the soil was allowed to cool down to room temperature. During this period the reactor was kept vented to the condenser and the condensate recovery system.

Once the soil had cooled to room temperature, the reactor was opened and the soil was transferred to a clean 1-gallon glass jar. The jar was sealed and tumbled on a roller table for a period of 20 min. A sample of the treated soil was obtained from the gallon jar and transferred to a sample jar. In some experiments two samples were obtained, one of which was spiked with a solution of known concentration of diesel in carbon disulfide.

3.4 EXPERIMENTAL RESULTS AND CONCLUSIONS

Five soil treatability experiments were performed. The experimental conditions and TPH concentration in soil are shown in Table 3. The TPH removal calculation is summarized in Table 4. Detailed information regarding each experiment along with temperature profiles are provided in Appendix A. The data shown in Tables 3 and 4 are based on TPH analysis performed by IITRI.

The data in Table 3 indicate that in 2 of the 5 experiments the soil did not have significant amount of TPH contamination as compared to the other samples from the site. Results from the other three experiments show that TPH can be reduced to the range of 60 to

Table 3. Soil Treatability Experimental Conditions and Results

Expt. No.	Soak Temperature C	Soak Time hr	Nitrogen/ Air Sweep	Water Injection g/min	TPH Concentration ppm	
					Initial	Final
1	113	122	Nitrogen	4.6	3124	227.7
2	150	118	Nitrogen	5.2	198	70
					198	59.1
3	151	102	Nitrogen	0.0	2740	94
4	153	112	Air	0.0	59.9	11.5
5	112	388	Nitrogen	0.5	18.2	13

Expt 1: soil from boring SB-17, 17-22 ft depth
Expt 2: soil from boring SB-18, 12-17 ft depth. Three different treated samples were analyzed. First line provides the results of the first sample and the second line gives the average of the other two.
Expt 3: soil from boring SB-18, 17-22 ft depth
Expt 4: soil from boring SB-18, 7-12 ft depth
Expt 5: soil from boring SB-18, 2-7 ft depth

Table 4. Calculation of TPH Removal During Treatability Study
(Basis: 100 gm of Initial Soil)

	IN INITIAL SOIL			IN FINAL SOIL		TPH REMOVED	PERCENT REMOVAL
Expt. No.	TPH Conc. μg/gm	Moisture %		TPH Conc. μg/gm	Moisture %	μg	%
1	3124.0	9.1%		227.7	0.1%	291747.8	93.4
2	198.0	26.8%		70.0	0.0%	14677.0	74.1
2	198.0	26.8%		59.1	0.0%	15474.8	78.2
3	2740.0	15.1%		94.0	0.0%	266044.4	97.1
4	59.9	23.4%		11.5	0.0%	5109.2	85.3
5	18.2	16.6%		13.0	2.8%	704.3	38.7

Expt 1.	Initial Soil average of two analysis: 3371, and 2877 μg/gm
Expt 2.	Three different treated soil samples were analyzed. First line provides the results of the first sample. The second line gives the average results of the other two samples.
Expt 3.	Initial Soil analyzed two ways: by dilution for low level calibration: 2270 μg/gm and by hi level calibration curve and no dilution: 2740 μg/gm. Use hi level result.

230 ppm depending upon the treatment condition. Thus increasing treatment temperature from 113 to 150°C has a significant effect on the final concentration of the soil. Even better removal is expected at 150°C if the treatment time is increased. In situ heating of 500 cu. yd. of soil will take approximately 1100 hrs (based on soil density of 1.35 tons/cu. yd., energy required to heat to 150°C, 15% moisture is 154 kW hr/ton of soil; available average power 95kW) of uninterrupted heating with a 120 kW power source. Due to the long residence time in the field, the actual removal of the TPH under field conditions is expected to be even higher than that seen in the laboratory.

The results of Experiments 1 to 3 indicate that with the specific combination of contaminants and the soil matrix there is no effect of the type of sweep gas (steam/nitrogen versus nitrogen alone) on the residual concentration of the TPH. In Experiment 2 a low percent removal was attained due to the low initial concentration of the TPH in the soil. Table 4 is a summary of the removal calculations which take into account the change in soil moisture upon heating.

The calculations summarized in Table 4 are based on a mass balance for TPH and moisture. The basis for performing the mass balance was 100 gm of initial soil. Consider, as an example, 100 gm of initial soil used in Experiment 1. The soil contains 312,400 μg of TPH, 9.1 gm of moisture, and 90.59 gm of solids. The 90.59 gm of solids (considered as inert) remain unchanged upon heating, but the moisture content reduces to 0.1% and the TPH concentration reduces to 227.7 μg/gm. Thus, in the final soil, solids represent 99.88% of the total residual mass. The residual mass of final soil is 90.70 gms. Thus the amount of TPH present in 90.7 gms of final soil is 20,652 μg. The amount of TPH removed from the initial soil is (312,400 - 20,652) = 291,748 μg. Therefore, the removal of TPH, expressed as a percentage of initial TPH present in 100 gm of soil is (291,748/312,400) * 100 = 93.4 percent.

Examination of residual concentrations (Table 4) indicate differences in the nature (chemical composition) of the weathered TPH contamination present in soil used for these experiments. For example, why was the residual concentration in Experiments 4 and 5 much lower than those obtained in the first three experiments even when the treatment conditions were approximately the same. To check this hypothesis, the chromatograms of the treated and initial soil samples were examined to see whether any clues can be garnered regarding the composition of the TPH contamination. This is described below.

An examination of diesel calibration standards' chromatograms indicated that the diesel peaks were eluting in the time window of 10 to 25 minutes. The areas of all peaks in this time window were summed to prepare the calibration curve for determining the concentration of the unknown samples. Accordingly, the chromatogram for each sample was examined by splitting the window into two equal time intervals: 10 to <17.5 min and 17.5 min to 25 mins. It is well known that the peak order and peak elution times are correlated with the boiling points of the individual chemical species present in diesel. Thus the peaks in the second time window represent chemicals which are higher boiling than those in the first half of the window. The number of peaks and their area was determined in these two windows. These data are summarized in Table 5. The areas listed in Table 5 were normalized to 1.0 microliter of injection volume. The area response from different samples are comparable only if all of the following are true: amount of soil extracted in all analysis is the same, all the extractions were done with the same amount of solvent, the final volume of all concentrates was the same. All the above conditions are true for all the samples except for Sample No. 5, Experiment 3 initial soil. To make this sample comparable with others, correction factors were developed and the actual areas were corrected to make Sample No. 5 areas approximately comparable.

The data in Table 5 show that in all cases where the initial concentration in soil was low, there were fewer peaks in the first window and further these components were in lower concentration than the higher boiling materials of the second window. Soil from Experiments 4 and 5 was obtained from bore hole SB-18. Both samples were from the depth interval of 2 to 12 ft. These data indicate that in the upper regions the lighter components of the TPH fraction have been removed from the soil or were not present to begin with. Soil from Experiments 2 and 3 was also obtained from SB-18, but from a depth interval of 12-22 ft.

Table 5. Area and No. of Peaks Distribution for TPH Chromatograms

Sample I.D.		Sample Description, (ppm)	Total Area in window per microliter injected	Split Time Windows			
				10<t<17.5 min		17.5<t<25 min	
Sample No.	File No.			Peaks	Area	Peaks	Area
12831dup	37	Expt 1, initial (2877)	1959.8	24	1047	10	913
12831	11	Expt 1, initial (3371)	2616	23	1498	14	1591
12834	47	Expt 1, final (227)	224.6	10	10.8	10	214
1	46	Expt 2, initial (198)	196.9	14	13.1	16	183.4
2	44	Expt 2, final (70)	81.7	7	0.56	16	81.1
5	57	Expt 3, initial (2740)	2240	23	1144	17	1095
6	58	Expt 3, final (94)	103.6	17	7.78	22	95.8
9	52	Expt 4, initial (59.9)	72.7	13	4.2	16	68.5
13	53	Expt 4, final (<11.5)	2.35	7	0.55	17	1.8
13dup	59	Expt 4, final (11.5)	3.3	4	0.19	12	3.11
7	22	Expt 5, initial (23)	3.86	5	1.43	12	2.42
7 reanal.	10	Expt 5, initial (13.7)	6.28	6	1.71	17	4.57
14	39	Expt, 5 final (13)	1.54	2	0.89	13	0.65

Table 1 provides information on the source of samples used for the treatability study. Experiments four and five were performed from soils obtained from bore hole SB-18 as marked on Table 1. The OVA readings obtained in the field for the core interval used for Experiments 4 and 5 were 100 to 1000 ppm. As the data in Table 1 show, there is no correlation between the observed OVA readings obtained in the field and the concentration of TPH in the soil. A high OVA reading does not ensure that the TPH contamination is also high.

The data presented in Tables 1 and 3 indicate that the upper 12 ft of the soil column is not heavily contaminated by diesel range TPH, but there is significant contamination of the upper zone in the vicinity of SB-17 as shown by data in Table 1. Further, the OVA readings (Table 1) taken in the field indicate that there is significant contamination in the entire soil column to a depth of 30 ft by volatile organics.

In Experiment 4, and particularly in 5, the initial soil had extremely low concentration of diesel range TPH to begin with. Such dilemmas can be avoided if initial soil analysis are performed prior to initiation of an experiment.

The results of the feasibility experiments have shown that the diesel range organics can be removed from the soil by treatment in the temperature range of 150°C. In samples which had significant initial concentration, 93 to 97 percent removal was obtained. The final soil concentration ranged from 70 to 227 ppm. The results show that the in situ heating method should remove significant amounts of the semi-volatile contaminants as represented by diesel. The removal of lower boiling TPH, including VOC and BTEX components should be better under these treatment conditions.

3.5 ANALYTICAL PROCEDURE

Samples of the initial and final soils derived from the soil treatability experiments were extracted and analyzed in the following manner according to California Department of Health GC/FID procedure (4). The method is summarized below. Details may be found in Reference 4.

Approximately 20 gm of the soil samples were weighed into screw capped bottles of 250 mL capacity and 80 mL of methylene chloride solvent was added. The capped jar was placed on a wrist action shaker for a period of 4 hours. The soils were extracted with sodium sulfate-dried methylene chloride. In some samples there were a large number of fine particles in the dried extract. The extract was filtered through a 1.2 micron filter. The extract was then dried by passing through a bed of anhydrous sodium sulfate. The dried extract was collected in a 250 mL volumetric flask and the volume adjusted to the mark with clean solvent. Then, the prepared extract was concentrated in a Kuderna Danish Concentrating device. The concentrated extract was recovered in a 5 mL volumetric flask and the volume brought up to 5 mL. The extracts were analyzed by GC/FID using the following equipment.

Equipment:

Gas Chromatograph:	Perkin Elmer, Model Sigma 1 B
Column:	Supelco Tight-Spec glass column 2 m x 2 mm ID X 0.25 in. OD. 5% SP2100 on 60/80 mesh Supelcoport.
Injector:	Injector Temperature 290°C
FID Detector Temp:	320°C.
Oven Temperature cycle:	40°C for 4 mins followed by 10°C/min ramp to 265°C. Hold for 15 min or longer if necessary
Integrator:	Sigma 1B Console

Calibration:

Standards were prepared in dried methylene chloride from diesel oil no 2. The standard solutions were injected and the resulting diesel oil peaks were found to elute between 10 and 25 mins. All peak areas in this retention time window were summed and the area was normalized to 1.0 μL injection volume. A least squares fit was then performed with the concentration of the standards injected as the independent variable. Calibration standards greater than 0.4 mg/L

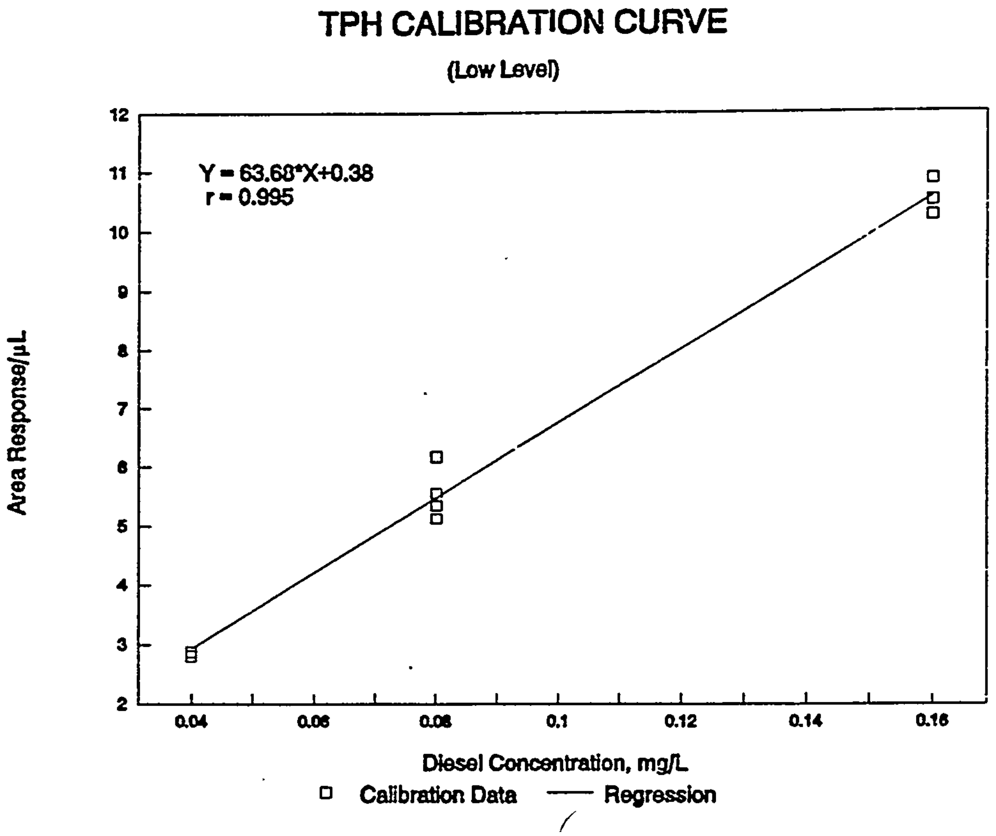

Figure 3. Calibration Curve for TPH (Low Level)

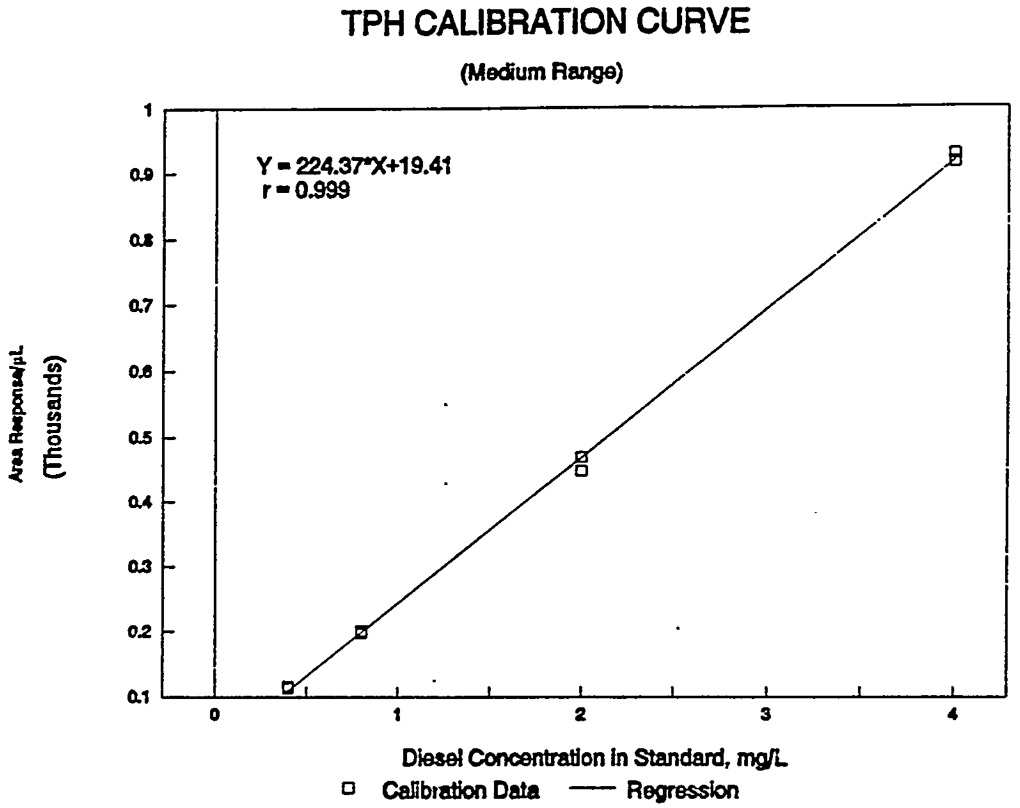

Figure 4. Calibration Curve for TPH (Medium Level)

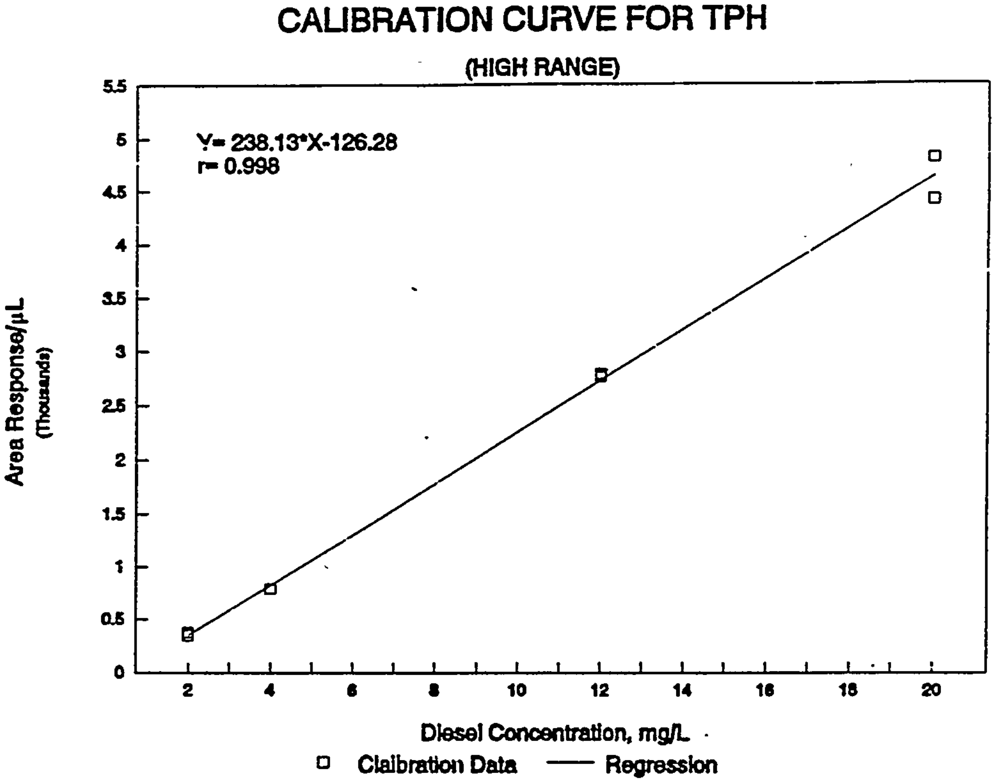

Figure 5. Calibration Curve for TPH (High Level)

were found to be linear and reproducible over a number of days. The highest level of standard which was calibrated was 20 mg/L. Three calibration curves were developed. These were the low range curve,(0.04 to 0.16 mg/L), the medium range curve (0.4 to 4.0 mg/L) and the high range curve (2 to 20 mg/L). Typical curves for each of the three ranges are illustrated in Figures 3 to 5. The low range calibration needed daily multi-point checks by injection of low level calibration standards. Extract concentration of 0.04 mg/L is approximately 10 ppm in soil.

Samples were injected and concentrations determined from the calibration curve. In cases where the sample concentration was below the calibration range, unknowns were quantified either with a low level calibration curve ranging in concentration from the detection limit of 0.04 to 0.16 mg/L or by use of response factor of the standard producing a total area closest to that of the unknown sample. When an unknown sample was found to have an area less than that of the 0.04 mg/L standard it was classified as below the detection limit. Both the method blanks as well as a 2μL injection of the carbon disulfide used to prepare the matrix spiking solutions (discussed in the next section) were found to be below the detection limit. It was noted however that in one method blank a large peak was present at about 28.2 min. This peak was also observed in some sample extracts. However it does not effect the quantification of the diesel range organics because it was outside the diesel range window.

It should be noted also that in several samples which had high levels of TPHs there were numerous other peaks due to higher boiling compounds which eluted substantially after the diesel retention time window. The presence of these high boiling peaks in some samples necessitated extended run time at high column temperatures to ensure that subsequent chromatograms would be free of "ghost" peaks produced by incomplete elution of components from a prior injection. In some samples the area of peaks eluting after the diesel window was as great or greater than the diesel range peaks.

3.6 QA/QC RESULTS

Three different types of QA/QC samples were analyzed. These were: matrix spikes; blind standards given to the analyst to check the accuracy of the GC/FID system; method and solvent blanks. The results of these QA/QC samples are described below.

3.6.1 Spike Recoveries

During the course of the treatability experiments soil samples were collected in small glass jars. In some instances the sample was split into jars with one of the jars receiving a spike of a diesel solution of known concentration. The solution was prepared in carbon disulfide. A 20 gm aliquot of the soil was used from the sample jars for extraction and analysis of all samples. The results of spike recovery are presented in Table 6. The spike recovery varies between 65 to 136%. In one sample the spike recovery was -83.2% (in other words concentration of the spiked sample was less than that of the unspiked original). The reason for this result is not clear.

Column 3 of Table 6 provides the TPH concentration of unspiked soil samples. Column 4 of Table 6 gives the total concentration of TPH in spiked soils as determined through analysis. Column 5 of Table 6 gives the theoretical increase in TPH concentration of the spiked soil sample. Amount shown in Column 5 was calculated, based on the concentration and volume of the spiking solution and the weight of soil sample that was spiked. Column 6 gives the calculated percentage recovery for the spike. As an example, consider the sample pair 12834 and 12833. Sample No. 12834 is a sample of the treated soil from Experiment No. 1. Sample No. 12833 is treated soil from Experiment No. 1, which was spiked with diesel spiking solution. The expected increase in TPH concentration of sample 12833 was 29.3 ppm. The actual increase in TPH concentration of sample 12833 was (250 - 227.7) = 22.3 ppm. Thus the calculated spike recovery is (22.3/29.3) * 100 = 76.1 percent.

Table 6. Results of Matrix Spike Samples

Sample No.	Description	Analyzed Conc. ppm	Spiked Sample Analyzed Conc. ppm	Incremental Amount of Spike ppm	Spike Recovery %
12834	Expt. 1 Final Soil	227.7			
12833	Expt. 1 Final Soil+Spike		250	29.3	76.1
1	Expt 2 Final Soil	70			
3	Expt. 2 Final Soil+Spike		34.9	42.2	-83.2
4	Expt. 2 Final Soil+Spike		827	1171	64.6
13dup	Expt. 4 Final Soil	11.5			
12	Expt. 4 Final Soil+Spike		55	35	124
12831	Expt. 1 Initial Soil	3371			
12831dup	Expt 1. Initial Soil	2877			
12832	Expt. 1 Initial Soil+Spike		3817	508	136

3.6.2 Blind Standards for Instrumental Check

Two solutions of diesel in methylene chloride were presented to the analyst as blind samples. The concentration of these two solutions were 0.8 mg/L and 1.6 mg/L. These were analyzed as 0.81 mg/L and 1.6 mg/L.

3.6.3 Method and Solvent Blanks

Three 100 percent method blanks were prepared and analyzed. In addition solvent blanks were run on a regular and frequent basis. Table 7 presents the results of three method blanks and solvent blanks run in the same time period. The results of these samples show that every method and solvent blank had an area response which was 20 to 60 percent of the area response of the lowest calibration standard in the calibration range. As mentioned in the previous section, one method blank indicated the presence of a large peak at a elution time of approximately 28.5 min. This peak was well outside the diesel retention time window as determined by injection of standards.

Table 7. Results of Method and Solvent Blanks

Date	Type of Blank	File No.	Area Counts/μL of Blank	Calibration Curve Range, mg/L	Area Counts of Lowest Standard	File No.
3/4/92	Method	56	2.68	0.16 - 4.0	13.4	17
3/4/92	Solvent	59	1.60	0.16 - 4.0	13.4	17
3/9/92	Solvent	38	1.60	0.04 - 0.16	2.9	41
3/9/92	Solvent	30	1.39	0.04 -0.16	2.9	41
3/10/92	Method	20	1.22	0.04 - 0.16	2.9	41
3/24/92	Method	67	0.67	0.04 - 0.16	1.07	63
3/24/92	Solvent	71	0.52	0.04 - 0.16	1.07	63

SECTION 4

MEASUREMENT OF SOIL DIELECTRIC PROPERTIES

4.1 INTRODUCTION

Figure 6 is a block diagram of the RF heating method. The RF heating process utilizes high-power radio frequency energy by converting 60 Hz AC power to RF frequencies in a modified radio transmitter (power source). The output of the power source is applied to the medium to be heated. The power is conveyed by coaxial cables through a matching network to the target material. For in situ applications, an array of electrodes inserted in bore holes drilled through the target material is energized with RF power. A frequency is used such that the waves can penetrate to sufficient depth into the deposit. As the material absorbs energy from the applied electromagnetic field, heat is liberated and causes the temperature of the material to rise.

The purpose of the matching network is to optimize power transfer between the RF power source and the heated medium by matching their impedances. This can be done continuously by making real-time, on-line measurements of impedance as heating progresses and adjusting the matching network to provide an impedance matching function.

The term RF generally refers to frequencies that are used in wireless communications. These frequencies can be as low as 45 Hz (in a prototype submarine communication system) or extend well above 10 GHz (for satellite communication systems). The frequencies of principal interest for heating earth and mineral formations are between 0.01 and 60 MHz. The precise frequency of operation would ideally be determined by the electrical parameters of the medium of interest (oil shale, tar sand, contaminated soil) and the size of the region to be heated.

As a general rule, the higher the operating frequency, the more readily the material will absorb the energy. Too rapid an absorption, however, can cause most of the energy to be absorbed within the surface layers nearest the applicator at the expense of not heating the

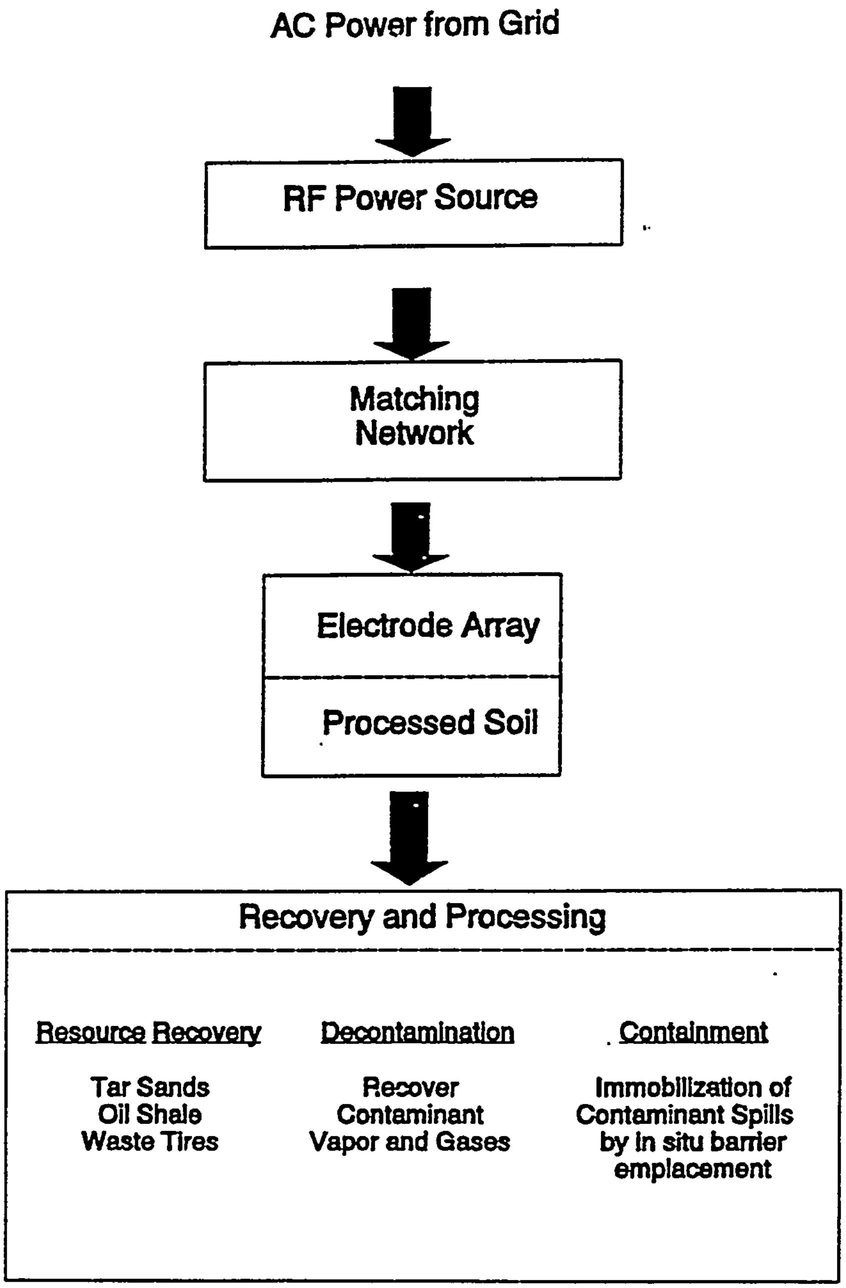

Figure 6. General Block Diagram of the RF Process

material deeper in the volume. Lowering the operating frequency improves the depth of penetration since less power is absorbed in the surface layers. There is a limit, however, to which the frequency can be decreased. Since the energy absorption drops off with frequency, the heating rate decreases as the frequency is decreased unless the electromagnetic fields are increased in amplitude. The amplitude can only be increased to a certain point before corona discharges or electrical breakdown seriously affects the system operation.

A variety of phenomena can be responsible for the absorption of electromagnetic energy and the resulting temperature rise in a material. For the purpose of heating and drying soil, only two principal mechanisms need be considered: ohmic and dielectric heating. Ohmic heating arises from an ionic current or conduction current that flows in the material in response to the applied electric field. This is similar to the current that flows in flashlight batteries or in oven heating elements.

Dielectric heating arises from the physical distortion of the atomic or molecular structure of the material in response to the applied electromagnetic field. Since the applied field changes direction rapidly, the alternating physical distortion is readily transferred into mechanical and then into thermal energy in the material, adding heat and increasing the material temperature.

From a theoretical point of view, the heating mechanism that dominates in a given material cannot always be determined. This is not important in evaluating the electromagnetic heating properties of materials since both phenomena are generally considered in the dissipation relationship as given in Equation 1.

$$p = \omega \epsilon_o \epsilon_r \tan \delta \, [E_{rms}]^2, \ Watts/(meter)^3 \qquad (1)$$

Where:

P = the power absorbed, Watts/(meter)^3
f = frequency of the applied electric field, Hertz
ω = $2\pi f$, radian/sec

ϵ_o = 8.85×10^{-12} Farads/meter
ϵ_r = the relative dielectric constant as measured at frequency f (unit less)
$\tan \delta$ = the loss tangent as measured at frequency f
E_{rms} = the root mean square electric field intensity in volts/meter

The loss tangent of a dielectric material is defined as:

$$\tan \delta = \sigma/\omega\epsilon_o\epsilon_r = 1/\rho\omega\epsilon_o\epsilon_r \qquad (2)$$

Where:

σ = the apparent conductivity of the material at frequency f in mhos/meter
ρ = the apparent resistivity of the material at frequency f in ohm-meters

The loss tangent is proportional to the ratio of the power lost in the material through heating to the energy stored in the material per cycle. Loss tangent is therefore a measure of how "lossy" a dielectric material is.

Thus,

$$P = \sigma[E_{rms}]^2 = [E_{rms}]^2/\rho,\ \mathit{Watts}/(\mathit{meter})^3 \qquad (3)$$

Equation 1 gives a general definition for power absorbed per cubic meter for dielectric heating. It considers both the contributions from ohmic heating as well as the dielectric absorption mechanisms. This equation can be simplified into a more intuitively appreciated form as shown in Equation 3. This equation is analogous to the standard ohmic heating relationship as shown in Equation 4.

$$P = V^2/R \tag{4}$$

Where V is the applied voltage across a resistor R. The terms of conductivity or resistivity used in Equation 3 applies only to those measured for the specific frequency.

4.2 SOIL DIELECTRIC PROPERTY MEASUREMENTS

The effect of frequency on the operation of RF heating systems was described above. A mathematical relationship was also shown between the power absorbed by a material in an electromagnetic field and the conductivity of that material. The electrical properties of a material must be known, therefore, before a complete RF heating system can be designed. This section describes measurements made on a sample of soil from Kelly AFB as necessary for the design of the RF soil decontamination system.

The electrode array design to be used at Kelly AFB approximates a parallel plate transmission line with soil as the dielectric present between the conducting planes. Initially the soil is made up of at least 10% water and acts as a very lossy dielectric. When energy is applied to the array, it is absorbed by that dielectric and heat is liberated causing the temperature of the material to rise and the water to eventually evaporate. The ability to absorb energy in the soil dielectric is a function of moisture content and chemical composition and is quantified in the dielectric parameters (i.e., dielectric constant, loss tangent and conductivity). Standard transmission line calculations can therefore be used to predict the heating pattern within the array as the dielectric parameters of the soil change due to evaporation of water. It is necessary to quantify those parameters for a given soil type before such calculations can be made.

The measurement technique used at IITRI involves placing the soil inside a coaxial transmission line and measuring the complex input impedance at the front of the line. The basic measurement arrangement is shown in Figure 7 below. Heat tape is wrapped around the outside of the transmission line to vary the temperature of the soil. The temperature for the Kelly soil measurements was brought up to the boiling point of water (105°C) over 3 hours while

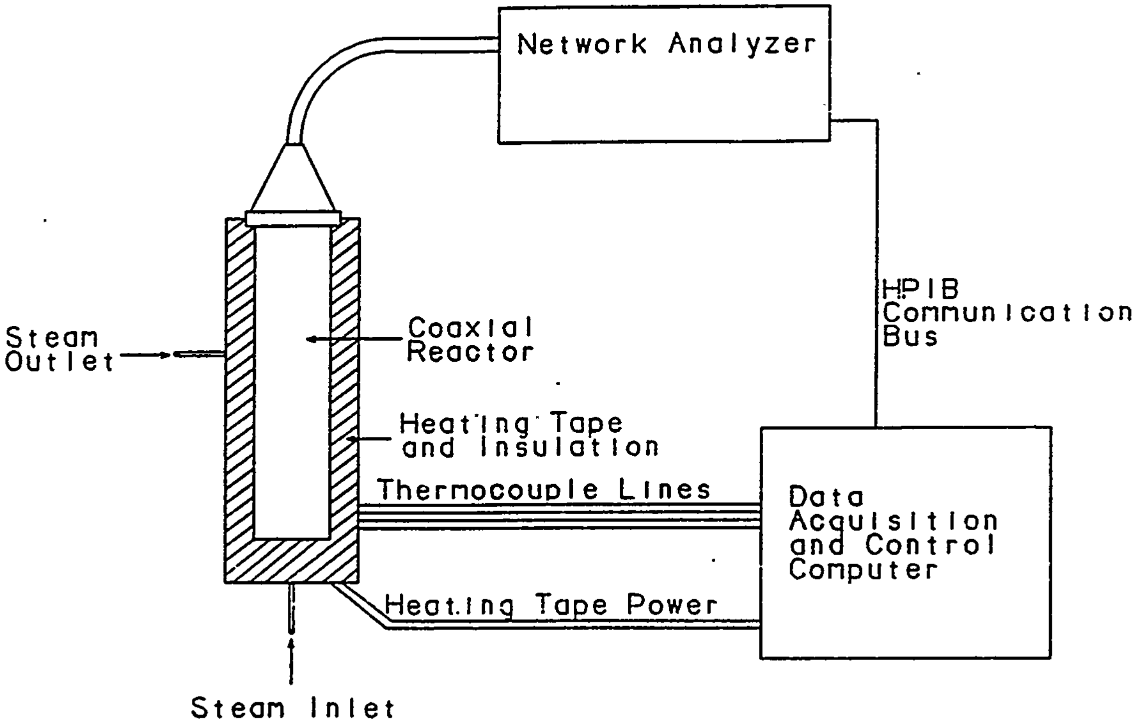

Figure 7. Block Diagram of Dielectric Parameter Measurement System

impedance measurements were made at varying time intervals. The soil temperature was then maintained at 105°C overnight to allow all of the water to boil out. The dry soil was then ramped up in temperature to 130°C and held constant for several hours. Steam was also injected while the soil was at 130°C to simulate the flow of steam through hot soil from cooler wet regions. This would occur during the in situ heating process as the heated zone propagates through the array. The steam injection test was repeated at 150°C.

The measured impedance values were corrrected to compensate for the effects of the transmission line from the measurement end to the sample surface. The dielectric parameters were then calculated from the derived impedances.

The dielectric properties of soil were measured by placing the material inside a coaxial transmission line sample holder and measuring the complex input impedance at the front of the line. Figure 8 is a schematic cross section view of this low frequency, low permittivity sample holder and which is divided into three regions. Regions 1 and 2 are modeled using the equation for the capacitance between two cylindrical conductors.

$$C = \frac{2\pi \ell \epsilon *}{\ell n\ (b/a)} \tag{5}$$

where ,

$$\epsilon * = \epsilon_o\ (\epsilon_r - j\ \frac{\sigma}{\omega \epsilon_o})$$

$\epsilon *$ = complex permittivity in Farads/meter

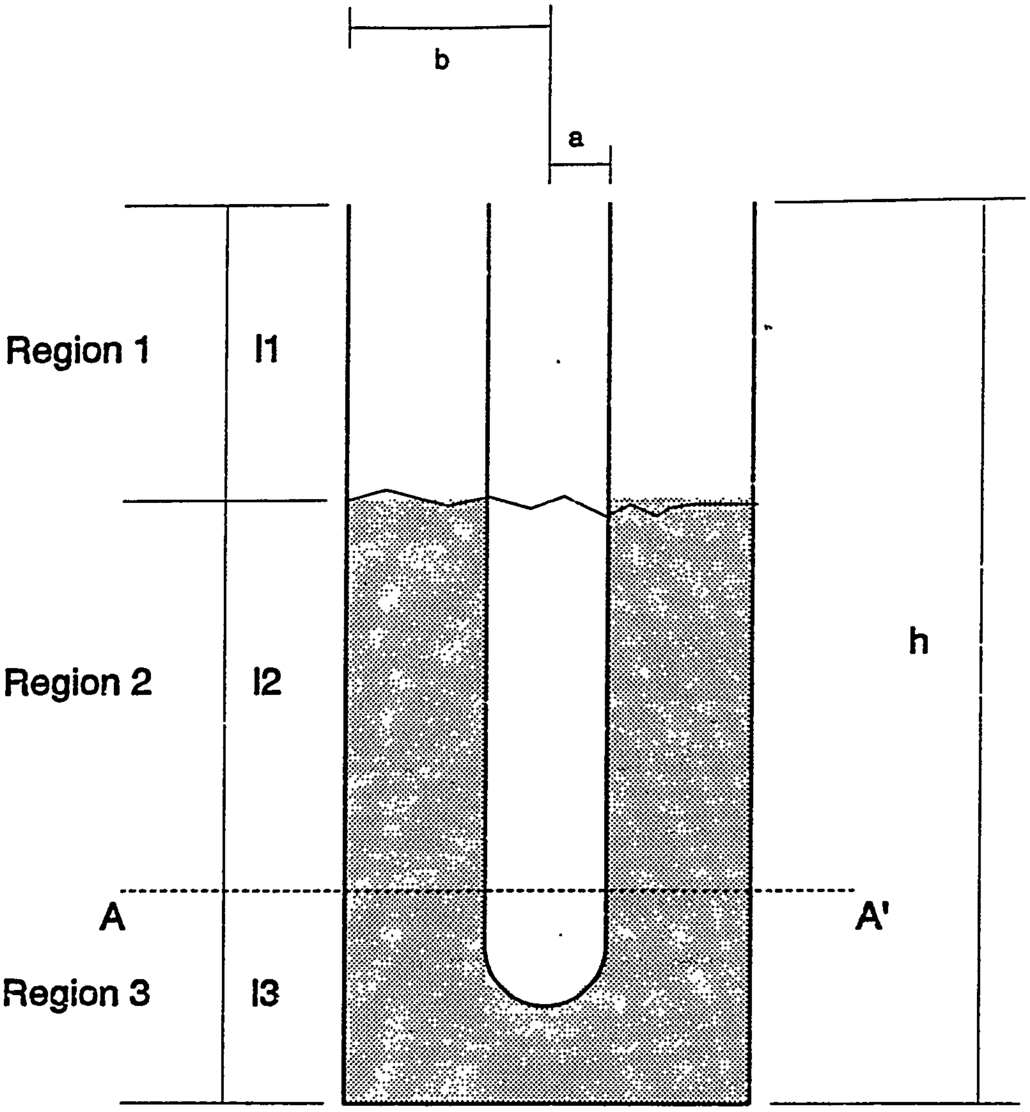

Figure 8. Schematic Cross Section View of Co-axial Sample Holder

Because of its complex geometry, the capacitance of Region 3 was determined experimentally. The capacitance of Region 3 can be expressed as,

$$C_3 = K\epsilon^* \tag{6}$$

where

K = a constant that depends only on the geometry of Region 3

By combining equations 5 and 6, the total capacitance of the sample holder is,

$$C_T = \frac{2\pi\ell_1\epsilon_o}{\ell n(b/a)} + \frac{2\pi\ell_2\epsilon^*}{\ell n(b/a)} + K\epsilon^* \tag{7}$$

Here it is assumed that Region 1 is air-filled and Regions 2 and 3 are filled with a homogeneous dielectric of permittivity ϵ^*.

To determine K, a value for ℓ_3 is selected such that AA' lies in the region of the test fixture where equation (5) is valid. The impedance of the empty test fixture, Z_e, is then measured. The total capacitance of the empty sample holder can then be written as,

$$C_e = \frac{1}{j\omega Z_e} = \frac{2\pi\epsilon_o[h - \ell_3]}{\ell n\ (b/a)} + K\epsilon_o \tag{8}$$

Solving equation (8) for K yields,

$$K = \frac{1}{j\omega\epsilon_o\ Z_e} - \frac{2\pi[h - \ell_3]}{\ell n\ (b/a)} \tag{9}$$

Inserting this expression into equation (7) yields,

$$C_T = \frac{1}{j\omega Z_r} = \frac{2\pi \ell_1 \epsilon_o}{\ell n\ (b/a)} + \frac{2\pi \ell_2 \epsilon*}{\ell n\ (b/a)} + [\frac{1}{j\omega \epsilon_o\ Z_e} - \frac{2\pi (h - \ell_3)}{\ell n\ (b/a)}]\epsilon* \tag{10}$$

where

Z_r = the measured impedance when Regions 2 and 3 are filled with the material under test

Solving equation (10) for $\epsilon*$ yields,

$$\epsilon* = \frac{1/j\omega Z_r - 2\pi\epsilon_o\ \ell_1/\ell n\ (b/a)}{1/j\omega\epsilon_o\ Z_e - 2\pi/\ell n\ (b/a)\ [\ h - \ell_2 - \ell_3\ ]} \tag{11}$$

But since h - ℓ_2 - ℓ_3 = ℓ_1 and $\epsilon* = \epsilon_o(\epsilon_r - j\ \sigma/\omega\epsilon_o)$ so equation (11) can be rewritten as,

$$\epsilon_r - j\ \sigma/\omega\epsilon_o = \frac{1/j\omega\epsilon_o\ Z_r - 2\pi\ell_1/\ell n\ (b/a)}{1/j\omega\epsilon_o\ Z_e - 2\pi\ell_1\ /\ell n\ (b/a)} \tag{12}$$

Since the measured impedance is rotated down to the sample surface, $\ell_1 = 0$, so equation (12) reduces to:

$$\epsilon_r - j\ \sigma/\omega\epsilon_o = \frac{1/j\omega\epsilon_o\ Z_r}{1/j\omega\epsilon_o\ Z_e} = \frac{Z_e}{Z_r} \tag{13}$$

Which can be rewritten as:

$$\epsilon_r - j\ \sigma/\omega\epsilon_o = \frac{1}{j\omega C_e\ Z_r} \tag{14}$$

Equation (14) therefore allows the measured impedance values along with the previously measured impedance of the empty fixture to be used to calculate the dielectric parameters.

4.3 RESULTS

The measured dielectric parameters are graphed in Figure 9 through 11. In general, the data shows that the dried out soil will absorb much less energy than the initial wet soil. This is seen as a decrease in conductivity by 3 to 4 orders of magnitude as a result of the overnight 105°C drying. The effect of steam injection at the higher temperatures was an increase in conductivity. This indicates that during the in situ process steam from the wet, cooler regions of soil will tend to increase the energy absorption in the hotter regions, even after the water has been evaporated from those regions. The key data used in designing the array for in situ soil heating are the dielectric properties measured as described above. As mentioned earlier, the array approximates a parallel plate transmission line. The propagation of energy along that line can be predicted using standard transmission line calculations for the measured properties and the geometry of the array. For example, the ability to heat (and decontaminate) soil down to 30 ft. depth is affected by all of the aforementioned properties.

The dielectric parameters discussed above are required to determine the range of usable frequencies, to confirm the viability of the geometry of the electrodes used to apply electric field to the deposit and to bound performance requirements for the combination of the matching network and RF power source. While the possible values of the dielectric parameters can range over several orders of magnitude, various independent parameters--such as the moisture content,

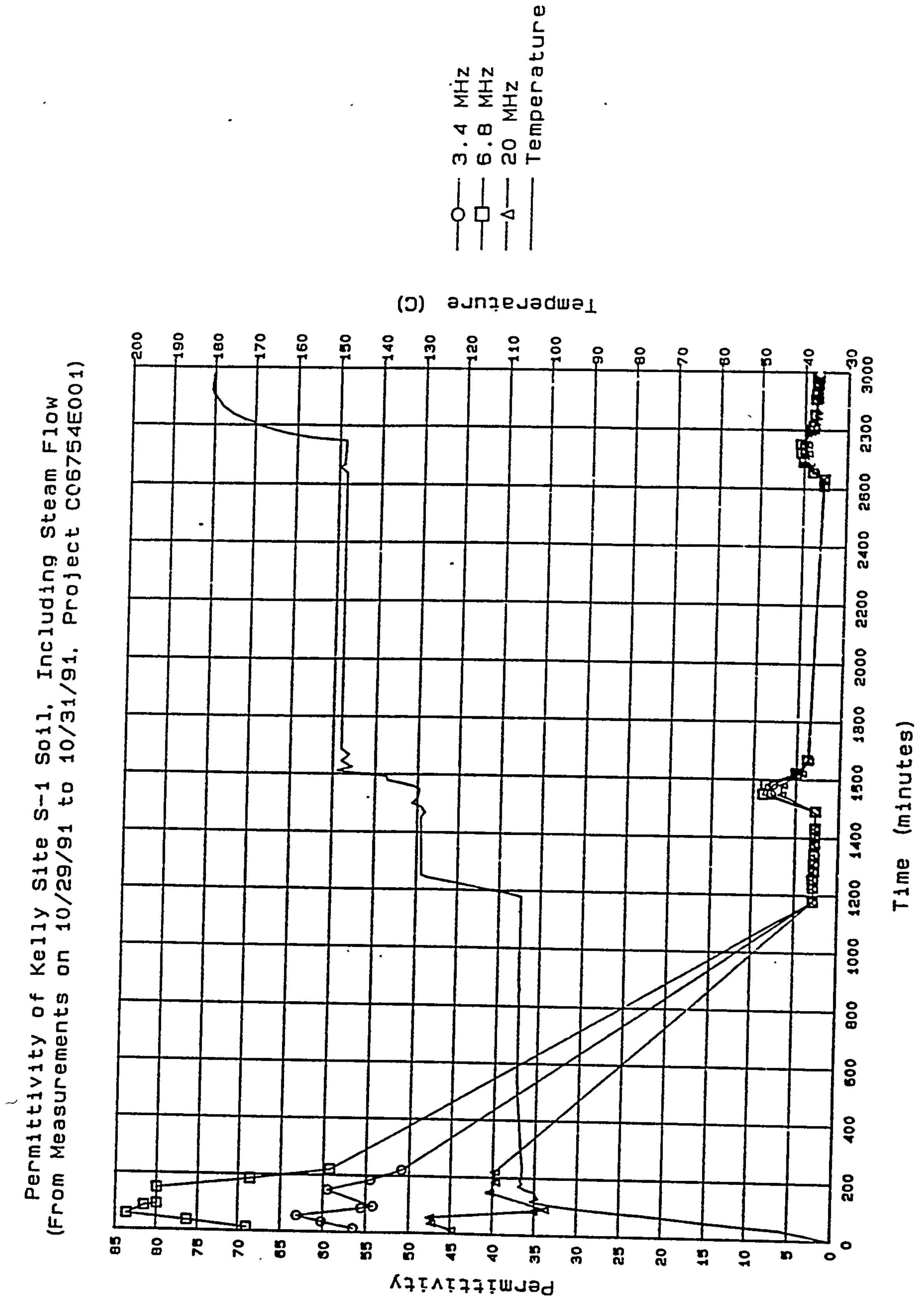

Figure 9. Permittivity of Kelly AFB Site S-1 soil

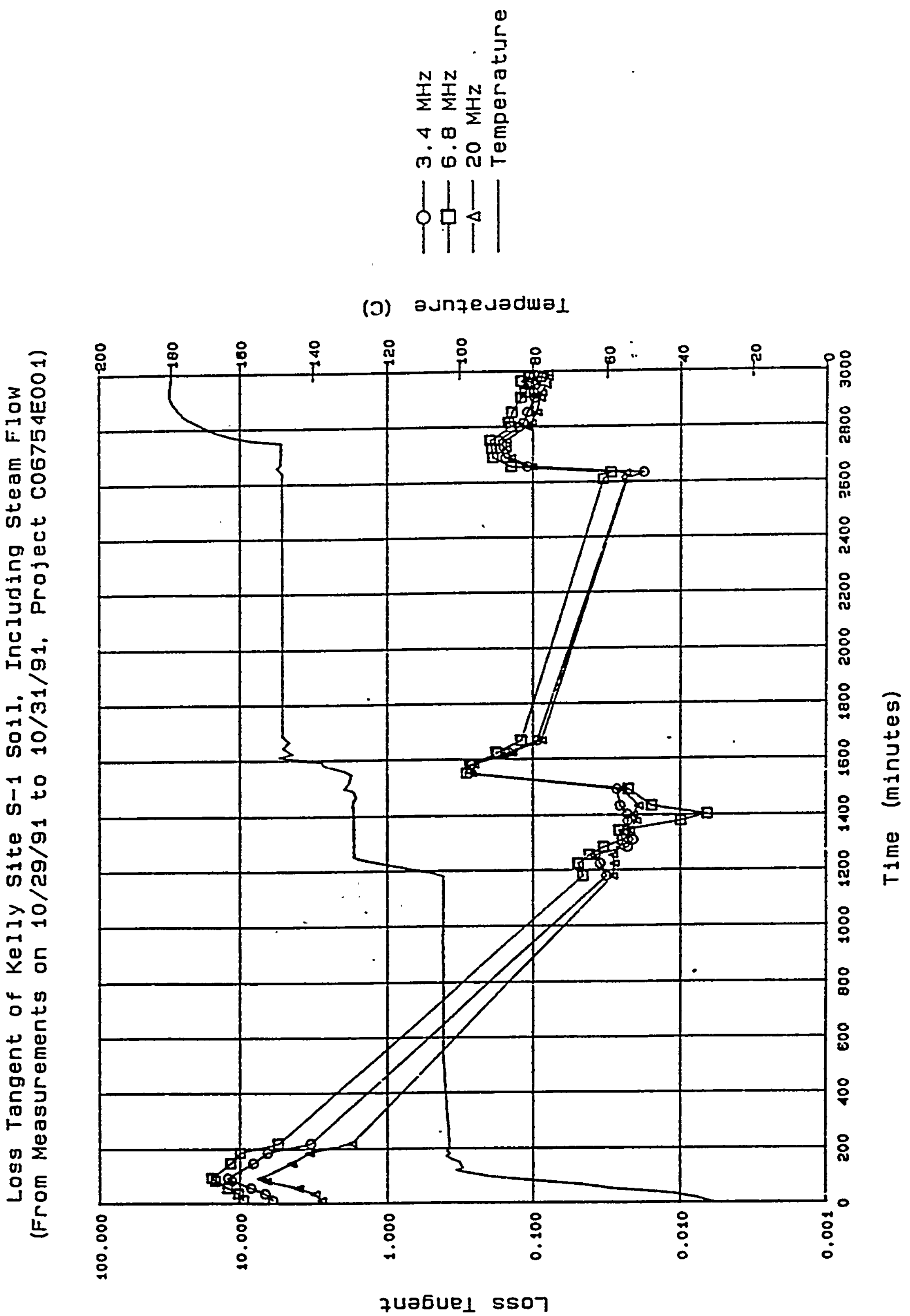

Figure 10. Loss tangent of Kelly AFB Site S-1 soil.

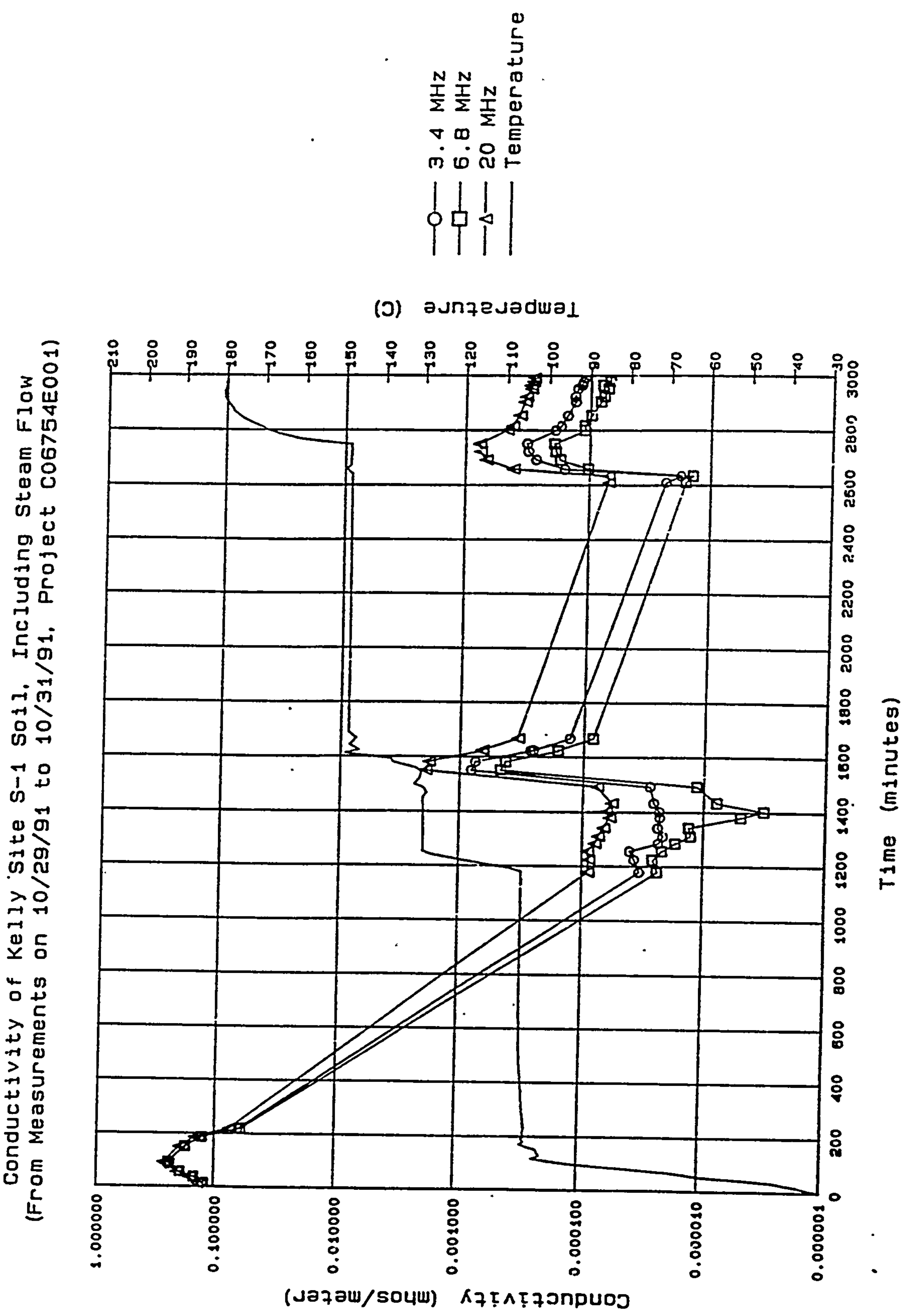

Figure 11. Conductivity of Kelly AFB Site S-1 soil.

the clay content and presence or absence of steam--can be used to estimate a range of predictable patterns of behavior for the dielectric constant. These parameters are best measured for each site under simulated in situ conditions. Such measurements may disclose an order of magnitude variation, for example, as a function of the steam content, which is difficult to estimate. To cope with such variations, a great deal of flexibility in the design of the RF source and matching network is required. Hence the requirements for two operating frequencies and a matching network with a capability to handle a wide variation of possible value of input impedance.

Fundamental to all in situ earth heating systems, either the bound-wave exciters as proposed for the demonstration test, or the antennas which radiate or propagate waves into the earth, is the absorption or path loss. This path loss can be expressed independently of the divergence of the electromagnetic wave from an antenna or the resonant behavior of the open ended triplate line being considered for Kelly AFB.

The power dissipation distribution in soil can crudely be expressed for bound antennas as a function of radial distance as:

$$P(r) = P(r_1)\, e^{-2\alpha r}\, (4\pi r)^{-2} \tag{15}$$

for the open ended top-driven triplate line planned for Kelly, the power dissipation is approximately, for fixed values of dielectric parameters:

$$P(r) = P(r_1)\, e^{-2\alpha r}\left[\cos 2\pi \frac{(L - r)}{\lambda}\right] \tag{16}$$

where

P(r) = the power dissipation at distance in Watts/(meter)^3
λ = the wavelength in the soil, meters
r = the distance from r_1, the reference point, meters
L = the depth of the triplate line, meters
$\propto$ = can be defined independent of the functions unique to each exciter as follows.

$$\alpha = \frac{\sigma \sqrt{\mu/\epsilon}}{2} \quad nepers/meter \tag{17}$$

where

σ = the conductivity of the soil, mho/m
μ = the permeability of the soil, Henry/m
ϵ = the permitivity of the soil, farad/m
α = the attenuation constant, nepers/m

for typical dried earth

$\sigma = 10^{-5}$ to 10^{-3}; $(\mu/\epsilon)^{1/2} = 200$

whence the relative power absorption becomes:

$$P(r)/P(r_1) = \exp(-200\sigma)L \tag{18}$$

As shown in an earlier section and also in past measurements, typical values for σ at 6.8 and 3.4 MHz are summarized as follows along with the attenuation for L = 10 meters.

	σ		**10m Relative Path Loss**	
	3.4 MHz	**6.8 MHz**	**3.4 MHz**	**6.8 MHz**
Sandy soil (no clay)	5×10^{-6} mho/m	1×10^{-5}mho/m	0.99	0.98
Clayey soil (no steam)	5×10^{-5}	10^{-4}	0.90	0.82
Clayey soil (steam)	2.5×10^{-4}	5×10^{-4}	0.6	0.37

For a clayey soil with steam the path loss means that the power dissipation is only 60 and 37% respectively for that experienced by soil nearest the source. Obviously a power dissipation at 6.8 MHz for the more distal position of 37% of that for the closer position is difficult to compensate except by decreasing the frequency to 3.4 MHz. The 60% value at 3.4 MHz is more tractable by taking advantage of the open circuit end resonant effect, which can compensate partially for the path loss.

The worst-case performance requirements are also estimated for the matching network based on the more plausible ranges of values for the dielectric parameters in conjunction with the geometry of the electrodes. The dielectric values of the earth as a function of the moisture content must also be developed, since two-thirds of the energy applied and time of heating are expended in vaporizing the moisture. As a consequence, a large segment of the deposit will be undergoing vaporization with varying degrees of moisture content and dielectric parameters.

Analyses of the drying out dynamics is obviously complex, but simple relationships can be used to crudely estimate the initial fully moist input impedance to the array and the final fully-dry input impedance. The following relationship applies for the type of electrode array considered here, which is an open ended, top driven, bound-wave, buried transmission line.

Input impedance =

$$\left[\frac{(jw10^{-6}/F)}{\sigma F + jw\epsilon F)}\right]^{1/2}\coth\{\,[(jw10^{-6}/F)(\sigma F + jw\epsilon F)]^{1/2}L\,\} \qquad (19)$$

Where

w = 2π x frequency

F = the form factor dependent on the geometry of the electrode

j = $(-1)^{1/2}$

σ = the conductivity

ϵ = the permitivity

L = the effective length of the exciter electrodes

coth = the hyperbolic cotangent

Based on plausible values of the dielectric parameters, the very approximate, values of the input impedance for the initial moist condition would be about $1.4 + j1.4$ ohms, and for the final fully dry condition would be about $2-j50$ ohms.

SECTION 5

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APPENDIX A

BENCH SCALE TREATABILITY EXPERIMENTS OPERATING CONDITIONS AND DATA

EXPERIMENT 1 TEMPERATURE AND OPERATING DATA

Elapsed Time hr	INSIDE TEMPERATURE T1	T2	Average Temperature C	Wet Test Meter Rdg. Liter	Total N2 Volume Liter	Remarks
0.0			ERR			
0.1	42	50	46	1286.50	0	
0.5	92	92	92			
1.2	86	98	92	1331.00	45	
1.7	89	107	98	1352.50	66	
2.5	109	132	121	1393.60	107	
3.2	106	118	112			
3.6	106	111	109	1440.50	154	
3.9	106	105	106	1454.00	168	Nitrogen Off
4.1	105	105	105	1454.00	168	Start Steam
4.6	104	101	103	1453.85	167	
5.6	110	108	109	1453.85	167	
7.0	110	106	108	1453.86	167	
43.5	105	98	102	1454.62	168	Tightened Insulation around T2
44.9	106	101	104	1454.62	168	
46.5	122	102	112	1454.78	168	
47.1	128	101	115	1459.58	173	
68.5	115	124	120	1459.75	173	
70.9	113	122	118	1459.76	173	
73.9	111	121	116	1459.76	173	
76.3	111	124	118	1459.78	173	
78.5	111	124	118	1459.79	173	
93.0	112	124	118	1459.88	173	
96.5	111	122	117	1459.90	173	
100.2	111	123	117	1459.91	173	
102.8	111	123	117	1459.94	173	
117.2	110	123	117	1460.04	174	
119.2	112	123	118	1460.05	174	Steam off; Nitrogen On.
121.1	115	129	122	1531.85	245	
124.0	112	112	112	1647.80	361	
124.4	112	111	112			All Heaters Off
125.6	56	52	54	1709.80	423	Nitrogen Off

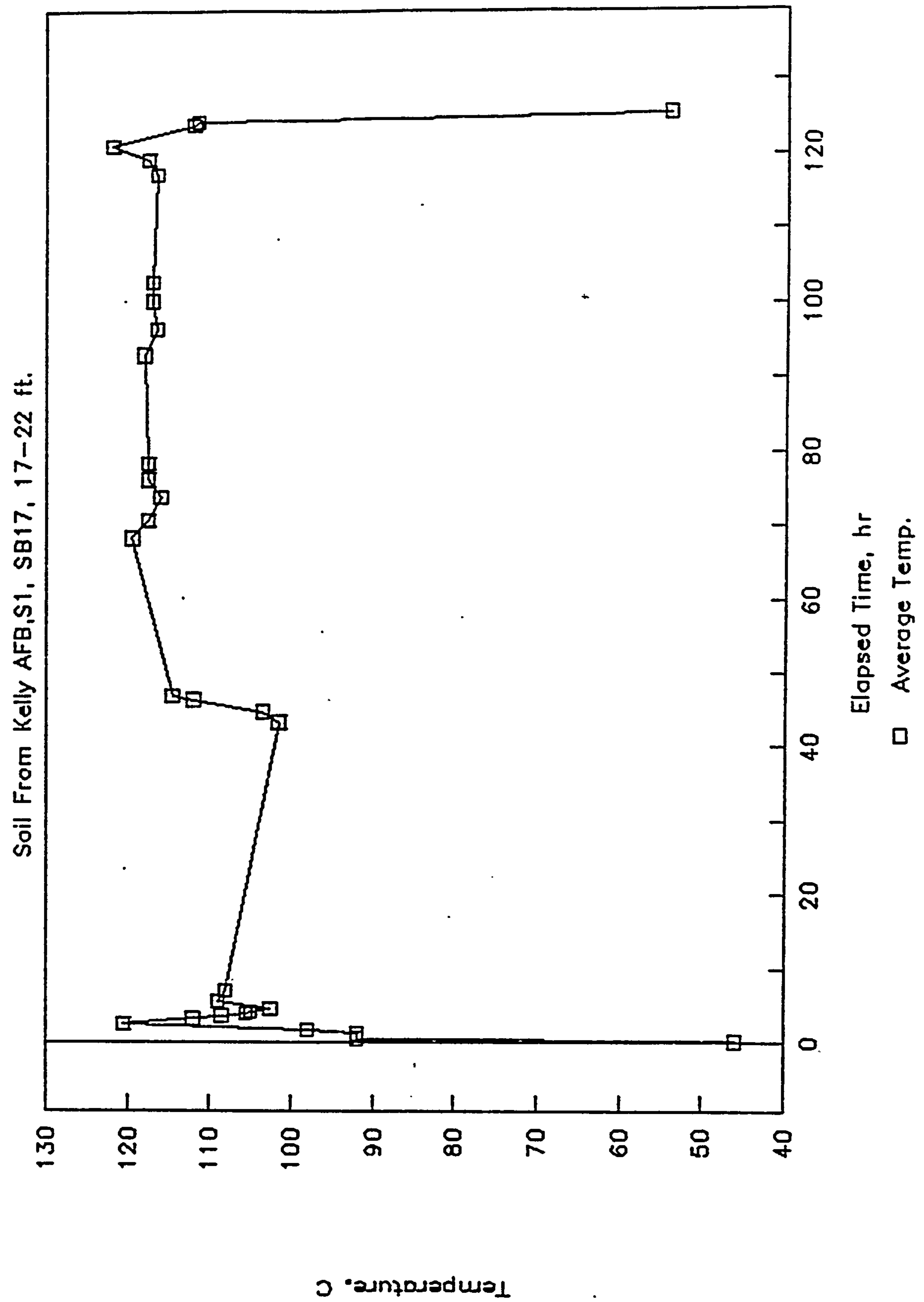
Experiment 1 Details

Soil Source:
Kelly AFB, Site S-1, Bore Hole SB17,17-22 ft depth
Date Sampled in the field: 10/20/91
HNUS Sample No.:KS1-SB17-U1722
Two jars with same labels were used.

Date Reactor Packed: 11/22/91

Wt of Soil packed in the reactor:	1478 gm
Wt of soil removed from storage jar 1	819 gm
Wt of soil removed from storage jar 2	890 gm
Initial Soil Moisture,%	9.1 % wt
Weight of final soil removed from reactor,	1292 gm

Final Soil Moisture, %	0.1 % wt	
Time with initial nitrogen sweep:	3.9 hr	167.5 liters nitrogen
Steaming Time	115.1 hr	6.05 liters gas
Time with nitrogen sweep after steami	6.3 hr	249.75 liters nitrogen
Initial Wt. of water in Reservoir:	1260 gm	
Final Wt of water in the reservoir:	730 gm	
Wt of water injected	530 gm	



SOIL TEMPERATURE DURING EXPERIMENT 1

EXPERIMENT 2 TEMPERATURE AND OPERATING DATA

Elapsed Time hr	INSIDE TEMPERATURE T1	T2	Average Temperature C	Wet Test Meter Rdg. Liter	Total N2 Volume Liter	Remarks
0.0	24	24	24	1709.8	0.0	Initial Readings, Start heating
0.7	79	82	81	1710.2	0.4	
3.2	101	144	123	1765.0	55.2	
4.2	135	157	146	1799.5	89.7	
5.5	157	151	154	1840.8	131.0	
6.3	159	145	152	1874.4	164.6	Nitrogen off, water on
7.3	155	144	150	1873.0	163.2	
22.3	149	144	147	1874.1	164.3	
25.0	142	151	147	1874.3	164.5	
26.3	147	153	150	1874.3	164.5	
45.5	148	152	150	1874.5	164.7	
70.7	150	152	151	1874.5	164.7	
72.5	147	151	149	1875.0	165.2	
76.0	148	153	151	1875.7	165.9	
79.7	149	153	151	1876.2	166.4	
94.0	147	151	149	1876.4	166.6	
102.9	150	153	152	1877.0	167.2	
117.8	147	152	150	1877.3	167.5	
118.8	148	153	151	1877.3	167.5	Water off; nitrogen on
121.9	149	152	151	1996.8	287.0	All heaters off
126.8	48	40	44	2172.0	462.2	Nitrogen off

Experiment 2 Details

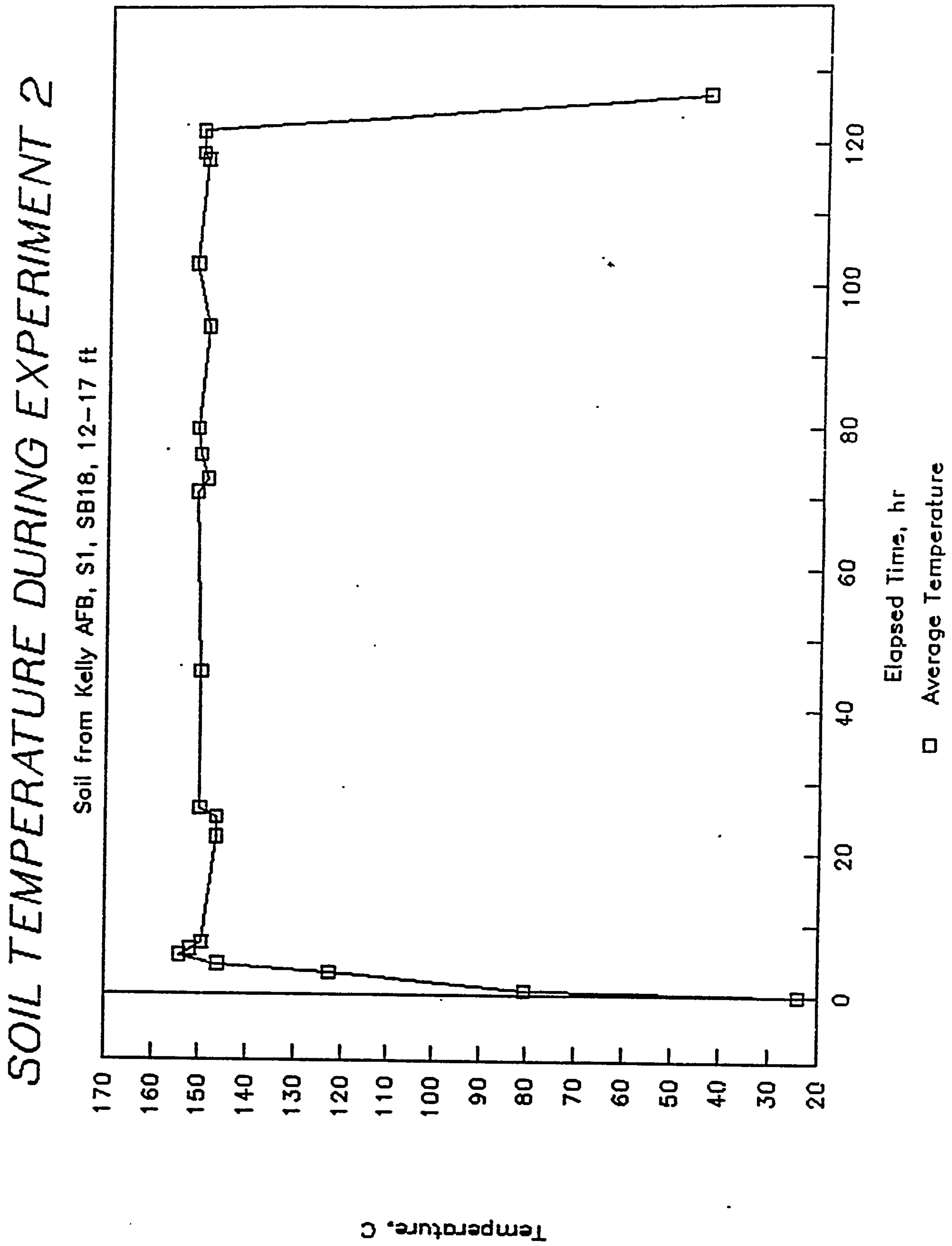
Soil Source:
Kelly AFB, Site S-1, Bore Hole SB18,12-17 ft depth
Date Sampled in the field: 10/20/91
HNUS Sample No.:KS1-SB18-U1217
Two jars with same labels were used.

Date Reactor Packed: 11/29/91

Wt of Soil packed in the reactor:	1319.1 gm
Wt of soil removed from storage jar 1	806 gm
Wt of soil removed from storage jar 2	785 gm
Initial Soil Moisture, %	26.8 % wt
Weight of final soil removed from reactor:	940 gm
Final Soil Moisture,%	% wt

Time with initial nitrogen sweep:	6.3 hr	164.61 liters nitrogen
Steaming Time	112.5 hr	2.89 liters gas
Time with nitrogen sweep after steaming		
with heat on:	3.1 hr	119.45 liters nitrogen
with heat off	4.9 hr	175.25 liters nitrogen

Initial Wt. of water in Reservoir:	1282.8 gm
Final Wt of water in the reservoir:	696.5 gm
Water injected	586.3 gm



SOIL TEMPERATURE DURING EXPERIMENT 2

Soil from Kelly AFB, S1, SB18, 12–17 ft

EXPERIMENT 3 TEMPERATURE AND OPERATING DATA

Elapsed Time hr	INSIDE TEMPERATURE T1	T2	Average Temperature C	Wet Test Meter Rdg. Liter	Total N2 Volume Liter	Remarks
0.0	23	23	23	2172.40	0.0	Initial Reading., Start heating
1.2	159	101	130	2174.77	2.4	
2.1	132	136	134	2188.88	16.5	
2.5	152	152	152	2203.86	31.5	
3.0	157	158	158	2220.80	48.4	
4.1	159	164	162	2260.46	88.1	
8.0	157	157	157	2406.00	233.6	
27.6	156	155	156	3175.30	1002.9	
56.4	157	152	155	4184.97	2012.6	
69.7	154	152	153	4672.47	2500.1	
79.8	154	152	153	5035.35	2863.0	
94.4	153	152	153	5570.00	3397.6	
103.5	153	152	153	5903.60	3731.2	Heaters off
105.0	99	100	100	5927.70	3755.3	
120.4	24	24	24	6089.12	3916.7	NItrogen off

Experiment 3 Details

Soil Source:
Kelly AFB, Site S-1, Bore Hole SB18,17-22 ft depth
Date Sampled in the field: 10/20/91
HNUS Sample No.:KS1-SB18-U1722
Two jars with same labels were used.

Date Reactor Packed: 12/4/91

Wt of Soil packed in the reactor:	1244.1 gm
Wt of soil removed from storage jar 1	709 gm
Wt of soil removed from storage jar 2	764 gm

Initial Soil Moisture, %	15.1 % wt

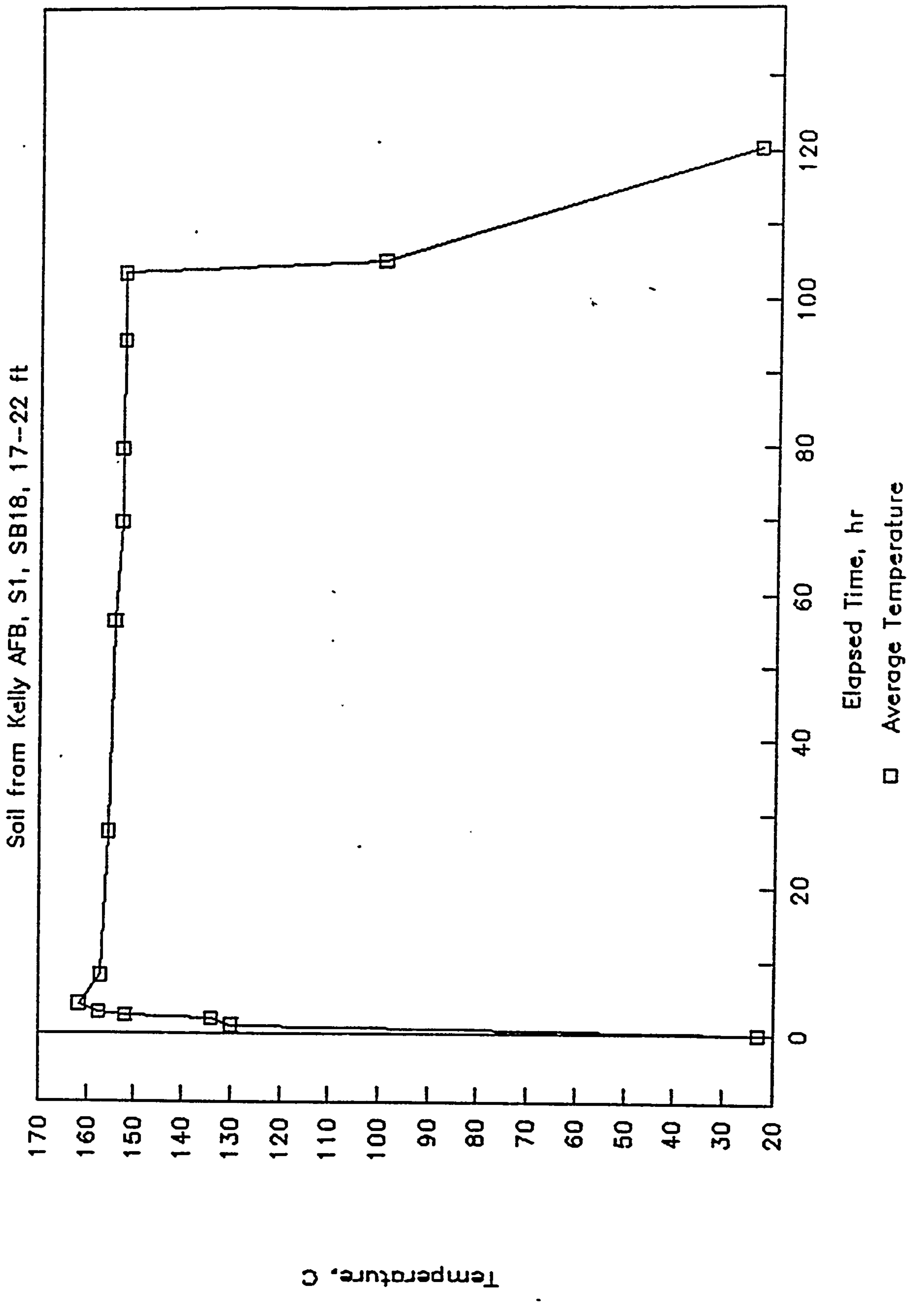
Weight of final soil removed from reactor:	1028 gm

Final Soil Moisture, %	0 % wt

Time with initial nitrogen sweep:	103.5 hr	3731.2 liters nitrogen
Steaming Time	0.0 hr	0
Time with nitrogen sweep after steaming	16.8 hr	185.52 liters nitrogen

Initial Wt. of water in Reservoir:	none added
Final Wt of water in the reservoir:	none added
Wt. of water injected	none

SOIL TEMPERATURE DURING EXPERIMENT 3



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EXPERIMENT 4 TEMPERATURE AND OPERATING DATA

ELAPSED TIME	T1	T2	AVG.	Wet Test Meter liter	Air liter	REMARKS
0.00	26.0	26.0	26.0	88.85	0.00	Air supply at 20 psi; no flow at start; permeability low
0.65	93.0	99.0	96.0	89.69	0.84	
1.62	95.0	94.0	94.5	103.73	14.88	Air flow started
3.40	120.0	132.0	126.0	163.18	74.33	
5.30	147.0	170.0	158.5	225.84	136.99	
6.95	152.0	169.0	160.5	280.57	191.72	
19.55	150.0	159.0	154.5	738.50	649.65	
23.38	150.0	158.0	154.0	875.95	787.10	
24.73	150.0	158.0	154.0	924.43	835.58	
26.92	150.0	158.0	154.0	1002.30	913.45	
29.38	150.0	158.0	154.0	1089.00	1000.15	
30.82	150.0	158.0	154.0	1141.03	1052.18	
73.17	143.0	149.0	146.0	2661.23	2661.23	
76.22	145.0	152.0	148.5	2762.00	2673.15	
92.55	149.0	157.0	153.0	3334.25	3245.40	
93.60	149.0	157.0	153.0	3369.40	3280.55	Fuse failure in vapor tube heater controller
97.55	149.0	156.0	152.5	3402.25	3313.40	
98.38	149.0	156.0	152.5	3531.81	3442.96	
101.13	149.0	156.0	152.5	3624.00	3535.15	
116.63	149.0	156.0	152.5	4107.00	4018.15	
117.13	148.0	156.0	152.0	4182.40	4093.55	End run; Shut down controllers

Experiment 4 Details

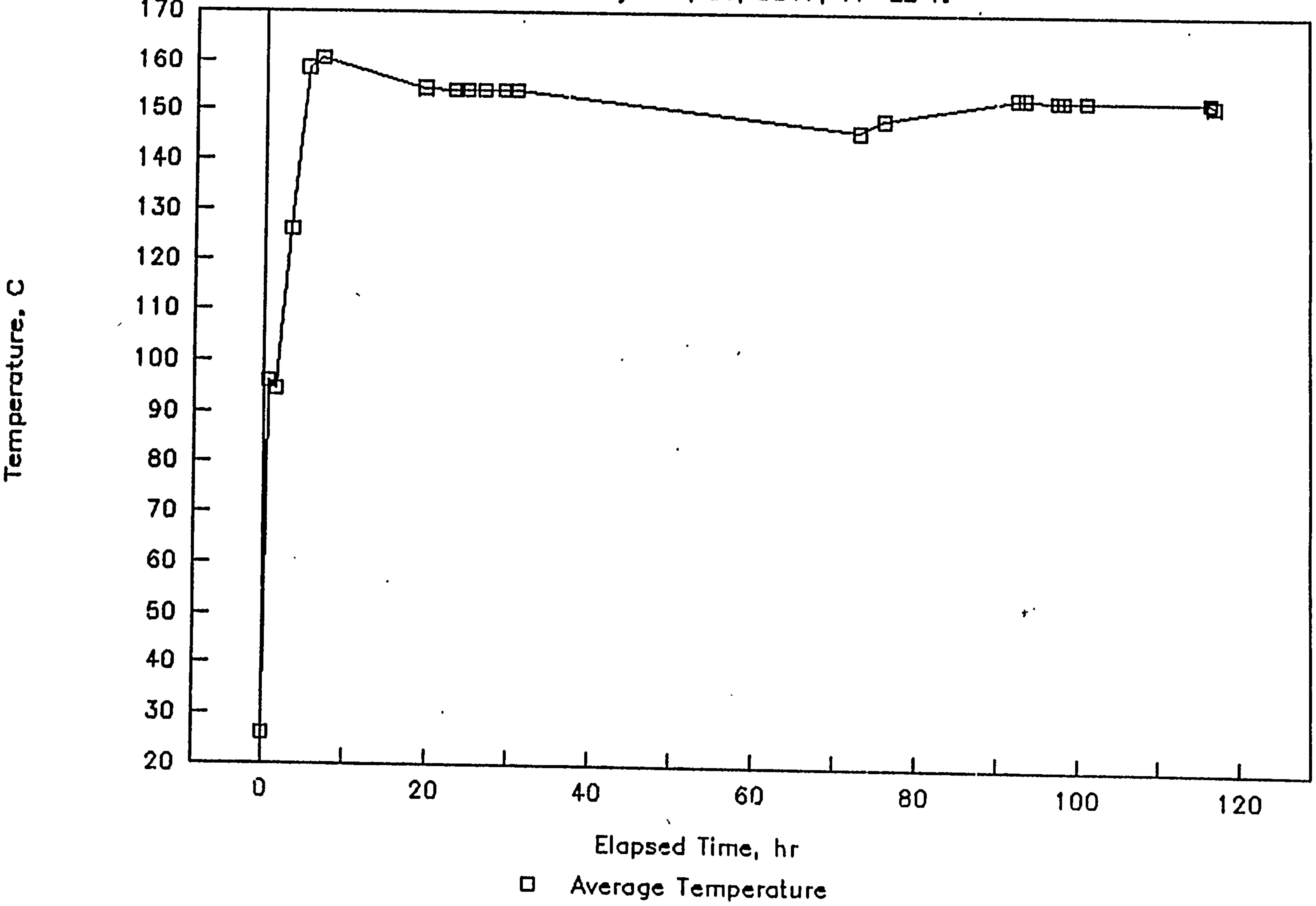
Soil Source:
Kelly AFB, Site S-1, Bore Hole SB18,7-12 ft depth
Date Sampled in the field: 10/20/91
HNUS Sample No.:KS1-SB18-U0712
Two jars with same labels were used.

Date Reactor Packed: 12/12/91

Wt of Soil packed in the reactor:	1239 gm	
Wt of soil removed from storage jar 1	505 gm	
Wt of soil removed from storage jar 2	775 gm	
Initial Soil Moisture, %	23.4	
Weight of final soil removed from reactor:	909 gm	
Final Soil Moisture, %	0	
Time with initial air sweep:	115.5 hr	4078.67 liters air
Steaming Time	0.0 hr	
Time with air sweep after steaming	N.A.	
Initial Wt. of water in Reservoir:	none	
Final Wt of water in the reservoir:	none	
Water Added	none	

SOIL TEMPERATURE DURING EXPERIMENT 4.

Soil from Kelly AFB, S1, SB17, 17–22 ft



EXPERIMENT 5 TEMPERATURE AND OPERATING DATA

ELAPSED TIME	T1	T2	AVG.	Wet Test Nitrogen Meter liter	liter	REMARKS
0.00	24.7	24.4	24.6	1392.70	0.00	unable to inject nitrogen; permeability is very low
0.67	50.4	50.2	50.3	1393.19	0.49	
1.00	69.6	70.4	70.0	1393.40	0.70	
1.67	107.9	101.4	104.7	1393.40	0.70	
2.00	109.7	99.4	104.6	1393.40	0.70	
2.45	108.0	99.0	103.5	1393.47	0.77	
3.00	109.7	99.3	104.5	1393.50	0.80	
3.75	112.0	99.4	105.7	1393.53	0.83	
4.00	109.2	97.3	103.3			
4.50	110.4	99.4	104.9	1393.55	0.85	
5.00	110.8	99.5	105.2	1393.57	0.87	
5.58	110.8	99.9	105.4	1393.59	0.89	
6.00	115.6	99.7	107.7	1393.63	0.93	
6.50	116.2	99.5	107.9	1393.67	0.97	Nitrogen flow just starting
7.00	120.6	97.5	109.1	1393.94	1.24	
7.17				1397.90	5.20	
7.50	117.8	91.9	104.9	1403.00	10.30	
7.83	114.1	90.1	102.1	1407.90	15.20	
22.58	119.8	118.9	119.4	2031.90	639.20	
23.50	119.8	118.9	119.4	2070.50	677.80	Nitrogen off; 09:45 water pump on
24.50				2116.60	723.90	
25.00	118.4	120.2	119.3	2116.61	723.91	
26.50	118.3	117.6	118.0	2117.59	724.89	
27.08	118.6	117.3	118.0	2117.59	724.89	
28.00	118.9	117.3	118.1	2117.59	724.89	
29.67	119.3	117.3	118.3	2117.61	724.91	
30.67	119.3	117.2	118.3	2117.62	724.92	
30.93	119.0	117.0	118.0	2117.63	724.93	
54.13	120.0	116.0	118.0	2117.63	724.93	
59.10	112.0	109.0	110.5	2117.63	724.93	
93.33	116.0	113.0	114.5	2117.75	725.05	
99.90	113.0	115.0	114.0	2117.89	725.19	
117.73	113.0	116.0	114.5	2117.94	725.24	
128.38	112.0	115.0	113.5	2117.96	725.26	
165.33	112.0	116.0	114.0	2116.00	725.30	
169.15	112.0	115.0	113.5	2118.02	725.32	
176.20	112.0	115.0	113.5	2118.05	725.35	
192.88	111.0	115.0	113.0	2118.05	725.35	
194.65	111.0	115.0	113.0	2118.05	725.35	
195.42	111.0	115.0	113.0	2118.05	725.35	
200.45	111.0	115.0	113.0	2118.05	725.35	
222.33	108.0	112.0	110.0	2118.15	725.45	
224.33	107.0	114.0	110.5	2118.15	725.45	
225.38	110.0	114.0	112.0	2118.16	725.46	

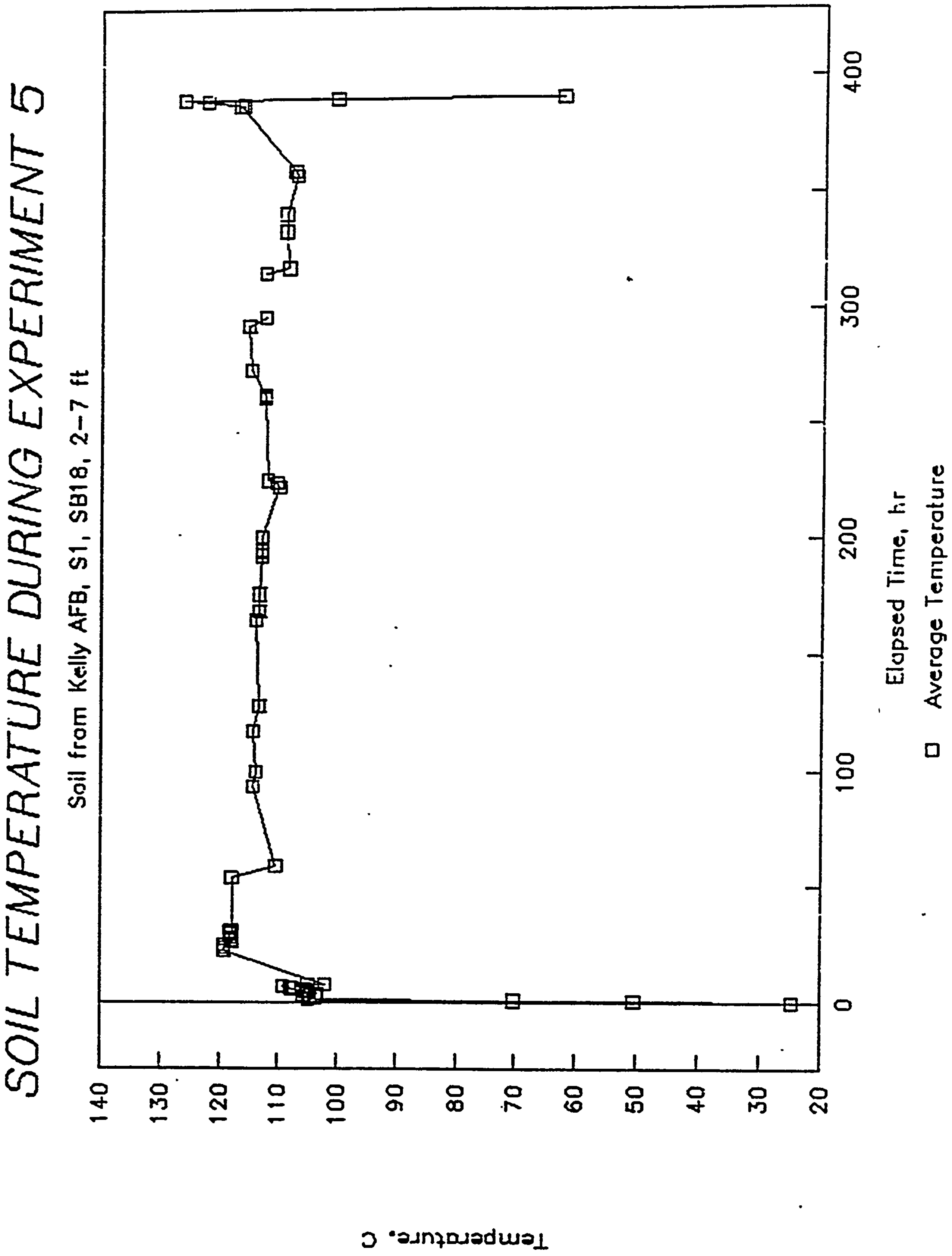
EXPERIMENT 5 TEMPERATURE AND OPERATING DATA

ELAPSED TIME	T1	T2	AVG.	Wet Test Meter liter	Nitrogen liter	REMARKS
261.17	110.0	115.0	112.5	2118.27	725.57	
262.38	110.0	115.0	112.5	2118.28	725.58	
273.17	112.0	118.0	115.0	2118.34	725.64	
292.20	113.0	118.0	115.5	2118.38	725.68	
295.88	109.0	116.0	112.5	2118.44	725.74	
315.00	110.0	115.0	112.5	2118.49	725.79	
317.32	104.0	113.0	108.5	2118.57	725.87	
333.25	103.0	115.0	109.0	2118.81	726.11	
340.82	102.0	116.0	109.0	2118.90	726.20	
357.50	100.2	114.0	107.1	2119.00	726.30	
359.67	100.0	115.0	107.5	2119.00	726.30	
387.23	112.0	122.0	117.0	2119.24	726.54	
387.70	112.0	121.0	116.5	2119.24	726.54	Water pump off; nitrogen on
389.25	111.0	134.0	122.5	2164.95	772.25	
389.82	116.0	137.0	126.5	2181.94	789.24	All heaters off
390.78	94.0	107.0	100.5	2210.45	817.75	
391.48	63.0	62.0	62.5	2230.80	838.10	Nitrogen off

Experiment 5 Details

Soil Source:
Kelly AFB, Site S-1, Bore Hole SB18, 2-7 ft depth
Date Sampled in the field: 10/20/91
HNUS Sample No.:KS1-SB18-U0207
Two jars with same labels were used.

Date Reactor Packed: 12/17/91		
Wt of Soil packed in the reactor:	1456 gm	
Wt of soil removed from storage jar 1	562 gm	
Wt of soil removed from storage jar 2	929 gm	
Initial Soil Moisture, %	16.6	
Wt. of soil removed from the reactor	1210 gm	
Final Soil Moisture, %	2.82 %	
Time with no gas sweep	7.0 hr	low gas permeability
Time with initial nitrogen sweep:	17.5 hr	722.66 liters nitrogen
Steaming Time	363.0 hr	2.63 liters gas
Time with nitrogen sweep after steaming	2.1 hr	62.70 liters nitrogen
Initial Wt. of water in Reservoir:	1270 gm	
Final Wt of water in the reservoir:	1090 gm	
Water injected	180 gm.	



SOIL TEMPERATURE DURING EXPERIMENT 5

Soil from Kelly AFB, S1, SB18, 2–7 ft

APPENDIX B

SOIL ANALYSIS

It was mentioned in Section 3 of this report that initially soil samples were sent to an outside independent laboratory for analysis. This was done to due to scheduling constraint and the need to obtain data in a timely fashion. It was specified that the samples be analyzed for TPH by the California DHS method. However, when the soil sample results were obtained it was clear that the matrix spike recovery were in the unacceptable range. At this time it was decided to repeat all the sample analysis in-house in IITRI. The data provided by the independent laboratory was presented in a raw data report submitted to Halliburton NUS in February 1992. The purpose of this Appendix is to summarize the results of the sample analysis as performed by the outside laboratory. Table B-1 gives the concentration of treated and initial soil from each of the five experiments. Table B-2 summarizes the spike recovery efficiency based on the outside laboratory analysis.

Table B-1 . Soil Treatability Experimental Conditions and Results

Expt. No.	Soak Temperature C	Soak Time hr	Nitrogen/ Air Sweep	Water Injection g/min	TPH Concentration ppm		Percent TPH Removal %
					Initial	Final	
1	113	122	Nitrogen	4.6	1510	249	85
2	150	118	Nitrogen	5.2	87	18	85
3	151	102	Nitrogen	0.0	1360	81	95
4	153	112	Air	0.0	116	<5	97
5	112	388	Nitrogen	0.5	<5	<5	---

Table B-2. Results of Matrix Spike Samples

Sample No.	Description	Analyzed Conc. ppm	Spiked Sample Analyzed Conc. ppm	Incremental Amount of Spike ppm	Spike Recovery %
12834	Expt. 1 Final Soil	249			
12833	Expt. 1 Final Soil+Spike		318	29.3	235
2	Expt 2 Final Soil	17.8			
3	Expt. 2 Final Soil+Spike		<5	42.2	-30.3
4	Expt. 2 Final Soil+Spike		195	1171	15.1
13dup	Expt. 4 Final Soil	<5			
12	Expt. 4 Final Soil+Spike		6.3	35	<3.7
12831	Expt. 1 Initial Soil	1510			
12832	Expt. 1 Initial Soil+Spike		1280	508	-45.2

APPENDIX A.3.

TABLE A.3. - 1
SUMMARY OF CONCENTRATION LEVELS, PPB
VOLATILE ORGANIC COMPOUNDS
IITRI PRETREATMENT SOIL SAMPLES

SAMPLE LOCATIONS	TRPH	BENZENE	TOLUENE	ETHYLBENZENE	XYLENES	METHYL ETHYL KETONE	ACETONE	CHLOROBENZENE	2-HEXANONE	4-METHYL-2-PENTANONE
EA01-0406	200.0	2.7 *	3.4 *	2.4 *	7.5 *	50.0	210.0	2.6	5.1 *	3.4 *
EA01-2426	6900.0	2500.0	1900.0	3700.0	15000.0	270.0 *	640.0 *	35000.0	95.0 *	64.0 *
EA02-1214	400.0	0.5 *	1.1	1.2 *	1.9 *	5.4 *	110.0	11.0	4.3 *	5.0 *
EA03-0204	1900.0	0.5 *	0.8	1.1 *	1.7 *	43.0	170.0	4.8	4.0 *	4.6 *
EA03-1618	26000.0	29.0	22.0	120.0	120.0	50.0	160.0	1000.0	4.3 *	5.0 *
EA04-0002	110.0	0.5 *	0.5	1.0 *	3.0	4.8 *	27.0	4.0	3.9 *	4.5 *
EA04-2022	12000.0	220.0	57.0 *	76.0	120.0 *	240.0 *	570.0 *	16000.0	85.0 *	57.0 *
EA05-2224	3100.0	340.0	59.0 *	77.0	130.0 *	250.0 *	590.0 *	19000.0	88.0 *	59.0 *
EA06-1820	750.0	1.8	0.4 *	0.9 *	1.5 *	4.2 *	14.0 *	200.0	3.4 *	3.9 *
EA07-1214	610.0	2.7 *	3.4 *	2.3 *	7.4 *	14.0 *	51.0	43.0	5.1 *	3.4 *
EA07-0810	340.0	2.6 *	3.2 *	2.2 *	7.1 *	27.0	100.0	4.3	4.8 *	3.2 *
EA08-1416	260.0	6.3	3.1 *	2.1 *	6.7 *	28.0	110.0	260.0	4.6 *	3.1 *
EA08-2830	30.0 *	170.0	11.0	37.0	42.0	13.0 *	33.0	4800.0	4.6 *	3.1 *
TW01-0406	300.0	2.6 *	3.3 *	2.3 *	7.2 *	110.0	400.0	2.5 *	4.9 *	3.3 *
TW01-1416	1400.0	2.9 *	11.0	2.5 *	7.8 *	67.0	240.0	45.0	5.3 *	3.5 *
TW01-2426	4600.0	270.0	2500.0	880.0	6300.0	240.0 *	570.0 *	92000.0	85.0 *	57.0 *
TW02-0406	420.0	3.7 *	4.5 *	3.1 *	9.9 *	110.0	330.0	3.5 *	6.8 *	4.5 *
TW02-1416	980.0	2.9 *	11.0	2.5 *	7.9 *	35.0	140.0	100.0	5.4 *	3.6 *
TW02-2426	12000.0	3200.0	13000.0	4800.0	29000.0	350.0 *	830.0 *	400000.0	120.0 *	83.0 *
TW07-0406	270.0	3.7 *	4.6 *	3.2 *	10.0 *	58.0	200.0	3.5 *	6.9 *	4.6 *
TW07-1416	9300.0	2.4 *	3.0 *	2.8	6.6 *	13.0 *	30.0 *	46.0	4.5 *	3.0 *
TW07-2426	6100.0	390.0	5500.0	1500.0	11000.0	250.0 *	580.0 *	62000.0	88.0 *	58.0 *
EB01-0002	1200.0	7.9	3.0 *	7.1	6.7 *	28.0	140.0	1300.0	4.6 *	3.0 *
EB01-1214	2300.0	2.8 *	3.5 *	2.4 *	7.6 *	37.0	150.0	21.0	5.2 *	3.5 *
EB01-2628	4200.0	700.0	2700.0	1100.0	7000.0	1200.0 *	2900.0 *	120000.0	440.0 *	290.0 *
EB02-0406	350.0	2.7 *	3.3 *	2.3 *	7.3 *	14.0 *	33.0 *	4.2	5.0 *	3.3 *
EB02-0810	1100.0	2.6 *	3.2 *	2.2 *	7.0 *	13.0 *	57.0	5.4	4.8 *	3.2 *
EB02-1214	51000.0	12.0 *	15.0 *	11.0 *	34.0 *	65.0 *	150.0 *	230.0	23.0 *	15.0 *
EB03-0204	61.0	2.6 *	3.3 *	2.3 *	7.2 *	77.0	380.0	12.0	4.9 *	3.3 *
EB03-1012	21000.0	3.7	2.8 *	1.9 *	6.1 *	12.0 *	28.0 *	7.4	4.1 *	2.8 *
EB04-1618	12000.0	68.0	17.0 *	12.0 *	37.0 *	71.0 *	270.0	1000.0	25.0 *	17.0 *
EB04-2022	8800.0	93.0	58.0 *	40.0 *	130.0 *	250.0 *	580.0 *	11000.0	88.0 *	58.0 *
EB04-2224	10000.0	640.0	150.0 *	170.0	330.0 *	640.0 *	1500.0 *	34000.0	230.0 *	150.0 *
EC02-0608	460.0	2.5 *	3.1 *	2.2 *	6.9 *	45.0	130.0	2.4 *	4.7 *	3.1 *
EC02-2022	24000.0	490.0	12000.0	2800.0	22000.0	270.0 *	630.0 *	5700.0	94.0 *	63.0 *
EC03-0002	33.0 *	2.8 *	3.4 *	2.4 *	7.5 *	14.0 *	67.0	2.6 *	5.1 *	3.4 *
EC03-1820	11000.0	180.0	5300.0	1500.0	12000.0	290.0 *	690.0 *	1100.0	100.0 *	69.0 *
EC03-2224	12000.0	410.0	5000.0	1600.0	5400.0	1200.0 *	2800.0 *	48000.0	430.0 *	280.0 *
EC05-1012	3700.0	2.4 *	3.0 *	2.1 *	6.6 *	39.0	74.0	8.2	4.5 *	3.0 *
EC05-2830	450.0	150.0	92.0	120.0	410.0	260.0 *	620.0 *	14000.0	94.0 *	62.0 *
EC06-0204	120.0	2.5 *	3.1 *	2.1 *	6.8 *	13.0 *	130.0	5.4	4.6 *	3.1 *
EC06-1820	6100.0	16.0	17.0 *	12.0 *	37.0 *	72.0 *	500.0	890.0	26.0 *	17.0 *
EC06-2426	6200.0	1100.0	2900.0	1600.0	9200.0	660.0 *	1600.0 *	200000.0	230.0 *	160.0 *
EC07-0406	32.0 *	2.7 *	3.3 *	2.3 *	7.2 *	14.0 *	33.0 *	2.5 *	4.9 *	3.3 *
EC07-0810	8500.0	3.3 *	4.1 *	2.8 *	8.9 *	17.0 *	56.0	21.0	6.1 *	4.1 *
EC08-0406	320.0	2.7 *	3.4 *	2.3 *	7.4 *	14.0 *	83.0	5.6	5.0 *	3.4 *
EC08-1416	58.0	3.6	3.3 *	2.3 *	7.2 *	24.0	120.0	340.0	4.9 *	3.3 *
EC08-2224	2400.0	140.0	60.0 *	160.0	130.0 *	250.0 *	600.0 *	15000.0	90.0 *	60.0 *

* BELOW DETECTION LIMIT

TABLE A.3. - 2
SUMMARY OF CONCENTRATION LEVELS, PPB
SEMI-VOLATILE ORGANIC COMPOUNDS
IITRI PRETREATMENT SOIL SAMPLES

SAMPLE LOCATIONS	BENZO(A) ANTHRACENE	BENZO(A) PYRENE	BENZO(B) FLUORANTHENE	BENZO(K) FLUORANTHENE	CHRYSENE	1,2-DICHLORO-BENZENE	1,3-DICHLORO-BENZENE	1,4-DICHLORO-BENZENE
EA01-0406	20.0	22.0	77.0	77.0	34.0	30.0	1.0 *	0.87 *
EA01-2426	50.0	43.0	46.0	49.0	55.0	270.0	140.0	1600.0
EA02-1214	20.0	21.0	19.0	19.0	20.0	0.94 *	1.1 *	0.89 *
EA03-0204	1500.0	1500.0	1700.0	1600.0	1800.0	0.86 *	0.99 *	0.82 *
EA03-1618	0.67 *	0.76 *	1.3 *	1.5 *	0.8 *	170.0	1100.0	1100.0
EA04-0002	180.0	210.0	420.0	420.0	210.0	0.85 *	0.97 *	0.81 *
EA04-2022	1.6 *	36.0	52.0	33.0	61.0	2.3 *	2.6 *	130.0
EA05-2224	36.0	28.0	34.0	27.0	49.0	2.4 *	2.7 *	2.2 *
EA06-1820	0.53 *	0.6 *	1.1 *	1.2 *	0.64 *	0.74 *	17.0	88.0
EA07-1214	21.0	18.0	20.0	11.0	18.0	49.0	1.0 *	0.86 *
EA07-0810	31.0	30.0	63.0	6.3	34.0	33.0	0.99 *	0.83 *
EA08-1416	30.0	31.0	64.0	64.0	36.0	39.0	0.94 *	14.00
EA08-2830	1.8 *	2.0 *	3.5 *	3.9 *	2.1.*	48.0	2.8 *	88.0
TW01-0406	51.0	50.0	130.0	130.0	97.0	190.0	1.0 *	38.0
TW01-1416	22.0	21.0	41.0	41.0	33.0	140.0	1.1 *	44.0
TW01-2426	23.0	17.0	38.0	38.0	34.0	85000.0	6600.0	17000.0
TW02-0406	89.0	96.0	220.0	220.0	120.0	140.0	1.4 *	34.0
TW02-1416	26.0	30.0	51.0	51.0	35.0	180.0	1.1 *	62.0
TW02-2426	240.0	200.0	200.0	200.0	190.0	34000.0	3900.0	14000.0
TW07-0406	68.0	73.0	180.0	180.0	94.0	1.2 *	1.4 *	1.2 *
TW07-1416	81.0	58.0	200.0	200.0	120.0	0.81 *	0.93 *	0.77 *
TW07-2426	37.0	1.9 *	21.0	31.0	46.0	13000.0	640.0	1500.0
EB01-0002	760.0	850.0	1900.0	1900.0	1100.0	4.1 *	4.7 *	110.0
EB01-1214	18.0	25.0	33.0	33.0	36.0	0.94 *	1.1 *	73.0
EB01-2628	33.0	52.0	38.0	29.0	39.0	9800.0	2400.0	12000.0
EB02-0406	78.0	79.0	82.0	71.0	90.0	0.89 *	1.0 *	0.85 *
EB02-0810	3.0 *	50.0	59.0	59.0	3.7 *	4.3 *	4.9 *	4.1 *
EB02-1214	1500.0	6.7 *	3000.0	3000.0	1700.0	8.3 *	9.5 *	450.0
EB03-0204	35.0	48.0	85.0	51.0	59.0	15.0	1.0 *	0.84 *
EB03-1012	5.3 *	6.0 *	140.0	140.0	6.4 *	7.4 *	8.5 *	7.1 *
EB04-1618	54.0	48.0	86.0	88.0	75.0	0.9 *	72.0	140.0
EB04-2022	19.0	47.0	110.0	110.0	79.0	2.3 *	110.0	530.0
EB04-2224	55.0	34.0	82.0	82.0	96.0	2.4 *	300.0	1900.0
EC02-0608	19.0	32.0	67.0	67.0	47.0	38.0	0.96 *	0.80 *
EC02-2022	170.0	210.0	470.0	470.0	320.0	55000.0	3400.0	10000.0
EC03-0002	0.0	1600.0	1200.0	1300.0	1400.0	35.0	1.1 *	0.88 *
EC03-1820	46.0	48.0	110.0	110.0	78.0	5000.0	600.0	4200.0
EC03-2224	53.0	38.0	92.0	92.0	75.0	78000.0	4300.0	10000.0
EC05-1012	45.0	60.0	110.0	110.0	99.0	140.0	2.8 *	2.3 *
EC05-2830	1.8 *	2.0 *	3.6 *	3.9 *	2.1 *	240.0	56.0	270.0
EC06-0204	18.0	24.0	40.0	22.0	30.0	0.83 *	1.0 *	0.79 *
EC06-1820	26.0	0.75 *	79.0	79.0	48.0	39.0	190.0	440.0
EC06-2426	38.0	2.0 *	99.0	99.0	55.0	5900.0	2300.0	11000.0
EC07-0406	36.0	28.0	58.0	58.0	35.0	0.89 *	1.0 *	0.84 *
EC07-0810	92.0	120.0	210.0	210.0	130.0	5.5 *	6.3 *	5.2 *
EC08-0406	14.0	12.0	30.0	30.0	20.0	170.0	1.0 *	0.86 *
EC08-1416	0.63 *	8.1	9.7	5.9	0.76 *	0.88 *	1.0 *	24.0
EC08-2224	34.0	40.0	51.0	51.0	50.0	2.4 *	2.7 *	310.0

* BELOW DETECTION LIMIT

TABLE A.3. - 2 (continued)
SUMMARY OF CONCENTRATION LEVELS, PPB
SEMI-VOLATILE ORGANIC COMPOUNDS
IITRI PRETREATMENT SOIL SAMPLES

SAMPLE LOCATIONS	BIS(2-ETHYLHEXYL) PHTHALATE	FLUORANTHENE	FLUORENE	2-METHYL-NAPHTHALENE	NAPHTHALENE	PHENANTHRENE	PYRENE
EA01-0406	520.0	48.0	0.57 *	0.52 *	0.7 *	21.0	44.0
EA01-2426	5600.0	790.0	250.0	7100.0	4500.0	300.0	170.0
EA02-1214	76.0	36.0	0.58 *	9.3	0.72 *	19.0	38.0
EA03-0204	1000.0	3100.0	110.0	23.0	14.0	720.0	2900.0
EA03-1618	17000.0	0.72 *	0.58 *	1800.0	190.0	0.72	0.63
EA04-0002	120.0	430.0	11.0	11.0	0.64 *	110.0	370.0
EA04-2022	5900.0	550.0	230.0	4900.0	1.7 *	270.0	190.0
EA05-2224	4700.0	430.0	190.0	4200.0	1.8 *	210.0	140.0
EA06-1820	73.0	9.9	0.46 *	11.0	0.57 *	15.0	9.3
EA07-1214	36.0	38.0	0.56 *	14.0	15.0	27.0	35.0
EA07-0810	47.0	55.0	0.54 *	14.0	0.66 *	26.0	51.0
EA08-1416	170.0	50.0	0.51 *	14.0	20.0	26.0	57.0
EA08-2830	2.2 *	1.9 *	1.5 *	140.0	240.0	1.9	1.6
TW01-0406	380.0	100.0	0.55 *	37.0	26.0	31.0	94.0
TW01-1416	840.0	29.0	0.59 *	130.0	32.0	75.0	54.0
TW01-2426	4300.0	620.0	220.0	8000.0	7500.0	250.0	110.0
TW02-0406	790.0	200.0	0.8 *	26.0	20.0	65.0	170.0
TW02-1416	990.0	44.0	30.0	75.0	27.0	38.0	42.0
TW02-2426	13000.0	2000.0	10.0 *	26000.0	14000.0	860.0	410.0
TW07-0406	670.0	100.0	0.8 *	0.7 *	0.94 *	34.0	110.0
TW07-1416	2100.0	150.0	230.0	2300.0	0.62 *	240.0	180.0
TW07-2426	4700.0	680.0	280.0	6100.0	3300.0	300.0	150.0
EB01-0002	940.0	1600.0	51.0	530.0	3.1 *	430.0	1400.0
EB01-1214	470.0	34.0	51.0	55.0	0.71 *	65.0	53.0
EB01-2628	4700.0	740.0	230.0	7500.0	6000.0	290.0	130.0
EB02-0406	70.0	210.0	34.0	30.0	33.0	240.0	210.0
EB02-0810	270.0	25.0	2.6 *	2.4	3.2 *	3.2	84.0
EB02-1214	56000.0	4100.0	720.0	170.0	6.3 *	1500.0	3700.0
EB03-0204	480.0	75.0	0.54 *	10.0	0.67 *	25.0	70.0
EB03-1012	960.0	5.7 *	170.0	150.0	5.7 *	170.0	5.0
EB04-1618	13000.0	0.69 *	100.0	430.0	0.69 *	230.0	220.0
EB04-2022	14000.0	630.0	260.0	4400.0	1.8 *	430.0	250.0
EB04-2224	13000.0	910.0	380.0	11000.0	730.0	430.0	250.0
EC02-0608	340.0	51.0	0.52 *	0.48 *	0.64 *	17.0	55.0
EC02-2022	19000.0	3400.0	1.6 *	18000.0	12000.0	1400.0	11.0
EC03-0002	110.0	3600.0	570.0	310.0	850.0	3900.0	3200.0
EC03-1820	14000.0	2500.0	730.0	0.53 *	4700.0	640.0	300.0
EC03-2224	9100.0	1300.0	510.0	12000.0	11000.0	600.0	250.0
EC05-1012	920.0	110.0	1.5 *	81.0	1.8 *	67.0	250.0
EC05-2830	290.0	42.0	1.6 *	340.0	150.0	28.0	17.0
EC06-0204	260.0	43.0	0.52 *	0.48 *	0.63 *	15.0	38.0
EC06-1820	15000.0	310.0	200.0	1900.0	0.7 *	310.0	190.0
EC06-2426	5900.0	970.0	310.0	8400.0	5800.0	400.0	180.0
EC07-0406	39.0	78.0	7.3	9.2	14.0	65.0	65.0
EC07-0810	620.0	130.0	3.4 *	3.1 *	4.2 *	4.2	140.0
EC08-0406	200.0	16.0	0.56 *	0.51 *	0.69 *	0.69	18.0
EC08-1416	6500.0	14.0	0.55 *	0.5 *	0.67 *	0.67	14.0
EC08-2224	5300.0	620.0	210.0	5900.0	340.0	250.0	170.0

* BELOW DETECTION LIMIT

TABLE A.3. - 3
SUMMARY OF CONCENTRATION LEVELS, PPB
VOLATILE ORGANIC COMPOUNDS
IITRI POST-TREATMENT SOIL SAMPLES

SAMPLE LOCATIONS	TRPH	BENZENE	TOLUENE	ETHYLBENZENE	XYLENES	METHYL ETHYL KETONE	ACETONE	CHLOROBENZENE	2-HEXANONE	4-METHYL--2-PENTANONE
EA01A-0608	319.0	1.04 *	2.06 *	1.0 *	4.65 *	46.4	162.0	23.0	10.1	2.62 *
EA01A-2426	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EA02A-1416	700.0	1.42 *	2.81 *	1.36 *	6.31 *	35.9	414.0	26.4	8.0 *	3.56 *
EA03A-0204	141.0	20.2 *	56.8	81.5	186.0	1530.0	11900.0	1680.0	114.0 *	81.4
EA03A-1820	19800.0	73.3	45.3 *	90.7	130.0	2500.0	3410.0	6270.0	419.0	265.0
EA04A-0002	30.1 *	2.15	2.45 *	2.16	7.93	797.0	6660.0	12.7	182.0	34.7
EA04A-2022	8970.0	20.8 *	41.2 *	20.0 *	92.7 *	230.0	305.0 *	949.0	117.0 *	52.3 *
EA05A-2223	9890.0	21.7 *	43.0 *	20.9 *	96.8 *	153.0 *	318.0 *	1560.0	123.0 *	54.7 *
EA06A-1820	5110.0	2.95	2.06 *	2.26	4.64 *	18.0	124.0	108.0	23.8	5.29
EA07A-1214	4500.0	2.53	2.05 *	0.995 *	4.62 *	271.0	1350.0	33.3	133.0	61.2
EA07A-0810	685.0	20.2 *	40.0 *	19.4 *	89.9 *	2210.0	9360.0	45.0	201.0	148.0
EA08A-1416	902.0	2.43 *	4.82 *	2.34 *	10.8 *	17.2 *	42.6	6.73	13.7 *	6.12 *
EA08A-2830	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TW01A-0608	271.0	1.01 *	2.0 *	0.969 *	4.50 *	1530.0	4380.0	158.0	93.5	40.3
TW01A-1416	2420.0	1.29 *	2.56 *	1.24 *	5.76 *	39.2	196.0	19.8	7.3 *	3.25 *
TW01A-2426	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TW02A-0406	50.9	129.0	133.0	66.0	154.0	2710.0	13400.0	2940.0	127.0	103.0
TW02A-1416	1390.0	5.22	3.21	2.74	5.15	113.0	353.0	175.0	168.0	62.4
TW02A-2426	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TW07A-0406	356.0	1.19 *	2.35 *	1.14 *	5.29 *	12.4	99.6	4.67	6.7 *	2.98 *
TW07A-1416	7030.0	5.45 *	10.8 *	5.24 *	24.3 *	45.1	289.0	20.5	30.8 *	13.7 *
TW07A-2426	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EB01A-0002	24.9 *	32.3	5.95	0.974 *	4.74	70.8	1060.0	38.7	8.37	6.98
EB01A-1618	204.0	239.0	100.0	19.4 *	103.0	142.0 *	296.0 *	2560.0	114.0 *	50.8 *
EB01A-2628	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EB02A-0406	24.9 *	90.3	13.1	2.03	12.1	6.99 *	170.0	4200.0	5.6 *	2.5 *
EB02A-0810	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EB02A-1214	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EB03A-0204	24.5 *	26.0	2.0 *	0.972 *	4.51 *	7.13 *	15.5	13.1	5.71 *	2.54 *
EB03A-1012	27.6 *	17.8	4.28	1.08 *	4.99 *	7.89 *	56.0	7.43	6.32 *	2.82 *
EB04A-1618	181.0	4.19	2.04 *	0.988 *	4.58 *	87.8	895.0	963.0	32.6	10.6
EB04A-2022	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EB04A-2224	2360.0	1.18 *	2.34 *	1.14 *	5.27 *	28.0	230.0	137.0	32.5	15.3
EC02A-0608	351.0	1.4 *	2.78 *	1.35 *	6.25 *	248.0	1110.0	12.2	8.79	6.13
EC02A-2022	24900.0	66.0	1450.0	654.0	5980.0	343.0	451.0	14000.0	128.0 *	57.2 *
EC03A-0002	130.0	1.22 *	2.42 *	1.17 *	5.45 *	1130.0	4550.0	17.3	70.7	35.8
EC03A-1820	23300.0	22.6 *	44.7 *	24.7	106.0	704.0	358.0	1180.0	127.0 *	56.7 *
EC03A-2224	7750.0	22.8 *	187.0	563.0	3930.0	640.0	335.0 *	54200.0	129.0 *	57.4 *
EC05A-1012	25.0 *	23.7	3.38	1.6 *	3.72 *	110.0	2910.0	17.3	8.85	6.19
EC05A-2830	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EC06A-0204	26.1 *	1.66 *	3.26	1.68 *	3.89 *	190.0	12700.0	14.6	10.7	5.28 *
EC06A-1820	2610.0	10.1 *	8.26 *	10.2 *	23.7 *	12700.0	30100.0	1750.0	4670.0	4010.0
EC06A-2426	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EC07A-0406	25.6 *	3.80	2.22	1.89	10.9	1780.0	12200.0	1270.0	127.0	38.9
EC07A-0810	629.0	6.82	6.0	1.61 *	9.54	1930.0	13600.0	52.4	154.0	48.1
EC08A-0406	1700.0	1.68 *	1.37 *	1.7 *	3.94 *	11.2 *	42.3 *	2.30 *	3.6 *	5.34 *
EC08A-1416	56.7	3.92 *	3.21 *	3.97 *	9.2 *	26.1 *	98.9 *	5.38 *	8.41 *	12.5 *
EC08A-2224	8110.0	50.0	29.3 *	1270.0	262.0	915.0	1550.0	75500.0	76.8 *	114.0 *

* BELOW DETECTION LIMIT

TABLE A.3. - 4
SUMMARY OF CONCENTRATION LEVELS, PPB
SEMI-VOLATILE ORGANIC COMPOUNDS
IITRI POST-TREATMENT SOIL SAMPLES

SAMPLE LOCATIONS	BENZO(A) ANTHRACENE	BENZO(A) PYRENE	BENZO(B) FLUORANTHENE	BENZO(K) FLUORANTHENE	CHRYSENE	1,2-DICHLORO-BENZENE	1,3-DICHLORO-BENZENE	1,4-DICHLORO-BENZENE
EA01A-0608	38.5	45.7	96.0	96.0	55.7	153.0	13.6 *	27.8 *
EA01A-2426	NA	NA	NA	NA	NA	NA	NA	NA
EA02A-1416	30.4	23.1	48.8	48.8	34.9	36.9 *	18.8 *	38.3 *
EA03A-0204	59.4	132.0	457.0	457.0	170.0	98.8	18.3	216.0
EA03A-1820	282.00 *	210.00 *	312.0 *	531.0 *	367.0 *	427.0 *	217.0 *	443.0 *
EA04A-0002	21.2 *	24.0	70.5	70.5	27.6 *	75.0	16.3 *	60.6
EA04A-2022	52.9 *	39.4 *	58.5	99.5 *	68.7 *	80.0 *	40.7 *	83.0 *
EA05A-2223	268.0 *	199.0 *	296.0 *	503.0 *	348.0 *	405.0 *	206.0 *	420.0 *
EA06A-1820	33.70	93.4	74.6	74.6	57.20	27.2 *	13.8 *	28.2 *
EA07A-1214	17.7 *	13.1 *	37.4	37.4	23.1	26.7 *	13.6 *	27.7 *
EA07A-0810	17.2 *	12.8 *	19.0 *	32.3 *	22.4 *	26.0 *	13.2 *	27.0 *
EA08A-1416	62.7	54.4	105.0	105.0	71.4	32.1 *	16.3 *	33.3 *
EA08A-2830	NA	NA	NA	NA	NA	NA	NA	NA
TW01A-0608	24.7	32.7	71.5	71.5	42.0	60.6	13.4 *	49.8
TW01A-1416	66.1 *	49.2 *	73.0 *	124.0 *	85.9 *	100.0 *	50.8 *	104.0 *
TW01A-2426	NA	NA	NA	NA	NA	NA	NA	NA
TW02A-0406	26.1	61.4	120.0	120.0	31.1	32.1	13.2 *	43.7
TW02A-1416	83.2	123.0	61.7	99.4 *	279.0	80.0 *	40.7 *	153.0
TW02A-2426	NA	NA	NA	NA	NA	NA	NA	NA
TW07A-0406	20.3 *	15.1 *	59.2	59.2	26.9	30.7 *	15.6 *	31.9 *
TW07A-1416	19.6 *	96.0	106.0	106.0	216.0	29.7 *	15.1 *	30.8 *
TW07A-2426	NA	NA	NA	NA	NA	NA	NA	NA
EB01A-0002	17.2 *	12.8 *	19.0 *	32.2 *	22.3 *	42.0	13.2 *	41.0
EB01A-1618	17.2 *	12.8 *	19.0 *	32.3 *	22.3 *	26.0 *	13.2 *	27.0 *
EB01A-2628	NA	NA	NA	NA	NA	NA	NA	NA
EB02A-0406	17.2 *	12.8 *	19.0 *	32.3 *	22.3 *	26.0 *	13.2 *	26.9 *
EB02A-0810	NA	NA	NA	NA	NA	NA	NA	NA
EB02A-1214	NA	NA	NA	NA	NA	NA	NA	NA
EB03A-0204	17.2 *	12.8 *	19.0 *	32.3 *	22.3 *	26.0 *	13.2 *	27.0 *
EB03A-1012	19.1 *	14.2 *	21.2 *	36.0 *	24.9 *	29.0 *	14.7 *	30.0 *
EB04A-1618	53.0 *	41.8	75.4	99.5 *	68.8 *	80.1 *	40.7 *	83.1 *
EB04A-2022	NA	NA	NA	NA	NA	NA	NA	NA
EB04A-2224	60.2 *	44.7 *	66.5 *	113.0 *	78.2 *	91.0 *	46.3 *	94.4 *
EC02A-0608	25.1	17.7 *	69.9	69.9	43.1	141.0	18.3 *	37.4 *
EC02A-2022	285.0 *	212.0 *	314.0 *	535.0 *	370.0 *	51400.0	3120.0	8490.0
EC03A-0002	62.1	92.4	241.0	241.0	127.0	143.0	15.8 *	41.4
EC03A-1820	283.0 *	211.0 *	313.0 *	533.0 *	387.0	429.0 *	218.0 *	445.0 *
EC03A-2224	274.0 *	203.0 *	302.0 *	514.0 *	355.0 *	148000.0	9040.0	249000.0
EC05A-1012	17.1 *	12.7 *	18.9 *	32.1 *	22.2 *	25.9 *	13.1 *	26.8 *
EC05A-2830	NA	NA	NA	NA	NA	NA	NA	NA
EC06A-0204	17.9 *	13.3 *	19.8 *	33.7 *	23.3 *	27.1 *	13.8 *	28.1 *
EC06A-1820	65.2 *	48.5 *	72.0 *	123.0 *	84.7 *	98.6 *	82.8	272.0
EC06A-2426	NA	NA	NA	NA	NA	NA	NA	NA
EC07A-0406	17.5 *	17.6	58.2	58.2	22.8 *	26.5 *	25.8	115.0
EC07A-1012	51.1 *	38.0 *	102.0	102.0	66.4 *	77.3 *	39.3 *	80.2 *
EC08A-0406	18.2 *	13.5 *	20.1 *	34.2 *	23.6 *	27.5 *	14.0 *	28.5 *
EC08A-1416	21.50 *	16.0 *	23.8 *	40.4 *	27.90 *	32.5 *	16.5 *	33.8 *
EC08A-2224	285.0 *	212.0 *	315.0 *	536.0 *	370.0 *	431.0 *	219.0 *	1610.0

* BELOW DETECTION LIMIT

TABLE A.3 - 4 (continued)
SUMMARY OF CONCENTRATION LEVELS, PPB
SEMI-VOLATILE ORGANIC COMPOUNDS
IITRI POST-TREATMENT SOIL SAMPLES

SAMPLE LOCATIONS	BIS(2-ETHYLHEXYL) PHTHALATE	FLUORANTHENE	FLUORENE	2-METHYL-NAPHTHALENE	NAPHTHALENE	PHENANTHRENE	PYRENE
EA01A-0608	504.0	86.3	11.6 *	22.7 *	25.1 *	42.0	71.5
EA01A-2426	NA	NA	NA	NA	NA	NA	NA
EA02A-1416	201.0	72.1	16.5	31.3 *	34.6 *	53.1	70.6
EA03A-0204	61.1 *	108.0	11.2 *	22.0 *	24.3 *	69.4	45.7
EA03A-1820	12800.0	866.0	379.0	3290.0	888.0	888.0	319.0
EA04A-0002	75.4 *	34.2	13.8 *	27.2 *	30.0 *	25.6 *	26.7
EA04A-2022	7520.0	512.0	34.5 *	67.8 *	74.9 *	74.0	97.4
EA05A-2223	9000.0	510.0	175.0 *	493.0	379.0 *	323.0 *	243.0 *
EA06A-1820	63.8 *	42.9	11.7 *	23.0 *	25.4 *	41.8	64.1
EA07A-1214	192.0	21.9 *	11.5 *	22.6 *	25.0 *	21.3 *	17.5
EA07A-0810	61.2 *	21.3 *	11.2 *	22.1 *	24.4 *	20.8 *	15.6 *
EA08A-1416	167.0	106.0	13.9 *	27.2 *	30.1 *	36.8	107.0
EA08A-2830	NA	NA	NA	NA	NA	NA	NA
TW01A-0608	62.0 *	32.4	11.4 *	22.4 *	24.7 *	26.1	15.8 *
TW01A-1416	632.0	81.9 *	43.1 *	154.0	93.6 *	137.0	101.0
TW01A-2426	NA	NA	NA	NA	NA	387.0 *	NA
TW02A-0406	61.1 *	21.3 *	11.2 *	32.8	49.7	20.8 *	22.6
TW02A-1416	188.0 *	65.5 *	34.5 *	588.0	195.0	132.0	48.0 *
TW02A-2426	NA	NA	NA	NA	NA	NA	NA
TW07A-0406	539.0	38.3	13.3 *	26.0 *	28.8 *	24.5 *	29.4
TW07A-1416	4350.0	177.0	168.0	25.1 *	27.8 *	525.0	683.0
TW07A-2426	NA	NA	NA	NA	NA	NA	NA
EB01A-0002	61.0 *	21.3 *	11.2 *	22.0 *	24.3 *	20.7 *	15.6 *
EB01A-1618	61.0 *	21.3 *	11.2 *	22.0 *	56.7	20.7 *	15.6 *
EB01A-2628	NA	NA	NA	NA	NA	NA	NA
EB02A-0406	61.0 *	21.3 *	11.2 *	22.0 *	24.3 *	20.7 *	15.6 *
EB02A-0810	NA	NA *	NA	NA	NA	NA	NA
EB02A-1214	NA	NA	NA	NA	NA	NA	NA
EB03A-0204	61.1 *	21.3 *	11.2 *	22.0 *	24.3 *	20.8 *	15.6 *
EB03A-1012	68.0 *	23.7 *	12.5 *	24.5 *	27.1 *	23.1 *	17.4 *
EB04A-1618	188.0 *	75.3	34.6 *	67.9 *	75.0	125.0	48.1 *
EB04A-2022	NA	74.5 *	NA	NA	NA	NA	NA
EB04A-2224	718.0	NA	39.3 *	77.1 *	85.2 *	72.7 *	54.7 *
EC02A-0608	460.0	62.1	15.6 *	30.6 *	33.8 *	28.8 *	51.4
EC02A-2022	6020.0	1100.0	707.0	17300.0	11100.0	917.0	401.0
EC03A-0002	72.9 *	203.0	13.4 *	26.3 *	52.2	115.0	102.0
EC03A-1820	20600.0	2040.0	301.0	2610.0	902.0	1570.0	864.0
EC03A-2224	7290.0	993.0	457.0	14800.0	10400.0	508.0	249.0 *
EC05A-1012	60.8 *	21.2 *	11.2 *	21.9 *	24.2 *	20.6 *	15.5 *
EC05A-2830	NA	NA	NA	NA	NA	NA	NA
EC06A-0204	63.7 *	22.2 *	11.7 *	23.0 *	25.4 *	21.6 *	16.3 *
EC06A-1820	8260.0	111.0	42.5 *	83.5 *	92.3 *	151.0	59.2 *
EC06A-2426	NA	NA	NA	NA	NA	NA	NA
EC07A-0406	62.3 *	21.7 *	11.4 *	22.5 *	24.8 *	21.2 *	15.9 *
EC07A-1012	182.0 *	63.3 *	33.4 *	65.5 *	72.4 *	61.7 *	46.5 *
EC08A-0406	209.0	22.5 *	11.9 *	23.3 *	25.7 *	22.0 *	26.4
EC08A-1416	76.4 *	26.7 *	14.0 *	27.6 *	30.5 *	26.0 *	19.6 *
EC08A-2224	7540.0	1060.0	503.0	19400.0	2510.0	452.0	259.0 *

* BELOW DETECTION LIMIT

APPENDIX A.4.

FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating
BORING NO. EA01
JOB NO. 3688
LOGGED BY: BPH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: JEDI
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger 4¼" ID
DRILLERS NAME: Danny Castillo
TOTAL DEPTH (FT.) ~~24.0'~~ 32.0'
TIME STARTED 1555
DATE 1/28/93
TIME COMPLETED 1454
DATE 1/29/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING Wet at ~24'
BACKFILLED, TIME
DATE
WEATHER CONDITIONS Cloudy, lo 50s°F, moderate breeze from SE
SURFACE ELEVATION showers

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
				KS1-EA01-U0406				4
3" SP w/ 1.5" liners	2.0	1.2	Good	@1609		38		5
								6
								7
								8
								9

COMMENTS

4'-6' Clay, silty, w/ gravel, dk br, FILL

#1 liner held for analysis
#2 liner regular analysis

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating	BORING NO.
JOB NO. 3688	E A01

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	150 blows w/ 140 lb hammer 0.6 rec
3" SP w-SS liners	2.0	0.5	Moist	KS1-EA01-U2426		>1000 ppm		5	24'-26' Gravel - fine, ~~poorly sorted~~, wet, w/
								6	free product, clay matrix
								7	
								8	
								9	TD @ ~~29'~~ 32'
								0	
								1	Navarro @ 31'
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

HALLIBURTON NUS
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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating

BORING NO. EA02

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: mobile B-61

DRILLING METHOD: Hollow Stem auger 4¼" ID

DRILLERS NAME: Danny Castillo

TOTAL DEPTH (FT.) 30'

TIME STARTED 0807 DATE 1/30/93

TIME COMPLETED 1045 DATE 1/30/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING Dry

BACKFILLED, TIME DATE

WEATHER CONDITIONS Overcast, cold, upper 30°sF, strong NE wind

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
3' SP w/ S.S. liners	2.0	0.7	Good	KS1-EA02-U810 @ 0842				9

COMMENTS

Gravel at sfc.

Sample falls out of split spoon while hitting spoon to get it open, difficult to unscrew, will discard sample (hit ground) and sample from 10'-12'

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EA02

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	OVA ~~HNU~~SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP w/ SS. liner		0			@ 0849			11
								12
3" SP w/ S.S. liner	2.0	1.4	Good		KSI-EA02-U1214 @ 0908	42		13
								14
								15
								16
								17
								18
								19
								20
								21
								22
								23
								24
								25
								26
								27
								28
								29
								30
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

10'-12' Sample falls out of liner in hole, will auger down to 12' and sample @ 12'-14'

12'-14' Clay, dk brn

#2 liner - regular

#1 liner - held for analysis

19' Driller reports gravel

TD @ 30'

NOTES:

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FIELD LOG OF BORING

SHEET: 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. EA03
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem auger 4¼" ID

DRILLERS NAME: Danny Castillo

TOTAL DEPTH (FT.) 29.5'

TIME STARTED 1238	DATE 1/30/93
TIME COMPLETED 1458	DATE 1/30/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING
Water @ ~24'

BACKFILLED, TIME	DATE

WEATHER CONDITIONS
Overcast, cold, mid 40°F, moderate breeze from NE

SURFACE ELEVATION

COMMENTS

Gravel @ sfc

2.0' - 4.0'

Clay, silty, w/gravel, red to dk brn

#2 Regular

#1 Hold for analysis

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
3" SP w/ S.S. liner	2.0	1.4	Good		KS1-EA03-U0304 @ D253	46		3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EA03

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNU/SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
				no sample				14	
3" SP w/ S.S. liners	2.0	0		K51-EA03-U1416 @ 1312				15	No recovery will try 16'-18'
								16	
3" SP w/ S.S. liners	2.0	1.4	Good	K51-EA03-U1618 @ 1330		>1000ppm		17	#2 liner Regular #1 liner Hold for analysis
								18	16'-18' Clay, silty, w/ gravel, dk brn,
								19	moist, odor - solvent like
								20	
								21	Gravel @ 19'
								22	
								23	
								24	
								25	
								26	
								27	
								28	
								29	TD@ 29.5'
								30	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. EA04
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Augers 4¼" ID
DRILLERS NAME: Danny Castillo
TOTAL DEPTH (FT.) 29.5

TIME STARTED 1542	DATE 1/30/93
TIME COMPLETED 1725	DATE 1/30/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING
~5' of water in borehole

BACKFILLED, TIME	DATE

WEATHER CONDITIONS
Partly Cldy, upper 50s°F, moderate wind from NE

SURFACE ELEVATION

COMMENTS
0.0' - 0.3'
Gravel @ sfc
#2 liner regular MS/MSD
#1 liner held for analysis

0.3' - 18.9' Clay, silty, w/gravel, wires, dk brn, FILL, large gravel up to 2.5" diam in liner

3" SP w/SS liners

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
	2.0	1.1	Good	KS-EA04-0002 1548		120		1
								2
								3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT: RF Heating

JOB NO. 3688

BORING NO. EA04

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNU/SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								11
								12
								13
								14
								15
								16
								17
								18
								19
								20
3" SP w/ S.S. liners	2.0	1.0	Good	KSV-EA04-112022 @ 1623		>1000ppm		21
								22
								23
								24
								25
								26
								27
								28
								29
								30
								-1
								2
								3
								4
								5
								6
								7
								8
								9
								0

Driller reports gravel @ 18.9'

200 blows for 1.0' drive

20'-22' Gravel w/ tan clay matrix
gravel poorly sorted

#1 liner regular - because #2 liner had
#2 liner hold for analysis

~1.5" unfilled res
of recovery was i
bottom shoe - put
it in #2 liner for
hold for analysis

T.D. @ 29.5'

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating

BORING NO. EA05

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger 4¼" ID

DRILLERS NAME: Tommy Castillo

TOTAL DEPTH (FT.) 29.5

TIME STARTED 0917

DATE 2/1/93

TIME COMPLETED 1511

DATE 2/1/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

Water @ ~23.5'

BACKFILLED, TIME

DATE

WEATHER CONDITIONS

Overcast, mid-upper 40's F, slight breeze

SURFACE ELEVATION

COMMENTS

Gravel @ sfc.

0 - 18' Clay, w/ gravel, dk brn, FILL

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EA05

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
								17	
								18	Driller reports gravel @ 18'
								19	
								20	
								21	
								22	
3' SP w/ S.S. liner	2.0	0.8	Poor	KSI-EA05-42224 @ 1001		82 ppm		23	22-24' Gravel, chert-gray, w/ clay, silty
								24	matrix, tan, moist
								25	Strong odor, hydrocarbon odor
								26	
								27	
								28	
								29	
								30	TD @ 29.5'
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. EA06
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow stem auger 4¼" ID

DRILLERS NAME: Tommy Castillo

TOTAL DEPTH (FT.) 29.5'

TIME STARTED 1543	DATE 2/1/93
TIME COMPLETED 1726	DATE 2/1/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING
Dry

BACKFILLED, TIME	DATE

WEATHER CONDITIONS
Partly cldy, lo 60°F, slight breeze from SE

SURFACE ELEVATION

COMMENTS

Gravel @ sfc.
0.0' - 0.2'

0.2' - 18' Clay, w/ gravel, dk brn, FILL

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EA06

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
					KSI-EA06-U1820D			17	Gravel @ 18.0'
					KSI-EA06-U1820			18	
3" SP w/ SS liners	0.7	0.7	Poor		KSI-EA06 @ 1620	>1000ppm		19	150 blows for 8" drive
								20	#1 liner regular
								21	4oz glass jar for duplicate
								-22	
								23	18.0' - 18.8' Gravel, chert, tan, clay
								24	matrix, tan
								25	
								26	
								27	
								28	
								29	
								30	TD @ 29.5'
								-1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET: 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. EA07
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger 4¼" ID

DRILLERS NAME: Manny Castillo

TOTAL DEPTH (FT.) 29.5'

TIME STARTED 0741	DATE 2/2/93
TIME COMPLETED 0932	DATE 2/2/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING
Water @ 21' below gr.

BACKFILLED, TIME	DATE

WEATHER CONDITIONS
Overcast, mid 50's F, slight SE breeze

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	0 - 17' Clay, slightly silty, w/ gravel, dk brn, FILL
								2	
								3	
								4	
								5	
								6	
								7	
								8	
3" SP w/ SS. liners	2.0	0.8	Fair		KS1-EA07-u0810 @ 0753	600 ppm		9	Clay, sl silty, w/ gravel, dk brn FILL #1 liner regular 4oz glass jar - hold for analysis
								10	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Hastings

JOB NO. 3688

BORING NO. EA07

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
					KS1- EA07 -UP14			11	
								12	
3" SP w/SS liner	2.0	1.2	Good		@0811	800ppm		13	#1 liner [illegible]
								14	#2 liner hold for analysis
								15	
								16	12-14 Clay, sl silty, w/gravel,
								17	dk brn, FILL
								18	
								19	
								20	
								21	
								22	
								23	
								24	
								25	
								26	
								27	Driller reports gravel @ ~17'
								28	
								29	
								30	
								31	
								32	
								33	Driller reports more gravel @ 23'
								34	
								35	TD at 29.5'
								36	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating

BORING NO. EA08

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: mobile B-61

DRILLING METHOD: Hollow Stem Auger 4¼" ID

DRILLERS NAME: Danny Castillo

TOTAL DEPTH (FT.) 29.5

TIME STARTED 1007

DATE 2/2/93

TIME COMPLETED 1223

DATE 2/2/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

Water @ 25' below sfc

BACKFILLED, TIME

DATE

WEATHER CONDITIONS

Overcast, mid 50s°F, slight breeze from SE

SURFACE ELEVATION

COMMENTS

gravel at sfc

0'-18.5' Clay, dk brn, w/ some gravel

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating	BORING NO. EA08
JOB NO. 3688	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
3" SP w/ S.S. liners	2.0	1.3	Good		KS1-EA08-U1416 @ 1031	240 ppm		5	# 2 Regular
								6	# 1 Hold for analysis
								7	14-16 Clay, w/ gravel dk brn
								8	
								9	Driller reports gravel @ 18.5'
								20	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
3" SP w/ S.S. liners	2.0	1.3	Good		KS1-EA08-U2830 @ 1126	260 ppm		9	Drove 1.0' in 105 blows
								30	28-30' gravel - chert, lt brn clay matrix
								1	
								2	# 2 liner regular
								3	# 1 liner duplicate
								4	4 oz glass jar hold for analysis
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating
BORING NO. EB01
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: JEDI
DRILL RIG TYPE: mobile B-61
DRILLING METHOD: Hollow Stem Auger 4 1/4" ID
DRILLERS NAME: Larry Taylor
TOTAL DEPTH (FT.) 28.00
TIME STARTED 1511
DATE 2/5/93
TIME COMPLETED 1700
DATE 2/5/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING
Water in hole
BACKFILLED, TIME
DATE
WEATHER CONDITIONS
Partly Cldy, cold, lo 40s F, strong wind from NE
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP w/ S.S. liners	2.0	1.6	Good	KS1-EB01-40002 @ 1517				1
								2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

Gravel @ sfc
Clay, orange brn, becoming dk brn w/ gravel, FILL
#1,3 liners - held
#2 liner regular

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT AF Heating

JOB NO. 3688

BORING NO. EB01

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
				KSI-EB01-U1214				12	3, 1# liners - held
3" SP w/ SS liners	2.0	1.7	Good	@ 1534				13	#2 regular
								14	
								15	12'-14' Clay, sl. silty, dk brn, w/ fragment
								16	of metal + gravels
								17	
								18	
								19	
								20	19.5' Gravel driller reports
								21	
								22	
								23	
								24	
								25	
				KSI-EB01-U2628				26	
3" SP w/ SS liners	2.5	0.5	Fair	@ 1609				27	Drove 1.5' for 100 blows
								28	26'-28' Gravel, clay matrix, tan,
								29	wet, sheen on chert frag., hydrocarbon odor
								30	#1 liner - regular
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET: 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: EB02
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: JEDI
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow stem auger 4¼" ID
DRILLERS NAME: Larry Castillo
TOTAL DEPTH (FT.) 28
TIME STARTED 1722
DATE 2/5/93
TIME COMPLETED 0931
DATE 2/6/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING
BACKFILLED, TIME
DATE
WEATHER CONDITIONS: Partly Cldy, cold low 40's F, wind from NW
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	Gravel @ sfc
								2	
								3	
3" SP w/ SS liners	2.0	0.6	Fair		KS1-EB02-U0406 @ 1731			4 5	4-6' clay, dk brn, wood frags gravel, clay very stiff 3 glass jars due to void in liner #1 jar - organic #2,3 jars - hold
								6 7	
3" SP w/ SS liner	2.0	0.6	Fair		KS1-EB02-U0810 @ 1742			8 9 10	8-10' same as 4-6' #1 liner organic 1 glass jar hold

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E B02

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								11
					K51-EB02-U1214			12
	2.0	1.2			①	32		13
				1751				14
								15
								16
								17
								18
								19
								20
								21
								22
								23
								24
								25
								26
								27
								28
								9
								0
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

#2 liner regular

#1 liner duplicate

4 oz glass jar - hold

12'-14'

Clay, dk brn, strong hydrocarbon odor

19.0' Gravel according to driller

TD @ 28'

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating
BORING NO. EB03
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: JEDI
DRILL RIG TYPE: mobile B-61
DRILLING METHOD: Hollow Stem Auger 4¼ ID
DRILLERS NAME: Danny Castillo
TOTAL DEPTH (FT.) 25.5'
TIME STARTED 1342
DATE 2/4/93
TIME COMPLETED 1442
DATE 2/4/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING
BACKFILLED, TIME
DATE
WEATHER CONDITIONS
Overcast, cool, lo 50s°F, strong wind from N
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
3" SP w/ S.S. liners	2.0	1.5	Good		KS1-EB03-40204 @ 1348			2
								3
								4
								5
								6
								7
								8
								9

COMMENTS

Gravel @ sfc.

2'-4' Clay FILL
#1 liner - regular
4oz glass jar - hold for analysis

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EB03

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
3" SP w/ SS liner	2.0	1.1	Good		KST EB03 @ 1403		41012	11	
								12	10'-12' Clay, silty, dk brn, w/ gravel, FILL
						280		13	
								14	
								15	#2 liner - regular
								16	#1 liner - hold for analysis
								17	
								18	
								19	19.8' Gravel
								20	
								21	
								22	
								23	
								24	
								25	
								26	TD @ 25.5'
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. EB04
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: JEDI	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem augers 4¼"	
DRILLERS NAME: Danny Castillo	
TOTAL DEPTH (FT.) 28	
TIME STARTED 1054	DATE 2/6/93
TIME COMPLETED	DATE 2/6/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING Wet at 22'	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Clear, cold, mid 40's F, strong wind from NW	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

Gravel @ sfc.

0-17.5' Clay, silty, w/ gravel, dk brn

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Testing

JOB NO. 3688

BORING NO. EB04

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~ SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								11
								12
								13
								14
					KS1-EB04-41618			15
								16
3"SP w/SS liners	2.0	0.4	Good		@ 1120			17
								18
								19
					KS1-EB04-42022			20
3"SP w/SS liners	0.8	0.8	Good		@ 1136			21
					KS1-EB04-42224			22
3"SP w/SS liners	0.8	0.8	Good		@ 1157			23
								24
								25
								26
								27
								28
								9
								0
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

16'-18' Clay, dk brn

hydrocarbon odor

#1 liner - regular

#2 liner - hold - due to 0.4' recovery

packed rest from shoe

17.5' Gravel driller reports

20'-22' drove 10" in 100 blows

sample wet @ bottom, strong hydrocarbon odor

22'-24' 100 blows for 10"

#1 liner - regular

rest of sample was rock, large rock in bottom of shoe

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PROJECT RF Heating	BORING NO. EC01
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger 4¼" ID
DRILLERS NAME: Danny Castillo
TOTAL DEPTH (FT.) 29.5

TIME STARTED 1346	DATE 2/2/93
TIME COMPLETED 1513	DATE 2/2/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

BACKFILLED, TIME	DATE

WEATHER CONDITIONS
Overcast, mid 50°s F, no breeze

SURFACE ELEVATION

COMMENTS
Gravel @ sfc.
(No samples taken at EC01), straight augering
0 - 19.5' Clay, dk brn, w/
gravel, FILL

PLAN

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EC01

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
								17	
								18	
								19	Gravel @ 19.5' - 29.5', chert gravel,
								20	clay matrix, lt brn to tan
								21	
								22	
								23	
								24	
								25	
								26	
								27	
								28	
								29	
								30	
								1	TD at 29.5'
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET: 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. EC02
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem auger 4¼" ID

DRILLERS NAME: Danny Castillo

TOTAL DEPTH (FT.) 29.5'

TIME STARTED 1535	DATE 2/2/93
TIME COMPLETED 1727	DATE 2/2/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING
Water @ ~23'

BACKFILLED, TIME	DATE

WEATHER CONDITIONS
Overcast, mid 50°s F, no breeze

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	
								2	
								3	
								4	
								5	
				KSF-EC02-40608				6	6-8' clay, w/ gravel dk brn
3" SP w/SS liner	2.0	1.8	Good	@ 1553		110		7	#1 liner hold for analysis #2 liner [illegible] 4 OZ glass jar hold for analysis
								8	
								9	
								10	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EC02

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP w/ SS liner	2.0	0.3	Poor	KS1-EC02-U202 @ 1624		>1000ppm		20–22

DEPTH (FEET): 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0

20.0'–20.2' Clay, w/ gravel, dk brn, contact w/ gravel @ 20.2'

20.2'–29.5 Gravel, clay matrix, tan

2 glass 4OZ jars

\# 2 jar hold for analysis - gravel

\# 1 jar regular (clay; dk brn)

TD @ 29.5'

NOTES:

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FIELD LOG OF BORING

SHEET: 1 OF 2

PLAN

PROJECT: RF Heating

BORING NO.: EC03

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger

DRILLERS NAME: Ricky Lane

TOTAL DEPTH (FT.) 29.5

TIME STARTED 0827 DATE 2/3/93

TIME COMPLETED 1124 DATE 2/3/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

BACKFILLED, TIME DATE

WEATHER CONDITIONS: Light rain, mid 50°sF, slight SE breeze

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP w/ S.S. liners	2.0	2.0	Good	X51-EC03-0002 @ 0835				1
								2
								3
								4
								5
								6
								7
								8
								9

COMMENTS

Gravel at sfc

0'-2' Clay, dk brn

4 full liners

#2 - regular

#1,3,4 liners - hold for analysis

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EC03

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	13'-14' Gravel, clayey
								14	14'-19.8' clay, dk brn, w/ gravel
								15	
								16	
								17	
								18	18'-19.8' Clay, silty, w/ gravel, dk brn
2"SP	2.0	1.6	Good		K51-EC03-U1820 @ 0901			19	strong hydrocarbon odor from sample
								20	#2 liner - regular
								21	#1,3 liner - hold for analysis
								22	19.8' Driller reports gravel
3"	0.9	0.9			K51-EC03-U2224 @ 1018			23	
								24	22'-24' Gravel, chert, clay matrix, lt b
								25	#1 liner - regular
								26	4oz glass jar - hold for analysis
								27	
								28	
								29	
								30	TD at 29.5'
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. EC04
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: JEDI	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem auger 4¼" ID	
DRILLERS NAME: Danny Castillo	
TOTAL DEPTH (FT.)	
TIME STARTED 1245	DATE 2/3/93
TIME COMPLETED 1417	DATE 2/3/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Overcast, showers, mid 50°F	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								10	

COMMENTS

No samples augering to TD

0-19.8' Clay, silty, w/ gravel, dk brn, FILL

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT R F Heating

JOB NO. 3688

BORING NO. EC04

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
								17	
								18	
								19	
								20	Gravel at 19.8'
								21	
								22	
								23	
								24	
								25	
								26	
								27	
								28	
								29	TD @ 29.5'
								30	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. EC05
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: JEDI	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem Auger 4¼" ID	
DRILLERS NAME: Danny Castillo	
TOTAL DEPTH (FT.) 29.5'	
TIME STARTED 1430	DATE 2/3/93
TIME COMPLETED 1331	DATE 2/4/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING Water in hole	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Overcast, showers, mid 50's F	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

Resume drlg @ 1026 on 2/4/93

@ 4' Construction rubble in Fill, concrete chunks, w/ red paint, concrete anchors, asphalt, soft drink can, liner material, wire,

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EC05

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	OVA ~~HNU~~SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP w/ 5.5 liner	2.0	1.5	Good		KSI-EC05-41012 @ 1044	600		11
								12
								13
								14
								15
								16
								17
								18
								19
								20
								21
								22
								23
								24
								25
								26
								27
3" SP w/ 5.5 liner	1.0	0.4	Poor		KSI-EC05-412830 @ 1126			28
								29
								30
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

#2 liner regular

#1, 3 liners - hold for analysis, put ~0.1' of soil from shoe into #3 liner to top off

19.9' Gravel, clay matrix start

Drove 1.0' after ~90 blows

28'-30' Gravel w/ clay matrix, wet, hydrocarbon odor, no OVA rdg - strong wind

TD @ 29.5'

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. EC06
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: JEDI	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem Auger 4¼" ID	
DRILLERS NAME: Donny Castillo	
TOTAL DEPTH (FT.) 29.5	
TIME STARTED 1507	DATE 2/4/93
TIME COMPLETED 1638	DATE 2/4/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Overcast, cool, lo 50s °F, strong wind from NE	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
3" SS w/ brass liners	2.0	1.3	Good		K51-EC06-110204 @ 1515			2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

Gravel @ sfc.

Clay, w/gravel, dk brn, FILL
#2 liner - regular
#1 liner - Hold for analysis

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EC06

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
								17	
								18	
3" SP w/SS liners	2.0	0.8	Fair	KSI-EC06-U1820				19	
				@ 1535		>1000 ppm		20	#1 liner
								21	1 glass jar
								22	18-20' Clay, w/gravel dk brn FILL
								23	strong hydrocarbon odor
								24	Gravel @ 20' - driller reports
3" SP w/SS liner	1.5	0.6		KSI-EC06-U2426				25	
				@ 1553		240 ppm		26	24'-26' Gravel, clay matrix, tan, chert
								27	gravel, poorly sorted, wet, strong hydrocarbon
								28	odor
								29	#1 liner regular
								30	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating

BORING NO.: EC07

JOB NO.: 3888

LOGGED BY: BDH

PROJ. MGR.: CFB

EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger

DRILLERS NAME: Danny Castillo

TOTAL DEPTH (FT.)

TIME STARTED: 0720 DATE: 2/15/94

TIME COMPLETED: 0900 DATE: 2/15/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

BACKFILLED, TIME: DATE:

WEATHER CONDITIONS: Showers, upper 40°F, N wind

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	
								2	0 – 19' Clay, silty, w/ gravel, dk brn
								3	
								4	4'-6' Clay, silty, w/gravel, dk brn, FILL
	2.0	1.3	Good	KS1-EC07-40406D KS1-EC07-40406 @ 0736				5	#2 – regular #1 liner – duplicate
								6	4oz glass jar – held for analysis
								7	
								8	8'-10' Clay, dk brn #1 liner – regular
	2.0	0.6		KS1-EC07-40810				9	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EC07

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
								17	
								18	
								19	Gravel at 19'
								20	
								21	
								22	
								23	
								24	
								25	
								26	
								27	
								28	
								29	TD at 29.5'
								30	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

HALLIBURTON NUS
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FIELD LOG OF BORING

SHEET: 1 OF 2

PLAN

PROJECT: RF Heating

BORING NO.: EC08

JOB NO.: 3688

LOGGED BY: BDH

PROJ. MGR.: CFB

EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger

DRILLERS NAME: Danny Castillo

TOTAL DEPTH (FT.)

TIME STARTED: 0914 DATE: 2/5/94

TIME COMPLETED: 1458 DATE: 2/5/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING: Wet @ 22'

BACKFILLED, TIME: DATE:

WEATHER CONDITIONS: Showers, upper 40°F, N wind

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	
								2	
								3	
				K51-EC08-U0406				4	4'-6' Clay, silty, w/ gravel, dk br to tan at bottom
	2.0	1.4		@ 0922				5	
								6	#2 liner - regular #1 liner - hold for analysis 4oz jar - " "
								7	
								8	
								9	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT AF Testing

JOB NO. 3688

BORING NO. EC08

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	14'-16' Clay, silty, w/ gravel, dk br
	2.0	1.1			KSI-EC08-U1416 @ 0950			15	
								16	
								17	#2 liner - regular
								18	#1 liner - hold for analysis
								19	
								20	Driller reports gravel at 19'
								21	
								22	
	1.3	1.7			KSI EC08-U2224 @ 1021			23	22'-24' Gravel, clay matrix, tan, wet
								24	hydrocarbon odor
								25	#2 liner - regular
								26	#1 liner - hold
								27	
								28	
								29	
								30	TD at 29.5'
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. TW01
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: JEDI	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem Auger 4¼ ID	
DRILLERS NAME: Danny Castillo	
TOTAL DEPTH (FT.) 35.5'	
TIME STARTED 1504	DATE 1/25/93
TIME COMPLETED 0943	DATE 1/26/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING Wet	
BACKFILLED, TIME	DATE

WEATHER CONDITIONS

Fair, cold, upper 40s°F, moderate breeze from NE

SURFACE ELEVATION

COMMENTS dugging down to predetermined depths per SAP for sampling w/ 3" split spoons and S.S. liners

0 - 0. Gravel backfill at sfc.

0. - 19.5' Clay, silty, w/ gravel, med. to dk brn.

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
3" S.P. w/ S.S. liners	2.0	0.8	Fair	KS1-TW01-U040i @ 1733		12		5
				#1 liner-regular				6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. TW01

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	[illegible]SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
				K51-TW01-U1416				13	
								14	
3" S.P. w/ SS. liner	2.0	1.8	Good	@ 1751		300 max.		15	14'-16' Clay, silty, w/ gravel, med. to dk brn
								16	
				#2 liner - regular				17	
				#3 liner - duplicate				18	
				#1 liner - hold for analysis				19	19.5' Gravel
								20	
								21	
								22	
				K51-TW01-U2426				23	24'-26' Gravel, chert, clay matrix
								24	
3" SP. w/ SS liners	2.0	0.5	Poor		@ 1825			25	100 blow counts for 0.5' recovery
								26	
				#1 liner - regular				27	Cuttings wet, odor
								28	
								29	
								30	
								31	31' Driller reports Navarro Clay
								32	@ 31'
								33	
								34	
								35	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. TW02
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger 4¼ ID

DRILLERS NAME: Danny Castillo

TOTAL DEPTH (FT.) 35.5

TIME STARTED 1412	DATE 11/26/93
TIME COMPLETED 1633	DATE 11/26/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING 24'

BACKFILLED, TIME	DATE

WEATHER CONDITIONS Fair, mild, lo-60s°F, wind slight breeze from NW

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
3" SP w/ 2.5' S.S. liners	2.0	1.2	Good	KS1-TW02-00406 @ 14				5
								6
								7
								8
								9
								10

COMMENTS auger to 4' and sample 4-6' w/ 3" SP and S.S. liners

0-0.3' Gravel @ sfc

0.3'-20' Clay, silty, w/ gravel, dk brn, mod. stiff, plastic, Fill

auger leads off to left a few inches according to driller,

#1 Hold for analysis

#2 Regular sample

20-30 ppm @ borehole, <1 ppm breathing zone

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT. RF Heating	BORING NO. TW02
JOB NO. 3688	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	14-16 Clay, silty w/ gravel, dk. brn., mod.
3" SP w/SS liner	2.0	1.3	Good	KSI-TW02-U1416 @ 1448		70		15	firm, plastic
								16	#1 Hold for analysis
								17	#2 Regular
								18	
								19	wind shifts, from SE
								20	
								21	Gravel @ 20'
								22	
								23	
								24	Water @ 24'
									50 blows for 0.5', 100 blows for 0.8', stop @
3" SP w/SS liner	2.0	0.6		KSI-TW02-U2426 @ 1517		>1000ppm wet		25	24'-26' Gravel (chert), clayey, silty,
								26	red brn., wet, strong odor - hydrocarbon /
								27	solvent like
								28	
								29	
								30	
								31	Navarro Clay @ 31.0'
								32	
								33	
								34	
								35	TD @ 35.5'
								36	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: TW03
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: JEDI
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger 4¼" ID
DRILLERS NAME: Danny Castillo
TOTAL DEPTH (FT.) 35.0'
TIME STARTED 0845
DATE 1/28/93
TIME COMPLETED 1050
DATE 1/28/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING
BACKFILLED, TIME
DATE
WEATHER CONDITIONS: Cloudy, cool; upper 40s °F, slight breeze, wind from SE
SURFACE ELEVATION
COMMENTS

Gravel @ sfc

0 – 17.5' Clay, silty, w/ gravel, dk. brn, FILL

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT	BORING NO.
RF Heating	TW03
JOB NO. 3688	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
								17	
								18	gravel @ 17.5'
								19	
								20	
								21	
								22	
								23	
								24	
								25	
								26	
								27	
								28	
								29	
								30	Navarro @ 31'
								31	
								32	
								33	
								34	
								35	Total depth 35'
								6	pushed split spoon 35-36' for
								7	SIAC for grain size analysis of
								8	Navarro Clay
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating

BORING NO.: TW04

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Augers 4¼" ID

DRILLERS NAME: Danny Castillo

TOTAL DEPTH (FT.) 35

TIME STARTED 1324

DATE 1/27/93

TIME COMPLETED 1502

DATE 1/27/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

Water @ ~20' below sfc

BACKFILLED, TIME

DATE

WEATHER CONDITIONS

Fair, upper 50s°F, wind from SW, slight breeze

SURFACE ELEVATION

COMMENTS no samples

0 - 0.0' Gravel, fill

0. - 18.5' Clay, w/ gravel; dk brn, FILL

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. TW04

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
								17	
								18	Driller reports gravel @ 18.5'
								19	
								20	
								21	Wet @ 20.0' noticeable odor, 10ppm in
								22	breathing zone, 90ppm @ borehole
								23	
								24	
								25	
								26	
								27	
								28	
								29	
								30	
								31	Driller reports Navarro Clay @ 31'
								32	
								33	
								34	
								35	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating

BORING NO. TW05

JOB NO. 3688

LOGGED BY: BPH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger 4¼" ID

DRILLERS NAME: Danny Castillo

TOTAL DEPTH (FT.) 35

TIME STARTED 1532 DATE 1/27/93

TIME COMPLETED 1726 DATE 1/27/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

Water @ ' below sfc

BACKFILLED, TIME DATE

WEATHER CONDITIONS

Fair; upper 50s°F, moderate breeze from SE

SURFACE ELEVATION

COMMENTS No samples

0-0.' Gravel fill @ sfc

0 - 17' Clay, silty, w/ gravel med. to dk brn, FILL

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Testing
JOB NO. 3688
BORING NO. TW05

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
								17	Driller reports gravel @ 17'
								18	
								19	
								20	
								21	
								22	
								23	
								24	
								25	
								26	
								27	
								28	
								29	
								30	Driller reports
								31	Navarro Clay @ 31.3'
								32	
								33	
								34	
								35	TD @ 35'
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. TW06
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger 4¼" ID

DRILLERS NAME: Donny Castillo

TOTAL DEPTH (FT.) 35.0'

TIME STARTED 0907	DATE 1/27/93
TIME COMPLETED 1132	DATE 1/27/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING 24.5'

BACKFILLED, TIME	DATE

WEATHER CONDITIONS slight breeze from S

SURFACE ELEVATION

COMMENTS

Gravel at sfc

0 - 10.5' clay, dk brown w/ gravel ; FILL

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. TW06

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	10.5' - 19' Clay, dk. brown, FILL
								12	
								13	
								14	
								15	
								16	
								17	17' Hg air 300ppm @ borehole, <1ppm
								18	breathing zone
								19	
								20	Gravel @ 19'
								21	
								22	
								23	
								24	
								25	Driller reports water @ 24.5'
								26	
								27	
								28	
								29	Driller reports
								30	Navarro Clay @ 30'
								31	
								32	
								33	
								34	
								35	TD @ 35'
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: TW07
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: JEDI
DRILL RIG TYPE: Mobile B 61
DRILLING METHOD: Hollow Stem Auger 4¼" ID
DRILLERS NAME: Tommy Castillo
TOTAL DEPTH (FT.) 30
TIME STARTED 1232
DATE 1/28/93
TIME COMPLETED 1515
DATE 1/28/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING
BACKFILLED, TIME
DATE
WEATHER CONDITIONS
Cloudy, upper 40s°F to lo 50s°F light Breeze from S.
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	Gravel at sfc.
								2	
								3	
								4	
3" SP w/SS liner	2.0	0.9	Good	KSI-TW07-0406 @ 1258		120		5	4'-6' Clay, silty, w/ gravel, red str dk bn FILL
								6	
								7	
								8	
								9	
								10	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Keating

JOB NO. 3688

BORING NO. TW07

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								11
								12
								13
								14
3" SP w/ SS. liner	2.0	1.4	Good	KS1-TW07-U1416 @ 1321		>1000ppm		15
								16
								17
								18
								19
								20
								21
								22
								23
								24
3" SP w/ SS. liner	2.0	0.6	Poor	KS1-TW07-U2426 @ 1345		>1000ppm		25
								26
								27
								28
								29
								30
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

14'-16' Clay, silty, w/ gravel, dk br,
Long piece of wire in Fill

#1 Duplicate
#2 Regular

Driller reports gravel @ 19'

24'-26' Gravel, lt brn clay matrix

#1 liner 150 blows w/ 140 lb
hammer drove split
spoon ~7"

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 1

PLAN

PROJECT RF Hatting Site S-1	BORING NO. DW01
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61 ID pilot hol

DRILLING METHOD: Hollow stem auger 3,

DRILLERS NAME: Larry Taylor 10" ID ream-ou

TOTAL DEPTH (FT.) 42.5 14" OD

TIME STARTED 0843	DATE 1/22/93
TIME COMPLETED	DATE 1/24/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

BACKFILLED, TIME	DATE

WEATHER CONDITIONS

Fair, cold, lo 40's F, strong NE wind

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

0'–0.3' Crushed stone, gravel

0.3'– ~19' Clay, gravelly; dark to med. brn, abund gravel; mod. firm roots at sfc, sl. moist; FILL

driller reports gravel @ ~19'

Navarro Clay at 34'

HALLIBURTON NUS
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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. DW02
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: JEDI	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem Auger	
DRILLERS NAME: Larry Taylor	
TOTAL DEPTH (FT.) 40.0	
TIME STARTED 1148	DATE 1/24/93
TIME COMPLETED 1528	DATE 1/25/93
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Fair, mid 40 to 50°F, strong wind from NE	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
3" SP w/ 2.5" S.S. liners	2.0	0.8	Poor					3
								4
								5
								6
								7
						<1		8
								9

COMMENTS

3'-5' Clay, gravelly, red to dk brn, firm

<1 ppm soil cuttings

20-30 ppm inside auger

Driller reports abundant gravel downhole, rig vibrating heavily

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT AF Testing

JOB NO. 3668

BORING NO. DW02

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
3" SP w/2.5" SS liners	2.0	1.6	Good			18ppm		1	
			1CS1-			@ sample		12	
			DW02- U1012					3	12-19
								4	Gravel, clayey + silty, lt brn to tan,
								5	sl moist
								6	
								7	
								8	19-21
					up to			9	Clay, gravelly or gravel w/ more clay
					4ppm			20	
					cuttings			1	
								2	21-32 Gravel, clayey, Clay
					up to 500ppm			3	light brn to tan, gravel generally sorted
		<1ppm			@ borehole when			4	subrounded to angular, cobble size to
		breathing zone			changing augers @ 25'			25	granular
								6	
								7	
								8	
								9	
								30	
								1	Driller reports Navarro Clay @ 32'
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	TD @ 40'
								40	

NOTES:

HALLIBURTON NUS
Environmental Corporation

HALLIBURTON NUS
Environmental Corporation

FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. DW03
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: JEDI

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger

DRILLERS NAME: Larry Taylor

TOTAL DEPTH (FT.) 35'

TIME STARTED 0921	DATE 1/27/93
TIME COMPLETED 1741	DATE 1/28/93

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

BACKFILLED, TIME	DATE

WEATHER CONDITIONS
Fair, cold lo 30°F, slight S. breeze

SURFACE ELEVATION

COMMENTS

0 - 0. Gravel fill @ sfc.

0 - 7.0 Clay, silty, w/ gravel, red to dk brn, mod. firm, plastic.

7.0' - 35' Gravel, chert, w/ clay, silt matrix, dk brn.

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. DW03

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
								15	15'-31' Gravel, chert, lt br
								6	clay matrix
								7	
								8	
								9	
								20	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								30	
								31	31' Driller reports Navarro Clay
								2	
								3	
								4	
								35	TD @ 35' in Navarro Clay
								6	
								7	
								8	
								9	
								0	

NOTES:

HALLIBURTON NUS
Environmental Corporation

APPENDIX A.5.

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
4/3/93	15:30	70	66	90	12	17	170	0.4	65		100
	16:35										
	18:25	70	66	90	13	17	170	0.6	65		100
	20:25	70	66	85	13	16	170	0.5	65		100
	23:10	70	66	85	13	18	170	0.4	68		100
4/4/93	1:30	70	66	88	13	18	180	0.6	60		110
	4:30	70	66	87	13	18	180	0.6	60		110
	6:25	70	66	86	13	18	180	0.5	60		110
	9:27	70	67	85	13	18	180	0.5	66		110
	11:45	70	68	90	13	18	180	0.5	66		110
	14:30	70	67	91	13	17	180	0.5	80		110
	16:30	70	66	90	13	18	180	0.6	80		110
	18:40	70	68	90	13	17	180	0.5	80		110
	20:30	70	67	90	12	16	180	0.4	65		110
	22:30	70	67	88	12	17	180	0.5	65		110
4/5/93	0:32	70	67	88	12	16	180	0.6	70		110
	2:25	70	67	91	12	16	180	0.7	70		110
	4:29	70	67	90	12	16	180	0.7	67		110
	6:27	70	67	90	11	16	180	0.7	67		110
	8:30	70	67	93	11	16	180	0.5	70		110
	10:30	65				16					
	11:40	75	78	105	11	16	190	0.6	90	56	115
	13:35	70	78	107	11	16	190	0.5	90	70	120
	15:40	70	79	115	10	15	190	0.5	110	72	120
	17:30	65	79	120	10	15	190	0.5	100	74	125
	19:30	65	79	120	10	15	190	0.4	90		125
	23:30	70	78	111	10	15	190	0.6	81		120
4/6/93	1:30	70	78	111	10	15	180	0.6	84		110
	3:30	70	78	112	10	14	190	0.6	84		120
	5:30	70	78	113	10	14	190	0.5	85		120
	7:30	70	78	115	10	14	180	0.5	90	56	110
	9:35	70	78	115	10	15	180	0.6	90	70	110
	11:30	70	78	116	10	15	180	0.5	90	72	110
	13:28	71	79	120	11	14	179	0.5	91	74	108
	16:00	71	78	120	10	14	180	0.4	90	74	109
	18:00	70	79	120	10	14	180	0.5	90	70	110
	20:00	70	78	120	9	14	180	0.5	90	68	110
	22:00	70	79	119	9	14	190	0.5	85	68	120
4/7/93	0:01	70	78	119	9	14	180	0.6	91	67	110
	1:55	70	78	119	9	14	180	0.6	91	67	110
	4:00	70	78	119	8	14	190	0.5	94	67	120
	6:05	70	78	120	9	14	180	0.5	94	66	110
	8:00	70	79	121	9	14	180	0.5	100	70	110
	10:00	70	78	121	9	14	180	0.6	100	72	110
	12:02	69	78	120	10	14	180	0.5	100	62	111
	13:55	70	78	130	12	17	190	0.6	110	80	120
	15:55	70	78	139	12	17	190	0.6	115	82	120
	18:00	70	78	140	12	17	180	0.5	110	74	110
	20:00	70	78	135	12	16	190	0.5	110	65	120
	22:00	69	79	135	12	16	185	0.6	110	64	116
4/8/94	0:02	70	78	134	12	16	190	0.5	100	62	120
	2:00	70	78	133	12	16	190	0.5	105	62	120
	4:00	70	78	131	12	15	190	0.5	104	63	120
	6:00	70	77	129	12	16	180	0.5	103	62	110
	8:00	70	78	129	12	15	190	0.6	103	62	120

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	10:00	70	78	130	12	16	190	0.6	105	74	120
	12:00	65	78	137	12	16	190	0.6	110	82	125
	14:00	65	78	140	12	16	190	0.6	110	86	125
	16:00	70	78	140	12	16	190	0.6	115	82	120
	18:00	70	78	140	11	17	190	0.5	110	70	120
	20:00	70	78	138	11	15	190	0.5	115	68	120
	22:00	70	78	140	12	17	190	0.6	110	62	120
4/9/94	0:01	70	78	135	11	15	190	0.6	107	56	120
	2:00	70	78	132	11	15	180	0.6	104	53	110
	4:00	70	78	131	11	15	190	0.6	104	50	120
	6:00	70	78	131	11	15	190	0.6	105	48	120
	8:00	70	78	131	11	15	190	0.6	105	72	120
	10:00	70	78	130	11	15	190	0.5	110		120
	12:05	70	78	135	11	15	190	0.5	110		120
	14:00	70	78	142	12	16	195	0.4	120	95	125
	16:00	70	78	145	12	16	195	0.4	118		125
	18:00	70	78	146	11	16	195	0.4	118		125
	20:00	70	78	147	11	16	190	0.4	118	78	120
	22:00	75	78	145	11	16	190	0.4	115	70	115
4/10/94	0:01	75	78	145	11	15	190	0.5	113	57	115
	2:00	75	78	142	11	15	180	0.5	113	52	105
	4:04	75	78	139	11	15	180	0.5	113	49	105
	6:00	75	78	139	11	15	193	0.5	113	48	118
	8:00	70	78	139	11	15	195	0.4	120	70	125
	10:00	70	78	140	11	15	195	0.4	125		125
	12:00	70	78	143	11	15	195	0.4	125		125
	14:00	70	78	147	11	15	195	0.4	130		125
	16:00	70	78	150	11	15	195	0.4	125	88	125
	18:00	70	78	151	11	15	195	0.4	121		125
	20:00	70	78	151	11	15	195	0.4	120		125
	22:00	70	78	149	11	15	190	0.4	115		120
4/11/93	0:01	70	78	145	11	15	180	0.5	117	68	110
	2:00	70	78	143	11	15	180	0.5	117	68	110
	4:00	70	78	143	11	15	180	0.4	117	64	110
	6:00	70	78	144	10	15	180	0.4	120	62	110
	8:00	70	78	145	10	15	190	0.4	120	59	120
	10:00	70	78	146	10	15	190	0.4	125	72	120
	12:00	70	78	150	10	15	190	0.4	130	76	120
	14:00	70	78	155	11	15	190	0.4	130		120
	16:00	70	78	154	12	15	190	0.5	130		120
	18:00	69	78	155	12	15	195	0.4	125	82	126
	20:00	66	78	145	10	15	195	0.4	115	78	129
	22:00	68	77	145	11	15	190	0.5	120	76	122
4/12/93	0:01	64	77	142	11	15	180	0.4	111	69	116
	2:00	63	78	142	11	15	180	0.4	113	68	117
	4:00	65	78	143	11	15	180	0.4	115	68	115
	6:00	65	78	144	10	15	185	0.4	115	67	120
	8:00	65	78	145	10	15	190	0.4	120		125
	10:00	65	78	145	10	15	190	0.3	125		125
	12:00	65	78	145	10	15	190	0.4	125	78	125
	14:00										
	16:00	71	89	155	10	14	197	0.4	125	88	126
	18:00	71	88	155	11	14	195	0.4	120	82	124
	20:00	71	88	150	10	14	195	0.4	120	78	124
	22:00	70	88	145	10	14	200	0.4	120	72	130

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
4/13/93	0:01	70	88	146	10	14	190	0.4	116	70	120
	2:00	75	88	146	10	14	190	0.4	118	70	115
	4:00	75	88	147	10	14	190	0.4	120	70	115
	6:00	75	88	147	10	14	190	0.4	120	70	115
	8:00	75	88	147	10	14	195	0.4	125		120
	10:00	75	88	148	10	14	195	0.4	120		120
	12:00	75	88	148	10	14	195	0.4	120		120
	14:00	80	88	150	10	14	195	0.4	125		115
	16:00	80	88	150	10	14	195	0.4	120		115
	18:00	80	89	150	11	14	195	0.4	118	78	115
	20:00	78	87	150	10	14	195	0.4	120	72	117
	22:00	80	86	150	10	14	200	0.4	120	70	120
4/14/93	0:01	78	87	148	9	14	190	0.4	118	70	112
	2:00	78	86	149	10	14	190	0.4	120	70	112
	4:00	78	87	148	9	13	190	0.4	118	69	112
	6:00	78	88	149	9	13	190	0.4	120	68	112
	8:00	70	88	149	9	13	190	0.4	120		120
	10:00	75	88	150	10	13	190	0.4	120		115
	12:00	75	88	150	10	14	190	0.4	125		115
	14:00	75	90	150	10	14	195	0.4	125		120
	16:00	75	89	150	10	14	196	0.4	124	86	121
	18:00	80	89	150	9	13	197	0.4	125	76	117
	20:00	80	89	151	10	14	195	0.4	125	60	115
	22:00	75	89	145	10	14	200	0.4	115	53	125
4/15/93	0:01	75	88	145	9	13	195	0.4	112	49	120
	2:00	75	88	145	9	13	195	0.4	112	49	120
	4:00	75	89	144	9	13	195	0.4	113	48	120
	6:00	70	90	144	9	13	200	0.4	114	45	130
	8:00	75	90	145	9	13	200	0.4	115		125
	10:00	75	89	146	9	13	200	0.4	115		125
	12:00	75	90	150	9	13	200	0.4	117		125
	14:00	75	90	152	9	13	200	0.4	120		125
	16:00	70	90	156	9	13	200	0.4	120	86	130
	18:00	70	90	155	9	13	200	0.4	120	75	130
	20:00	75	90	155	9	13	200	0.4	120	72	125
	22:00	75	90	155	9	13	200	0.4	120	60	125
4/16/93	0:01	80	90	145	9	13	200	0.4	115	58	120
	2:00	80	89	145	9	13	200	0.4	114	53	120
	4:00	80	89	144	9	13	200	0.4	115	50	120
	6:00	80	89	144	9	13	200	0.4	114	49	120
	8:00	80	89	145	9	13	200	0.4	115	64	120
	10:00	80	89	146	9	13	200	0.4	115		120
	12:00	80	90	150	9	13	200	0.4	120	78	120
	14:00	80	90	150	9	13	200	0.4	120		120
	16:00	80	89	150	8	13	200	0.4	120	80	120
	18:00	80	89	150	8	12	200	0.4	120	72	120
	20:00	75	88	145	8	12	200	0.4	115	66	125
	22:00	75	89	145	8	12	200	0.4	115	60	125
4/17/93	0:01	70	88	143	8	12	200	0.4	110	60	130
	2:00	75	87	140	8	12	195	0.4	110	58	120
	4:00	75	87	142	8	12	195	0.4	110	58	120
	6:00	70	87	142	8	12	195	0.5	111	59	125
	8:00	70	88	142	8	12	195	0.4	112	65	125
	10:00	70	8	146	8	13	195	0.5	115		125
	12:00	70	88	144	8	15	195	0.4	115		125

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	14:00	70	88	146	8	16	200	0.4	120	88	130
	16:00	70	89	150	8	16	200	0.4	120	88	130
	18:00	70	88	150	9	16	200	0.4	125	89	130
	20:00	75	88	143	8	16	200	0.4	120	69	125
	22:00	75	87	135	8	16	200	0.4	105	68	125
4/18/93	0:01										
	1:10	75	87	133	8	16	200	0.4	104	64	125
	2:00	75	87	137	8	16	200	0.4	105	63	125
	4:00	75	88	137	8	16	200	0.4	106	61	125
	6:00	70	88	138	8	16	200	0.4	108	62	130
	8:00	70	88	140	8	16	200	0.4	110	65	130
	10:00	70	88	141	8	16	200	0.4	111	68	130
	12:00	70	88	146	8	16	200	0.4	116	75	130
	14:00	70	88	147	8	16	200	0.4	120	92	130
	16:00	70	89	150	8	16	200	0.4	120	92	130
	18:00	70	88	150	8	16	200	0.4	120	88	130
	20:00	70	89	150	8	16	200	0.4	120	80	130
	22:00	70	86	140	8	115	200	0.4	110	75	130
4/19/93	0:01	70	87	139	8	15	195	0.4	110	66	125
	2:00	70	87	139	8	15	195	0.4	110	66	125
	4:00	70	87	139	8	15	200	0.4	110	66	130
	6:00	65	87	139	8	15	200	0.4	111	66	135
	8:00	65	88	142	8	15	200	0.4	111		135
	10:00	65	89	145	8	15	200	0.4	113		135
	12:00	70	88	149	8	15	200	0.4	120		130
	14:00	70	88	151	8	15	200	0.4	120		130
	16:00	70	88	150	8	15	200	0.4	120	88	130
	18:00	70	88	150	8	15	200	0.4	118	85	130
	20:00	70	87	149	8	15	200	0.4	115	82	130
	22:00	70	88	144	8	15	200	0.4	110	70	130
4/20/93	0:01	65	86	142	8	15	195	0.4	110	69	130
	2:00	65	87	143	8	15	200	0.4	113	70	135
	4:00	60	87	144	8	15	200	0.4	114	70	140
	6:00	60	87	144	8	15	200	0.4	114	68	140
	8:00	60	88	145	8	15	200	0.4	115	70	140
	10:00	60	88	145	8	15	200	0.4	115	70	140
	12:00	60	88	145	8	15	200	0.4	115	72	140
	14:00	60	88	145	8	15	200	0.4	115	78	140
	16:00	60	89	139	8	15	200	0.4	115	78	140
	18:00	60	88	140	8	15	200	0.4	115	74	140
	20:00	80	89	145	8	15	200	0.4	120	70	120
	22:00	80	89	140	8	15	200	0.4	110	62	120
4/21/93	0:01	80	89	138	8	15	200	0.4	107	60	120
	2:00	80	88	135	8	15	200	0.4	105	57	120
	4:00	80	88	135	8	15	200	0.4	106	54	120
	6:00	78	88	135	8	15	200	0.4	106	54	122
	8:00	79	88	135	8	15	200	0.4	108	57	121
	10:00	80	89	137	8	15	200	0.4	111	60	120
	12:00	75	89	143	8	15	200	0.4	115	75	125
	14:00	75	89	142	8	16	200	0.4	111	75	125
	16:00	65	90	145	8	16	200	0.4	110	76	135
	18:00	65	90	145	8	16	200	0.4	110	74	135
	20:00	65	90	145	8	16	200	0.4	110	72	135
	22:00	65	90	145	8	15	200	0.4	107		135
4/22/94	0:01	90	88	136	8	15	200	0.4	104	59	110

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	2:00	90	89	137	8	15	200	0.4	106	54	110
	4:00	90	89	137	8	15	200	0.4	106	50	110
	6:00	90	88	137	8	15	200	0.4	106	50	110
	8:00	90	88	137	8	15	200	0.4	110	60	110
	10:00	90	88	139	8	15	200	0.4	115	70	110
	12:00	85	88	145	8	15	200	0.4	115	72	115
	14:00	70	87	145	8	16	200	0.4	115	75	130
	16:00	75	87	143	8	16	200	0.4	115	75	125
	18:00	70	87	142	8	16	200	0.4	115	75	130
	20:00	80	88	142	8	16	200	0.4	115	72	120
	22:00	85	86	142	8	16	200	0.4	115	70	115
	24:00	85	86	140	8	16	200	0.4	110	67	115
4/23/93	2:00	90	84	135	8	15	200	0.4	110	60	110
	4:00	90	84	135	8	15	200	0.4	105	58	110
	6:00	90	84	134	8	15	200	0.4	105	56	110
	8:00	90	84	137	8	15	200	0.4	105	66	110
	10:00	85	84	142	8	15	200	0.4	110	75	115
	12:00	75	85	146	8	15	200	0.4	115	81	125
	14:00	75	84	145	8	15	200	0.4	115	85	125
	16:00	85	85	146	8	15	200	0.4	114	86	115
	18:00	85	84	146	8	15	190	0.4	112	86	105
	20:00	80	84	143	8	15	190	0.4	108	78	110
	22:00	80	84	138	8	15	195	0.4	102	72	115
	24:00	85	84	140	8	15	200	0.4	100	70	115
4/24/93	2:00	85	84	140	8	15	200	0.4	100	70	115
	4:00	85	84	142	8	15	200	0.4	100	67	115
	6:00	85	84	140	8	15	200	0.4	100	66	115
	8:00	85	84	142	8	15	200	0.4	105	70	115
	10:00	80	84	142	8	15	200	0.4	110	72	120
	12:00	80	84	143	8	15	200	0.4	110	74	120
	14:00	80	84	145	8	15	200	0.4	110	80	120
	16:08	80	85	149	7	15	190	0.4	117	80	110
	18:00	85	85	150	7	15	200	0.4	114	80	115
	20:00	80	84	145	7	15	200	0.4	109	75	120
	22:00	80	84	139	7	15	200	0.4	105	72	120
	24:00	80	84	140	7	15	200	0.4	100	72	120
4/25/93	2:00	75	84	142	7	15	200	0.4	100	71	125
	4:00	70	84	143	8	15	200	0.4	100	72	130
	6:00	70	84	145	7	15	200	0.4	100	72	130
	8:00	70	84	145	8	15	200	0.4	110	70	130
	10:00	70	83	147	8	15	200	0.4	110	74	130
	12:00	65	84	146	8	16	200	0.4	115	83	135
	14:00	70	84	148	8	16	200	0.4	120	85	130
	16:00	70	85	151	8	16	190	0.4	121	88	120
	18:00	75	85	151	8	15	190	0.4	117	85	115
	20:00	70	84	147	8	15	200	0.4	111	80	130
	22:00	70	85	141	8	15	200	0.4	105	75	130
	24:00	70	86	140	8	15	200	0.4	105	74	130
4/26/93	2:00	70	86	141	8	15	200	0.4	105	72	130
	4:00	70	86	140	8	15	200	0.4	105	71	130
	6:00	70	86	140	8	15	200	0.4	105		130
	8:00	70	87	141	8	15	200	0.4	108	73	130
	10:00	70	85	145	7.5	15	200	0.4	115	78	130
	12:00	70	86	145	7.5	15	200	0.4	115	83	130
	14:00	65	87	150	7.5	15	200	0.4	118	90	135

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	16:00	70	87	153	8	15	200	0.4	117	80	130
	18:00	70	87	153	8	15	200	0.4	110	80	130
	20:00	80	86	149	8	15	200	0.4	111	76	120
	22:00	75	86	142	8	15	200	0.4	106	71	125
	24:00	70	84	142	7.5	15	200	0.4	105	66	130
4/27/93	2:00	70	84	141	7.5	15	200	0.4	105	64	130
	4:00	8	84	145	7.5	15	200	0.4	105	60	192
	6:00	75	86	145	7.5	15	200	0.4	103	60	125
	8:00	75	85	141	7.5	15	200	0.4	110	62	125
	10:00	75	85	14	7.5	15	200	0.4	110	70	125
	12:00	75	85	147	7.5	15	200	0.4	115	72	125
	14:00	75	85	145	7.5	15	200	0.4	115	76	125
	16:00	75	85	146	7.5	15	200	0.4	115	76	125
	18:00	71	85	148	7.5	15	200	0.4	111	72	129
	20:00	70	84	145	7.5	15	200	0.4	105	68	130
	22:00	75	84	140	7.5	15	200	0.4	105	68	125
	24:00	75	84	143	7.5	15	200	0.4	105	66	125
4/28/93	2:00	75	84	143	7.5	15	200	0.4	105	65	125
	4:00	75	84	145	7.5	15	200	0.4	104	64	125
	6:00	75	84	145	7.5	15	200	0.4	107	64	125
	8:00	75	84	145	7.5	15	200	0.4	111	65	125
	10:00	70	84	145	7.5	15	200	0.4	111	70	130
	12:00	70	84	145	7.5	15	200	0.4	109	72	130
	14:00	70	84	145	7.5	15	200	0.4	110	76	130
	16:00	70	84	147	7.5	15	200	0.4	112	71	130
	18:00	70	84	148	7.5	15	200	0.4	112	72	130
	20:00	70	84	148	7.5	15	200	0.4	111	71	130
	22:00	70	84	147	7.5	15	200	0.4	110	70	130
	24:00	70	84	147	7.5	15	200	0.4	108	70	130
4/29/93	2:00	70	84	148	7.5	15	200	0.4	107	68	130
	4:00	70	84	149	7.5	15	200	0.4	105	67	130
	6:00	70	85	150	7.5	15	200	0.4	105	66	130
	8:00	69	85	145	7.5	15	200	0.4	108	70	131
	10:00	70	84	155	7.5	15	200	0.4	140	72	130
	12:00	70	84	160	7.5	15	200	0.4	145	68	130
	14:00	70	85	170	8.5	16	200	0.4	140	68	130
	16:00	70	84	167	8.5	16	200	0.4	135	62	130
	18:00	70	84	166	8.5	16	195	0.4	135	63	125
	20:00	70	85	165	8.5	16	200	0.4	135	63	130
	22:00	70	85	164	8.5	16	200	0.4	137	62	130
	24:00	70	86	165	8.5	16	200	0.4	140	62	130
4/30/93	2:00	70	85	165	8.5	16	200	0.4	140	61	130
	4:00	70	85	163	8.5	16	200	0.4	139	60	130
	6:00	70	85	165	8.5	16	200	0.4	140	60	130
	8:00	70	85	160	8.5	16	200	0.4	135	58	130
	10:00	70	84	160	8.5	16	200	0.4	140	70	130
	12:00	65	84	160	8.5	16	200	0.4	135	69	135
	14:00	68	84	160	8.5	16	200	0.4	130	68	132
	16:00	70	85	160	8.5	16	200	0.4	135	72	130
	18:00	67	84	160	8.5	16	200	0.4	133	66	133
	20:00	63	84	159	8.5	16	200	0.4	135	64	137
	22:00	63	84	158	8.5	16	200	0.4	132	63	137
	24:00	65	84	160	8.5	16	200	0.4	134	62	135
5/1/93	2:00	65	84	160	8.5	16	200	0.4	135	61	135
	4:00	65	84	160	8.5	16	200	0.4	140	62	135

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	6:00	60	84	160	9	16	200	0.4	140	62	140
	8:00	60	84	156	8.5	16	200	0.4	130	63	140
	10:00	60	84	155	8.5	16	200	0.4	130	64	140
	12:00	60	84	160	8.5	16.5	200	0.4	131	73	140
	14:00	60	84	161	8.5	16	200	0.4	135	78	140
	16:00	60	84	163	8.5	16.5	200	0.4	135	82	140
	18:00	63	84	163	8.5	16	200	0.4	130	80	137
	20:00	63	84	158	8.5	16	200	0.4	125	77	137
	22:00	60	84	155	8	16	200	0.4	110	74	140
	24:00	60	84	153	8	16	200	0.4	110	70	140
5/2/93	2:00	60	84	152	8	16	200	0.4	109	70	140
	4:00	60	84	150	8.5	16	200	0.4	109	60	140
	6:00	60	84	149	8.5	16	200	0.4	109	60	140
	8:00	60	85	149	8.5	16	200	0.4	110	57	140
	10:00	60	85	149	8.5	16	200	0.4	115	68	140
	12:00	60	85	148	8.5	16	200	0.4	115	68	140
	14:00	63	84	150	8.5	16	200	0.4	120	74	137
	16:00	60	86	153	8.5	16	200	0.4	125	76	140
	18:00	60	86	155	8.5	16	200	0.4	120	74	140
	20:00	60	87	155	8.5	16	200	0.4	120	70	140
	22:00	60	85	150	8.5	16	200	0.4	120	70	140
	24:00	60	82	150	8.5	16	200	0.4	120	60	140
5/3/93	2:00	60	85	151	8.5	16	200	0.4	121	60	140
	4:00	60	85	150	8	16	200	0.4	120	59	140
	6:00	60	85	151	8	16	200	0.4	120	58	140
	8:00	60	85	150	8	16	200	0.4	120	62	140
	10:00	60	88	155	8	16	200	0.4	120	76	140
	12:00	60	89	160	8	16	200	0.4	125	80	140
	14:00	60	89	160	8	16	200	0.4	130	82	140
	16:00	80	90	163	8	16	200	0.4	130	82	120
	18:00	75	90	163	8	16	200	0.4	130	82	125
	20:00	80	89	160	8	15	200	0.4	125	76	120
	22:00	80	88	158	8	15	200	0.4	124	74	120
	24:00	80	86	150	8	15	200	0.4	125	64	120
5/4/93	2:00	80	87	152	8	15	200	0.4	125	64	120
	4:00	87	88	154	8	15	200	0.4	122	64	113
	6:00	86	87	155	8	15	200	0.4	128	64	114
	8:00	85	87	155	8	15	200	0.4	120	66	115
	10:00	85	87	155	8	15	200	0.4	120	67	115
	12:00	85	87	155	8	15	200	0.4	120	69	115
	14:00	85	87	157	8	16	200	0.4	125	73	115
	16:00	85	88	160	8	15.5	200	0.4	130	76	115
	18:00	84	88	160	8	16	200	0.4	130	78	116
	20:00	85	87	160	8	16	200	0.4	125	76	115
	22:00	85	86	155	8	16	200	0.4	125	75	115
	24:00	85	87	157	8	16	200	0.4	126	74	115
5/5/93	2:00	85	87	156	8	16	200	0.4	125	70	115
	4:00	85	87	155	8	16	200	0.4	130	66	115
	6:00	85	86	155	8	16	200	0.4	125	60	115
	8:00	85	87	155	8	15	200	0.4	125	60	115
	10:00	85	87	155	8	15	200	0.4	125	60	115
	12:00	90	87	157	8.5	16	200	0.4	130	63	110
	14:00	89	87	157	8.5	16	200	0.4	135	60	111
	16:00	89	87	157	8.5	16	200	0.4	137	60	111
	18:00	89	88	157	8.5	16	200	0.4	135	60	111

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	20:00	89	88	157	8.5	16	200	0.4	135	60	111
	22:00	88	87	155	8.5	16	200	0.4	130		112
	24:00	88	87	156	8	16	200	0.4	130	60	112
5/6/93	2:00	88	86	155	8	16	200	0.4	127	59	112
	4:00	88	85	155	8	16	200	0.4	130	59	112
	6:00	87	86	160	8	16	200	0.4	135	60	113
	8:00	90	86	158	8	16	200	0.4	130	63	110
	10:00	85	87	161	8	15	200	0.4	130	68	115
	12:00	85	88	165	8	15	200	0.4	135	75	115
	14:00	90	87	164	8.5	16	200	0.4	135	77	110
	16:00	90	87	165	8	16	200	0.4	137	80	110
	18:00	90	87	164	8	16	200	0.4	137	80	110
	20:00	87	87	162	8	16	200	0.4	130	78	113
	22:00	87	87	162	8	16	200	0.4	130	78	113
	24:00	87	87	161	8	16	200	0.4	130	70	113
5/7/93	2:00	85	87	160	8	16	200	0.4	130	68	115
	4:00	85	86	160	8	16	200	0.4	130	68	115
	6:00	85	86	161	8	16	200	0.4	132	68	115
	8:00	85	86	160	8	16	200	0.4	132	69	115
	10:00	80	86	160	8	16	200	0.4	130	70	120
	12:00	75	86	162	8	16	200	0.4	127	79	125
	14:00	75	86	162	8	16	200	0.5	126	77	125
	16:00	75	86	162	8	15	200	0.5	125	69	125
	18:00	80	84	160	8	15	200	0.5	125	65	120
	20:00	80	86	160	8	15	200	0.4	125	65	120
	22:00	85	86	160	8	15	200	0.4	125	64	115
	24:00	85	86	160	8	15	200	0.4	130	62	115
5/8/93	2:00	85	87	160	8	15	200	0.4	125	62	115
	4:00	85	86	161	8	15	200	0.4	130	62	115
	6:00	85	86	158	8	15	200	0.4	130	62	115
	8:00	85	86	158	8	15	200	0.4	124	64	115
	10:00		86	156	8	15	200	0.5	124	68	200
	12:00		86	157	8	15	200	0.5	123	71	200
	14:00		86	159	8	15	200	0.5	123	73	200
	16:00		86	160	8	15	200	0.5	125	71	200
	18:00		86	159	8	15	200	0.4	125	69	200
	20:00		86	159	8	15	200	0.4	122	67	200
	22:00		86	160	8	15	200	0.4	125	67	200
	24:00		86	160	8	15	200	0.4	125	67	200
5/9/93	2:00		86	160	8	15	200	0.4	130	66	200
	4:00		86	157	8	15	200	0.4	130	64	200
	6:00		86	155	8	15	200	0.4	130	64	200
	8:00		86	157	8	15	200	0.4	121	65	200
	10:00		86	157	8	15	200	0.4	122	68	200
	12:00		86	159	8	15	200	0.4	124	70	200
	14:00		87	163	8	16	200	0.4	127	74	200
	16:00		87	164	8	16	200	0.4	127	77	200
	18:00		87	164	8	16	200	0.4	127	77	200
	20:00		87	163	8	16	200	0.4	125	73	200
	22:00		87	159	8	16	200	0.4	110	65	200
	24:00		86	155	8	15	200	0.4	115	58	200
5/10/93	2:00		87	155	8	15	200	0.4	120	56	200
	4:00		87	155	8	15	200	0.4	120	56	200
	6:00		86	152	8	15	200	0.4	120	56	200
	8:00		87	154	8	15	200	0.4	120	57	200

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	10:00		88	156	8	15	210	0.4	121	64	210
	12:00	80	88	159	8	15	210	0.4	123	68	130
	14:00	85	89	163	8	15	210	0.4	125	71	125
	16:00	85	89	163	8	15	210	0.4	125	72	125
	18:00	80	90	165	8	15	210	0.4	127	74	130
	20:00	80	90	165	8	15	205	0.4	127	70	125
	22:00	80	88	160	8	15	205	0.4	127	68	125
	24:00	80	88	159	8	15	205	0.4	125	50	125
5/11/93	2:00	80	88	160	8	15	210	0.4	125	50	130
	4:00	82	88	160	8	15	210	0.4	125	52	128
	6:00	80	88	155	8	15	210	0.4	120	54	130
	8:40	75	87	156	8	15	210	0.4	120	65	135
	10:00	75	88	158	8	15	210	0.4	121	72	135
	12:00	75	88	160	8	15	210	0.4	123	79	135
	14:00	80	89	162	7	15	210	0.4	124	82	130
	16:00	60	90	162	7	15	210	0.4	125	84	150
	18:00	70	90	162	7	15	200	0.4	125	84	130
	20:00	80	90	163	7	15	200	0.4	125	78	120
	22:00	80	88	161	7	15	200	0.4	123	70	120
	24:00		87	157	7	15	200	0.4	120	66	200
5/12/93	2:00	80	87	159	7	15	200	0.4	122	64	120
	4:00	80	87	152	7.5	15	205	0.4	110	64	125
	6:00	81	87	155	7.5	15	205	0.4	115	65	124
	8:00	80	88	153	8	15	210	0.4	115	69	130
	12:45	80	89	160	8	15	210	0.4	118	82	130
	14:00	80	89	161	8	15	210	0.4	118	80	130
	16:00	75	90	160	7	15	210	0.4	120	81	135
	18:00	75	90	162	8	15	210	0.4	120	78	135
	20:00	80	88	160	8	15	210	0.4	120	76	130
	22:00	80	88	155	8	15	210	0.4	120	72	130
	24:00	80	88	154	8	15	210	0.4	122	70	130
5/13/93	2:00	80	88	155	7.5	15	210	0.4	120	62	130
	4:00	80	87	154	7.5	15	210	0.4	119	56	130
	6:00	80	87	155	7.5	15	210	0.4	120	56	130
	8:00	80	86	153	8	15	210	0.4	116	66	130
	10:00	75	84	158	8	15	210	0.4	119	78	135
	12:00	75	84	162	8	15	210	0.4	121	82	135
	14:00	75	85	165	8	15	210	0.4	121	80	135
	16:00	75	88	166	8	15	210	0.4	125	84	135
	18:00	70	88	166	8	15	210	0.4	125	84	140
	20:00	80	88	165	8	15	210	0.4	125	76	130
	22:00	80	87	163	8	15	210	0.4	120	70	130
	24:00	80	83	159	7.5	15	210	0.4	120	64	130
5/14/93	2:00	80	84	160	7.5	15	210	0.4	120	63	130
	4:00	80	84	155	7.5	15	205	0.4	115	62	125
	6:00	80	84	155	7.5	15	205	0.4	115	58	125
	8:00	80	84	155	7	15	210	0.4	116	73	130
	10:00	85	84	158	7	15	210	0.4	120	77	125
	12:00	80	86	164	8	15	210	0.4	121	86	130
	14:00	70	86	165	8	15	210	0.4	126	89	140
	16:00	70	87	165	8	15	210	0.4	128	89	140
	18:00	65	86	165	8	15	210	0.4	130	85	145
	20:00	80	85	163	8	15	210	0.4	125	80	130
	22:00	80	84	160	8	15	210	0.4	120	74	130
	24:00	90	84	157	8	15	210	0.4	110	69	120

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
5/15/93	2:00	90	84	156	8	15	210	0.4	110	64	120
	4:00	90	84	156	8	15	210	0.4	110	62	120
	6:00	90	84	156	8	15	210	0.4	110	60	120
	8:00	80	84	156	7	15	210	0.4	117	77	130
	10:00	75	85	160	7	15	210	0.4	120	87	135
	12:00	80	85	165	7	15	210	0.4	122	88	130
	14:00	80	86	165	7	15	210	0.4	127	91	130
	16:00	80	86	165	7	15	210	0.4	129	89	130
	18:00	70	87	165	7	15	210	0.4	130	88	140
	20:00	70	86	165	7	15	210	0.4	127	80	140
	22:00	85	84	155	7	15	210	0.4	125	76	125
	24:00	80	84	155	7	15	210	0.4	115	72	130
5/16/93	2:00	85	84	154	7	15	210	0.4	115	68	125
	4:00	85	84	155	7	15	210	0.4	115	65	125
	6:00	85	83	155	7	15	210	0.4	115	63	125
	8:00	80	83	155	7	15	210	0.4	115	68	130
	10:00	80	84	157	7	15	210	0.4	119	76	130
	12:00	80	85	161	7	15	210	0.4	121	83	130
	14:00	85	86	163	7	15	210	0.4	125	86	125
	16:00	85	86	165	7	15	210	0.4	125	88	125
	18:00	80	86	165	7	15	210	0.4	125	88	130
	20:00	80	84	160	7	15	210	0.4	120	80	130
	22:00	80	84	157	7	15	210	0.4	120	76	130
	24:00	80	84	155	7	15	210	0.4	120	70	130
5/17/93	2:00	80	85	158	7	15	210	0.4	120	68	130
	4:00	80	84	155	7	15	210	0.4	115	68	130
	6:00	80	84	154	7	15	210	0.4	118	70	130
	8:00	80	84	154	7	15	210	0.4	115	70	130
	10:00	80	85	155	7	15	210	0.4	118	73	130
	12:00	80	86	161	7	15	210	0.4	120	80	130
	14:00	85	88	165	7	15	210	0.4			125
	16:00	80	86	159	7	15	210	0.4	122	88	130
	18:00	80	87	160	7	15	210	0.4	125	85	130
	20:00	80	88	160	7	15	210	0.4	123	82	130
	22:00	83	84	155	7	15	210	0.4	120	76	127
	24:00	80	84	154	7	15	210	0.4	115	73	130
5/18/93	2:00	80	84	156	7	15	210	0.4	117	72	130
	4:00	80	83	154	7	14	210	0.4	113	64	130
	6:00	80	84	154	7	15	210	0.4	115	63	130
	8:00	80	84	157	7	15	210	0.4	120	67	130
	10:00	85	84	160	7	15	210	0.4	120	65	125
	12:00	80	84	150	7	15	210	0.4	115	65	130
	14:00	80	85	155	7	15	210	0.4	120	78	130
	16:00	80	85	155	7	15	210	0.4	120	82	130
	18:00	80	86	165	7	15	210	0.4	125	80	130
	20:00	80	86	161	7	15	210	0.4	120	76	130
	22:00	80	86	160	7	15	210	0.4	115	76	130
	24:00	80	85	155	7	15	210	0.4	115	65	130
5/19/93	2:00	80	84	150	7	15	210	0.4	113	62	130
	4:00	80	84	150	7	15	210	0.4	111	60	130
	6:00	80	85	149	7	15	210	0.4	110	57	130
	8:00	80	85	150	7	15	210	0.4	115	70	130
	10:00	80	56	150	7	15	180	0.4	115	70	100
	12:00	80	46	155	7	14	160	0.4	120	70	80
	14:00	80	46	160	7	15	160	0.4	120	76	80

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	16:00	55	45	160	7	14	160	0.4	115	74	105
	18:00	60	46	160	7	14	160	0.4	125	74	100
	20:00	60	46	155	7	15	160	0.4	120	70	100
	22:00	60	45	152	7	14	160	0.4	110	64	100
	24:00	65	46	151	7	14	160	0.4	114	59	95
5/20/93	2:00	65	46	149	7	14	160	0.4	114	55	95
	4:00	70	46	148	7	14	160	0.4	112	53	90
	6:00	65	46	147	7	14	160	0.4	112	52	95
	8:00	60	46	148	7	14	155	0.4	110	60	95
	10:00	60	45	150	7	14	155	0.4	110	63	95
	12:00	60	46	152	7	14	157	0.4	115	70	97
	14:00	55	46	155	7	14	160	0.4	115	76	105
	16:00	55	46	154	7	14	160	0.4	115	76	105
	18:00	56	46	155	7	14	160	0.4	115	74	104
	20:00	60	46	152	7	14	160	0.4	115	69	100
	22:00	55	44	148	7	14	160	0.4	110	66	105
	24:00	55	44	144	7	14	160	0.4	108	61	105
5/21/93	2:00	55	44	144	7	13	160	0.4	108	58	105
	4:00	55	44	144	7	13	160	0.4	108	54	105
	6:00	55	44	144	7	14	160	0.4	107	53	105
	8:00	55	44	144	7	14	160	0.4	106	56	105
	10:00	55	44	145	7	14	160	0.4	110	69	105
	12:00	55	44	148	7	14	160	0.4	112	76	105
	14:00	55	45	151	7	15	160	0.4	115	76	105
	16:00	60	46	152	7	15	160	0.4	115	76	100
	18:00	60	46	150	7	14	160	0.4	120	76	100
	20:00	55	46	147	7	14	160	0.4	115	74	105
	22:00	55	46	145	7	14	160	0.4	115	61	105
	24:00	60	45	142	7	13	160	0.4	104	61	100
5/22/93	2:00	60	45	142	7	13	160	0.4	105	60	100
	4:00	60	45	142	7	13	160	0.4	105	60	100
	6:00	60	46	142	7	13	160	0.4	105	60	100
	8:00	60	46	144	7	13	160	0.4	105	62	100
	10:00	60	46	145	7	13	160	0.4	110	62	100
	12:00	60	46	145	7	13	160	0.4	110	68	100
	14:00	60	46	147	7	13	160	0.4	112	69	100
	16:00	60	46	145	7	14	150	0.4	110	65	90
	18:00	60	49	145	8	15	160	0.4	110	65	100
	20:00	60	50	150	8	14	160	0.5	110	61	100
	22:00	60	49	150	8	15	160	0.5	120	62	100
	24:00	55	48	149	8	14	160	0.5	119	63	105
5/23/93	2:00	60	48	149	8	14	160	0.4	120	63	100
	4:00	60	48	151	8	14	160	0.4	120	63	100
	6:19	55	48	147	8	14	160	0.4	119	54	105
	8:15	60	48	145	8	14	160	0.4	120	54	100
	10:00	60	48	150	8	14	160	0.4	125	57	100
	12:00	60	48	150	8	14	160	0.4	120	57	100
	14:00	60	48	146	8	14	160	0.4	120	57	100
	16:00	60	48	145	8	14	160	0.4	121	57	100
	18:00	60	48	152	8	14	160	0.4	125	56	100
	20:00	55	49	155	8	14	170	0.4	125	60	115
	22:00	55	50	155	8	14	165	0.4	125	60	110
	24:00	55	48	154	8	14	170	0.4	122	57	115
5/24/93	2:00	60	48	153	8	14	170	0.4	122	55	110
	4:00	60	48	152	8	14	170	0.4	120	54	110

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	6:00	60	48	152	8	14	170	0.4	120	54	110
	8:00	60	48	152	8	14	170	0.4	120	60	110
	10:00	60	46	155	8	14	180	0.4	125	65	120
	12:00	80	92	157	8	15	210	0.4	125	68	130
	14:00	75	90	157	8	15	210	0.4	125		135
	16:00	75	90	158	8	15	210	0.4	120	70	135
	18:00	78	91	158	8	15	211	0.4	120	68	133
	20:00	75	92	155	8	15	210	0.4	116	67	135
	22:00	80	91	154	8	15	210	0.4	120	62	130
	24:00	75	92	153	8	15	220	0.4	115	60	145
5/25/93	2:00	80	93	153	8	15	230	0.4	115	56	150
	4:00	80	93	151	8	15	230	0.4	114	55	150
	6:00	80	93	151	8	15	230	0.4	114	54	150
	8:00	80	92	152	8	15	230	0.4	115	66	150
	10:00	75	92	154	8	15	230	0.4	120	68	155
	12:00	80	92	155	8	15	230	0.4	122	70	150
	14:00	80	94	155	8	15	220	0.4	120	74	140
	16:00	80	85	156	8	15	210	0.4	120	75	130
	18:00	80	84	154	8	15	210	0.4	120	76	130
	20:00	80	84	153	8	15	210	0.4	115	70	130
	22:00	75	84	150	8	15	210	0.4	115	66	135
	24:00	75	84	149	8	15	220	0.4	113	62	145
5/26/93	2:00	75	84	149	8	15	220	0.4	113	61	145
	4:00	75	84	15	8	15	220	0.4	114	60	145
	6:00	75	84	149	8	15	220	0.4	113	60	145
	8:00	75	86	150	8	15	220	0.4	115	65	145
	10:00	75	86	151	8	15	220	0.4	115	68	145
	12:00	75	86	151	8	16	220	0.4	117	70	145
	14:00	75	86	155	8	16	220	0.4	117	72	145
	16:00	75	86	155	8	16	220	0.4	116	74	145
	18:00	75	86	152	8	16	220	0.4	115	72	145
	20:00	70	86	150	8	16	220	0.4	115	68	150
	22:00	75	86	150	8	16	220	0.4	113		145
	24:00	75	84	148	8	15	220	0.4	111	63	145
5/27/93	2:00	75	84	148	8	15	220	0.4	110	61	145
	4:00	75	85	147	8	15	220	0.4	110	59	145
	6:00	75	86	147	8	15	220	0.4	110	59	145
	8:00	75	86	150	8	15	220	0.4	112	62	145
	10:00	75	86	150	8	15	220	0.4	115	64	145
	12:00	75	87	155	8	16	220	0.4	115	66	145
	14:00	75	87	155	8	16	220	0.4	120		145
	16:00	75	88	154	8	16	220	0.4	118	76	145
	18:00	72	88	156	8	16	220	0.4	118	75	148
	20:00	75	85	150	8	15	215	0.4	110	72	140
	22:00	75	84	150	8	15	220	0.4	112	65	145
	24:00	75	85	147	8	15	220	0.4	108	63	145
5/28/93	2:00	75	86	147	8	15	220	0.4	107	61	145
	4:00	75	85	147	8	15	220	0.4	106	61	145
	6:00	75	85	147	8	15	220	0.4	106	60	145
	8:00	70	85	148	8	15	210	0.4	105	60	140
	10:00	70	85	150	8	15	210	0.4	108	67	140
	12:00	75	87	156	8	16	215	0.4	115	72	140
	14:00	75	86	159	8	16	210	0.4	118	76	135
	16:00	75	86	150	8	15	210	0.4	112	78	135
	18:00	75	85	150	8	15	210	0.4	111	78	135

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	20:00	75	86	150	8	16	220	0.5	115	72	145
	22:00	70	86	150	8	15	220	0.4	115	70	150
	24:00	75	86	150	8	15	220	0.4	113	60	145
5/29/93	2:00	75	86	150	8	15	220	0.4	110	60	145
	4:00	75	85	150	8	15	220	0.4	108	60	145
	6:00	75	84	150	8	15	220	0.4	108	60	145
	8:00	75	84	150	8	15	220	0.4	108	62	145
	10:00	75	85	155	8	16	215	0.5	110	69	140
	12:00	75	86	157	8	16	220	0.4	112	72	145
	14:00	70	86	160	8	16	220	0.4	120	74	150
	16:00	75	86	160	8	16	220	0.4	120	80	145
	18:00	75	86	160	8	16	220	0.4	122	76	145
	20:00	75	86	157	8	155	220	0.5	120	80	145
	22:00	70	84	155	8	15.5	220	0.5	120	76	150
	24:00	75	84	154	8	15	220	0.4	118	74	145
5/30/93	2:00	75	84	152	8	15	220	0.4	115	72	145
	4:00	75	82	152	8	15	220	0.4	113	68	145
	6:00	75	84	150	8	15	220	0.4	110	64	145
	8:00	75	84	150	8	15	220	0.4	110	65	145
	10:00	75	86	155	8	16	220	0.4	110	67	145
	12:00	75	86	158	8	16	220	0.4	114	70	145
	14:00	75	87	165	8	16	220	0.4	130	77	145
	16:00	75	86	165	8	16	220	0.4	135	82	145
	18:00	75	86	165	8	16	220	0.4	135	76	145
	20:00	75	84	160	8	16	220	0.4	120	72	145
	22:00	75	84	160	8	16	220	0.4	120	70	145
	24:00	75	84	158	8	16	220	0.4	120	68	145
5/31/93	2:00	75	86	155	8	16	220	0.4	115	65	145
	4:00	75	86	152	8	16	220	0.4	113	60	145
	6:00	75	86	150	8	16	220	0.4	110	60	145
	8:00	75	86	155	8	16	220	0.4	110	64	145
	10:00	75	87	160	8	16	220	0.4	110	74	145
	12:00	60	46	164	8	16	185	0.4	125	82	125
	14:00	60	46	165	8	16	190	0.4	130	83	130
	16:00	60	46	165	8	16	190	0.4	130	85	130
	18:00	60	46	164	8	16	190	0.4	130	82	130
	20:00	60	45	161	8	16	190	0.4	115	76	130
	22:00	60	46	161	8	16	190	0.4	117	68	130
	24:00	60	46	155	8	16	190	0.4	115	66	130
6/1/93	2:00	60	46	155	8	16	185	0.4	113	64	125
	4:00	60	46	155	8	16	190	0.4	110	62	130
	6:00	60	46	150	7	16	190	0.4	105	60	130
	8:00	60	46	151	7	16	190	0.4	110	64	130
	10:00	60	44	159	7	16	190	0.4	115	72	130
	12:00	60	44	160	8	16	190	0.4	118	76	130
	14:00	70	44	165	8	15	190	0.4	125	76	120
	16:00	70	46	165	8	15	180	0.5	124	78	110
	18:00	70	44	164	8	15	180	0.5	117	76	110
	20:00	70	44	160	7	14	170	0.5	113	73	100
	22:00	60	44	158	7	14	170	0.5	112	69	110
	24:00	60	44	155	7	15	170	0.5	112	67	110
6/2/93	2:00	60	45	154	7	15	170	0.4	110	65	110
	4:00	70	44	152	7	15	170	0.4	108	62	100
	6:00	70	44	152	7	15	170	0.4	105	60	100
	8:00	70	44	154	7	15	185	0.4	110	62	115

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
	10:00	70	44	155	7	15	190	0.4	110	74	120
	12:00	70	45	160	7.5	15	190	0.4	120	80	120
	14:00	70	45	163	7.5	15	190	0.4	130		120
	16:00	70	45	164	7	15	180	0.5	130	83	110
	18:00	70	45	164	7	14	180	0.5	125	84	110
	20:00	70	45	162	7	14	180	0.4	114	79	110
	22:00	70	44	137	7	14	180	0.4	110	73	110
	24:00	70	44	155	7	14	180	0.4	110	70	110
6/3/93	2:00	70	44	153	7	14	180	0.4	110	68	110
	4:00	70	44	151	7	14	180	0.4	108	66	110
	6:00	70	45	150	7	14	170	0.4	105	64	100
	8:00	70	45	155	7	14	180	0.4	105	68	110
	10:00	70	45	155	7	14	185	0.4	110	72	115
	12:00	70	44	162	7	15	200	0.4	128	80	130
	14:00	70	44	165	7	15	200	0.4	130	84	130
	16:00	75	86	165	8	16	210	0.4	132	85	135
6/4/93	8:00	70	88	155	8	15	240	0.4	100	69	170
	9:00	70	88	153	8	15	240	0.4	105	73	170
6/5/93	9:00	70	88	145	8	15	240	0.4	100	72	170
6/6/93	8:30	70	88	145	8	15	240	0.4	100	71	170
6/7/93	9:26	70	88	145	8	16	240	0.4	103	69	170
6/8/93	9:00	70	84	144	8	15	240	0.4	100	70	170
6/9/93	8:45	70	84	144	7.5	15	240	0.4	100	74	170
6/10/93	8:51	70	84	141	7.5	15	240	0.4	100	70	170
6/11/93	8:10	70	84	143	7	15	240	0.4	96	76	170
6/12/93	8:05	70	84	143	7.5	15	240	0.4	97	74	170
6/13/93	8:00	70	84	147	7.5	16	240	0.4	99	74	170
6/14/93	7:25	70	84	144	7.5	16	240	0.4	95	71	170
6/15/93	7:35	70	85	145	8	16	240	0.4	105	72	170
6/16/93	9:45	70	87	156	7.5	16	250	0.3	112	82	180
6/17/93	9:00	70	86	148	7.5	16	240	0.4	96	73	170
6/18/93	9:10	76	84	142	7.5	16	230	0.4	98	73	154
6/19/93	10:41	70	84	144	7.5	16	240	0.4	100	78	170
6/20/93	9:05	70	84	141	7.5	16	220	0.5	92	72	150
6/21/93	8:05	70	84	141	7.5	16	230	0.5	93	74	160
6/22/93	7:10	70	84	142	7.5	16	230	0.5	95	73	160
6/23/93	8:15	70	84	140	7.5	16	220	0.4	98	75	150
6/24/93	7:35	70	84	140	7.5	16	230	0.5	94	74	160
6/25/93	7:25	70	84	138	7.5	16	230	0.5	90	77	160
6/26/93	7:35	70	84	138	7.5	16	230	0.4	91	69	160
6/27/93	9:35	70	84	140	7.5	16	230	0.4	100	80	160
6/28/93	7:35	70	84	137	7.5	16	230	0.4	94	76	160
6/29/93	7:25	70	84	138	7.5	16	230	0.4	93	79	160
6/30/93	8:15	50	42	136	6.5	13	150	0.6	96	80	100
7/1/93	8:10	60	44	135	7	15	170	0.5	98	80	110
7/2/93	7:12	60	44	136	7	15	170	0.4	98	79	110
7/3/93	11:15	60	44	145	7	15	170	0.5	102	90	110
7/4/93	11:20	60	42	140	7	15	170	0.4	99	80	110
7/5/93	10:10	55	44	137	14	20	170	0.4	100	85	115
7/6/93	8:10	60	44	140	13	19	170	0.5	99	75	110
7/7/93	8:00	55	42	135	13	20	170	0.4	99	75	115
7/8/93	8:10	55	44	135	13	19	170	0.4	99	80	115
7/9/93	6:30	55	44	135	13	19	170	0.4	99	77	115
7/10/93	9:45	55	44	135	13	20	170	0.4	99	90	115
7/11/93	11:30	55	44	135	13	20	170	0.4	99	95	115

TABLE A.5.
IITRI OPERATING DATA

Date	Time	Inlet Air Flow (CFM)	Inlet Air Pres (psi)	Vapor Temp (F)	Suction (in Water)	Discharge (in Water)	Mixed Vapor Flow (CFM)	Mixed Vapor Press (psi)	Mixed Vapor Temp (F)	Ambient Temp (F)	Vapor Flow (SCFM)
7/12/93	8:00	55	44	135	13	19	170	0.4	99	85	115
7/13/93	7:45			80					78		
7/14/93	8:14			79					76		
7/15/93	6:25			78					79		
7/16/93	8:00			79					79		
7/17/93	8:00			81					79		
7/21/93	8:10	30	0.3	127	5	4	100	0.4	94		70
7/22/93	8:15	30	3	129	4	4	95	0.4	93		65
7/23/93	7:45	30	3.5	126	4	4	95	0.4	90		65
7/24/93	9:10	30	5	128	4	4	95	0.4	96		65
7/25/93	9:15	30	4	127	4	4	75	0.4	97		45
7/26/93	8:30	30	6	125	4	4	75	0.4	89		45
7/27/93	7:55	30	6	126	4	4	75	0.4	90		45
7/28/93	7:45	30	6	122	4	4	75	0.4	90		45
7/29/93	8:00	30	6	131	4	4	60	0.4	94		30
7/30/93	8:05	30	8	131	4	4	75	0.4	93		45
7/31/93	9:30	30	8	132	4	4	75	0.4	95		45
8/1/93	9:13	30	7	131	4	4	70	0.4	94		40
8/2/93	7:55	30	7	128	4	4	75	0.4	89	78	45

APPENDIX A.6.

[illegible] [illegible]

JUN 1993
RECEIVED
OAK RIDGE OFFICE

SAIC
Science Applications International Corporation
An Employee-Owned Company

May 27, 1993

Mr. Cliff Blanchard
Halliburton NUS Environmental Corporation
800 Oak Ridge Turnpike
Jackson Plaza, C-200
Oak Ridge, Tennessee 37830

RE: EPA Contract No. 68-C0-0048, WA 0-44
SAIC Project No. 01-0832-07-2249-014

Dear Mr. Blanchard:

Please find the enclosed four tables summarizing grain size distribution within the test plot. ASTM D422 was the procedure used for mechanical sieving, and specific gravity tests were conducted following procedure ASTM D845-83.

Tables 1-3 show the particle size distribution summary along the three plan-view cross sections A1-A8, TW1-B4, and C1-C8, respectively. Table 4 presents particle size data on selected samples which further subdivide the fines into silt and clay percentages, and present specific gravities. As a convenience, the particle sizes shown in Tables 1-3 are listed in order of descending percentage of the total, the dominant size listed first.

If you have any questions regarding this information, please do not hesitate to call me at (513) 723-2600, extension 2610.

Sincerely,

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

J Rawe

Jim Rawe
Work Assignment Manager

Encls.

b3.blnchrd4.ltr

635 West Seventh Street, Suite 403, Cincinnati, Ohio 45203 • (513) 723-2600 • FAX: (513) 723-2605
Other SAIC Offices: Albuquerque, Boston, Colorado Springs, Dayton, Huntsville, Las Vegas, Los Angeles, McLean, Oak Ridge, Orlando, Palo Alto, Seattle, Tucson

TABLE 1. PARTICLE SIZE DISTRIBUTION - CROSS SECTION A1-A8

	Particle Size Distribution by Soil Boring (% by weight)[a]							
Sample Interval Depth BLS (ft)	A1	A2	A3	A4	A5	A6	A7	A8
0 - 2				S-50[b] G-32 F-18				
2 - 4			G-45[b] S-36 F-19					
4 - 6	S-48[c] G-28 F-24							
6 - 8								
8 - 10							S-57[b] G-43	
10 - 12								
12 - 14		S-49[c] F-32 G-19					S-72[c] G-20 F-8	
14 - 16								F-49[b] G-26 S-25
16 - 18			S-53[c] F-33 G-14					
18 - 20						G-74[b] S-19 F-7		
20 - 22				G-63[b] F-21 S-16				
22 - 24					G-78[b] S-19 F-3			
24 - 26								
26 - 28								
28 - 30								G-58[b] S-25 F-17
30 - 32								
32 - 34								
34 - 36								

Notes:

[a] Percentages have been rounded to whole numbers

[b] Results are from one test

[c] Results are the average of two tests, one from a sample sleeve and the other from a bagged sample

— Approximate start of gravel zone.

___ Navarro Clay

G = Gravel
S = Sand
F = Fines (silt and clay)

TABLE 2. PARTICLE SIZE DISTRIBUTION - CROSS SECTION TW1-B4

Sample Interval Depth BLS (ft)	Particle Size Distribution by Soil Boring (% by weight)[a]					
	TW1	TW2	B1	B2	B3	B4
0 - 2			S-39[d] F-36 G-35			
2 - 4					S-40[b] G-38 F-22	
4 - 6	F-29 G-34 S-27	F-41 S-30 G-29		F-56[b] S-38 G-6		
6 - 8						
8 - 10				G-67[b] S-25 F-8		
10 - 12					G-50[b] S-26 F-24	
12 - 14			S-54[c] F-27 G-19	F-78[a] S-18 G-4		
14 - 16	S-51[b] F-35 G-14	F-41[b] S-33 G-19				
16 - 18						S-51[b] F-27 G-22
18 - 20						
20 - 22						G-37[b] F-35 S-28
22 - 24						G-86[b] F-10 S-4
24 - 26		G-92[b] S-6 F-2				
26 - 28			G-93[b] S-6 F-1			
28 - 30						
30 - 32						
32 - 34						
34 - 36		F-75[b,e] S-17 G-8				

Notes:

[a] Percentages have been rounded to whole numbers

[b] Results are from one test

[c] Results are the average of two tests, one from a sample sleeve and the other from a bagged sample.

[d] Results are the average of samples from two separate sleeves and one bag sample.

[e] The 75% includes 51% silt and clay and 24% of unacccountable solids that did not settle out of suspension during hydrometer testing.

- — Approximate start of gravel zone.
▬ Navarro Clay
G = Gravel
S = Sand
F = Fines (silt and clay)

TABLE 3. PARTICLE SIZE DISTRIBUTION - CROSS SECTION C1-C8

	Particle Size Distribution by Soil Boring (% by weight)[a]							
Sample Interval Depth BLS (ft)	C1	C2	C3	TW7	C5	C6	C7	C8
0 - 2			F-49[c] G-30 S-21					
2 - 4						S-46[c] F-27 G-27		
4 - 6				G-40[b] S-34 F-26			S-45[b] G-32 F-23	G-48[c] S-34 F-18
6 - 8		S-47[c] F-28 G-25						
8 - 10							S-43[b] G-43 F-14	
10 - 12					G-41[b] S-34 F-25			
12 - 14								
14 - 16				G-42[b] S-36 F-22				S-44[c] G-30 F-26
16 - 18								
18 - 20			S-60[c] F-36 G-4			G-64[b] S-22 F-14		
20 - 22								
22 - 24			G-79[b] S-15 F-6					G-86[b] S-10 F-4
24 - 26				G-72[b] S-19 F-9		G-64[b] S-24 F-12		
26 - 28								
28 - 30								
30 - 32								
32 - 34								
34 - 36								

Notes:

[a] Percentages have been rounded to whole numbers

[b] Results are from one test

[c] Results are the average of two tests, one from a sample sleeve and the other from a bagged sample

-- Approximate start of gravel zone.

— Navarro Clay

G = Gravel

S = Sand

F = Silt clay

TABLE 4. Particle Size Distribution and Specific Gravities of Selected Tests Samples

Boring No.	Sample Interval - BLS (ft.)	PARTICLE SIZE (% by weight)[a]				Specific Gravity
		Gravel	Sand	Silt	Clay	
A3	2-4	45	36	19		2.51
A4	20-22	74	17	5	4	2.55
A8	14-16	26	25	31	18	2.43
B1	0-2	48	30	13	9	2.42
B2	12-14	34[b]	17[b]	20[b]	29[b]	2.32
B3	10-12	50	26	11	13	2.41
B4	20-22	37	28	17	18	2.53
C3	0-2	30	21	22	27	2.52
C3	22-24	79	15	3	3	2.62
C5	10-12	41	34	15	10	2.54
TW1	4-6	34	26	24	16	2.49
TW2	4-6	29	30	24	17	2.51
TW2	14-16	19	33	26	22	2.24
TW3	35-36	8	17	75 includ. colloids		2.34

[a] Percentages have been rounded off to whole numbers and are adjusted where rounding off did not result in a sum of 100%.

[b] Percentages are the average of one sleeve sample and one bagged sample.

APPENDIX A.7.

Table A.7. - Soil Vapor Analytical Summary IITRI Demonstration

Chemical (mg/m3)	TPH	Benzene	Chloro-Benzene	Ethyl benzene	Toluene	Xylene total	Vinyl Chloride	PCE	Acetone	2-Butanone	Vinyl Acetate
Date											
3/30/93	190.00	1.15	5.00	0.14	0.39	0.20	0.23				2.90
3/30/93	220.00	0.37	4.80	0.09	0.79	0.14	0.29				5.50
3/31/93	250.00	2.80		0.18		0.19	0.10	0.02			2.50
4/1/93	2.50	0.04	2.80	0.02		0.10	0.01				0.02
4/2/93	1.00	2.20	8.50	0.29	0.55	0.38	0.04	1.20	0.26		1.80
4/3/93	210.00	0.65	7.00	0.22	0.50	0.02	0.02	0.60	0.13		1.90
4/3/93		0.93	8.00	0.22	0.46	0.21	0.01	0.61			4.10
4/4/93	100.00	0.98	7.30	0.22	0.61	0.30	0.02	0.98			2.70
4/4/93	220.00	1.10	3.00	0.24	0.70	0.22	0.02	1.20			2.10
4/5/93	1.00		4.20	0.15	0.28	0.19	0.02	0.60	0.13		0.90
4/5/93		0.02	2.90	0.02	0.02	0.05		0.02	0.04		
4/6/93	5.00		0.05								
4/6/93		0.04	1.50		0.01	0.10		0.02	0.04		
4/7/93	15.00	0.40	0.66		0.01						0.24
4/8/93	1.80	0.03	1.50			0.10				0.08	0.31
4/8/93	0.60	0.16	0.85		0.02						0.09
4/9/93	6.10	0.07	3.60	0.04	0.03	0.05		0.10			0.02
4/9/93		0.75	14.00	0.35	0.04	0.60		0.29			5.00
4/10/93	1.10	0.01	0.09						0.07		0.01
4/10/93		0.11	0.55		0.02					0.26	0.13
4/11/93	34.00	0.90	0.08	0.09				0.08		0.02	3.30
4/12/93	1.30	0.07								0.47	0.18
4/12/93		0.33	7.50		0.05	0.21		0.07	7.50	1.70	0.46
4/13/93	11.00	0.42	2.40		0.05			0.03		4.00	1.10
4/14/93	0.01										
4/14/93	0.13										
4/15/93	0.02										
4/16/93	0.06										
4/16/93					0.04						
4/17/93	0.16				0.03	0.02					
4/18/93					0.01						
4/18/93	0.02				0.02	0.01					
4/19/93	0.05							0.02			
4/19/93					0.01	0.01			0.07		
4/20/93	0.08	0.01			0.02	0.01			0.02		
4/20/93					0.01						
4/21/93	0.09										
4/22/93	0.09										
4/23/93	0.02										
4/24/93	0.08										
4/25/93	0.80										0.01
4/26/93	0.09										
4/26/93					0.01	0.01					
4/27/93	0.10										
4/28/93	0.14										
4/29/93	0.05										
4/30/93	0.12	0.01			0.05						
5/1/93	0.11				0.01						
5/2/93	0.07										
5/3/93	0.02	0.01			0.03	0.02					
5/3/93	0.04	0.16	0.05	0.02	0.11						
5/4/93		0.01			0.01	0.01					
5/6/93	6.30	0.16	0.08		0.12	0.02		0.06			
5/7/93		0.05			0.04				0.47		
5/7/93	2.70	0.64	8.30	0.39	0.74	0.60	0.64	0.39	2.40	1.70	

Table A.7. - Soil Vapor Analytical Summary
IITRI Demonstration

Chemical (mg/m3)	TPH	Benzene	Chloro-Benzene	Ethyl benzene	Toluene	Xylene total	Vinyl Chloride	PCE	Acetone	2-Butanone	Vinyl Acetate
5/8/93	0.02		0.01						0.36		
5/9/93	7.00										
5/9/93	0.04		0.03		0.01						
5/10/93	0.91	0.08	0.09	0.05	0.09					0.01	
5/11/93	7.10										
5/11/93	4.90										
5/12/93	45.00	0.19	0.12		0.07			0.01	32.00		0.50
5/14/93	98.00	3.20	3.60		2.30					13.00	
5/15/93	10.00	0.69			0.21				20.00		0.78
5/16/93	0.72	0.05			0.02				4.60		0.09
5/17/93	10.00	0.44			0.20						0.62
5/18/93	57.00	2.70	0.50	0.31	1.10	0.04	21.00		4.80	0.10	1.60
5/20/93	0.12	0.01								0.01	
5/21/93	0.18				0.03	0.02		0.01	0.01	0.01	
5/22/93	0.13	0.03	0.07	0.01	0.01				26.00	0.47	0.11
5/23/93	0.12										
5/24/93	93.00	3.90	0.05	0.05	3.40	0.17		0.06	19.00	0.07	0.09
5/25/93	0.35	0.02	0.01		0.02	0.01			0.01		
5/26/93	2.00	0.25	0.06	0.02	0.24	0.11				0.03	0.10
5/27/93	87.00	2.30	0.60	0.10	2.40	0.30		0.08			0.75
5/28/93	0.58	0.05	0.01		0.02				0.01	0.01	
5/29/93	0.12		0.01						0.01		
6/1/93	0.34		0.01		0.02					0.01	
6/2/93	0.10								0.06		
6/3/93	0.17	0.01	0.14		0.03		0.01		0.07	0.02	
6/4/93	0.02	0.02	0.03		0.01			0.03	0.07	0.03	
6/5/93	0.12	0.01	0.03	0.08	0.04	0.05				0.01	
6/6/93	4.20	0.37			0.01				0.90	0.09	0.27
6/7/93	0.02		0.01						0.01		
6/8/93	0.09			0.06	0.19	0.02					
6/9/93	0.06									0.02	0.05
6/10/93	ND									0.22	0.06
6/12/93	ND				0.19					0.13	
6/14/93	ND				0.02				0.22	0.30	0.26
6/16/93	0.04								0.05	0.26	0.01
6/18/93	0.56									0.05	0.39
6/20/93	0.19									0.02	
6/22/93	0.28										

APPENDIX A.8.

APPENDIX A.8.

DEWATERING SYSTEM

I. INTRODUCTION

The IITRI demonstration began in January 1993 with site preparation and the installation of a dewatering system around the demonstration area at Site S-1. The dewatering system was necessary to keep groundwater levels 5 feet below the bottom tip of the excitor electrodes. Initial water levels in January 1993 indicated the water table at approximately 22.4 feet below the surface. The top of the water table needed to be drawn down to a depth of approximately 24 feet or more below the surface. The dewatering system consisted of four dewatering wells six inches in diameter. One existing well (S1PW04) and three newly installed wells (DW01, DW02, and DW03) were used (Figure A.8.-1).

II. INSTALLATION

Installation of the three new dewatering wells was completed on January 28, 1993. DW01 was drilled to a depth of 42.5 feet and set at 39.8 feet. DW02 was drilled to a depth of 40 feet and set at 38 feet. DW03 was drilled to a depth of 35 feet and set at 35 feet. These dewatering wells were installed in a 14-inch diameter borehole with 20 feet of PVC screen 6 inches in diameter and a sump at the bottom. A sandpack was added and a bentonite seal was installed above the sandpack. Well S1PW04 had been installed in 1991 during a previous investigation to a depth of 38.9 feet with 14.5 feet of 6-inch diameter PVC screen. All dewatering wells were developed by using a surge block and a pump to remove suspended solids.

After well development the dewatering system was installed. The dewatering system consisted of ejectors in the wells, air lines from the electric air compressor and control panel located in a shed adjacent to the site office trailer, water lines leading from the wells to a "Frac" or storage tank located along the east side of the demonstration site. The dewatering system was installed during the end of January and the first part of February (see Figure A.8.-2).

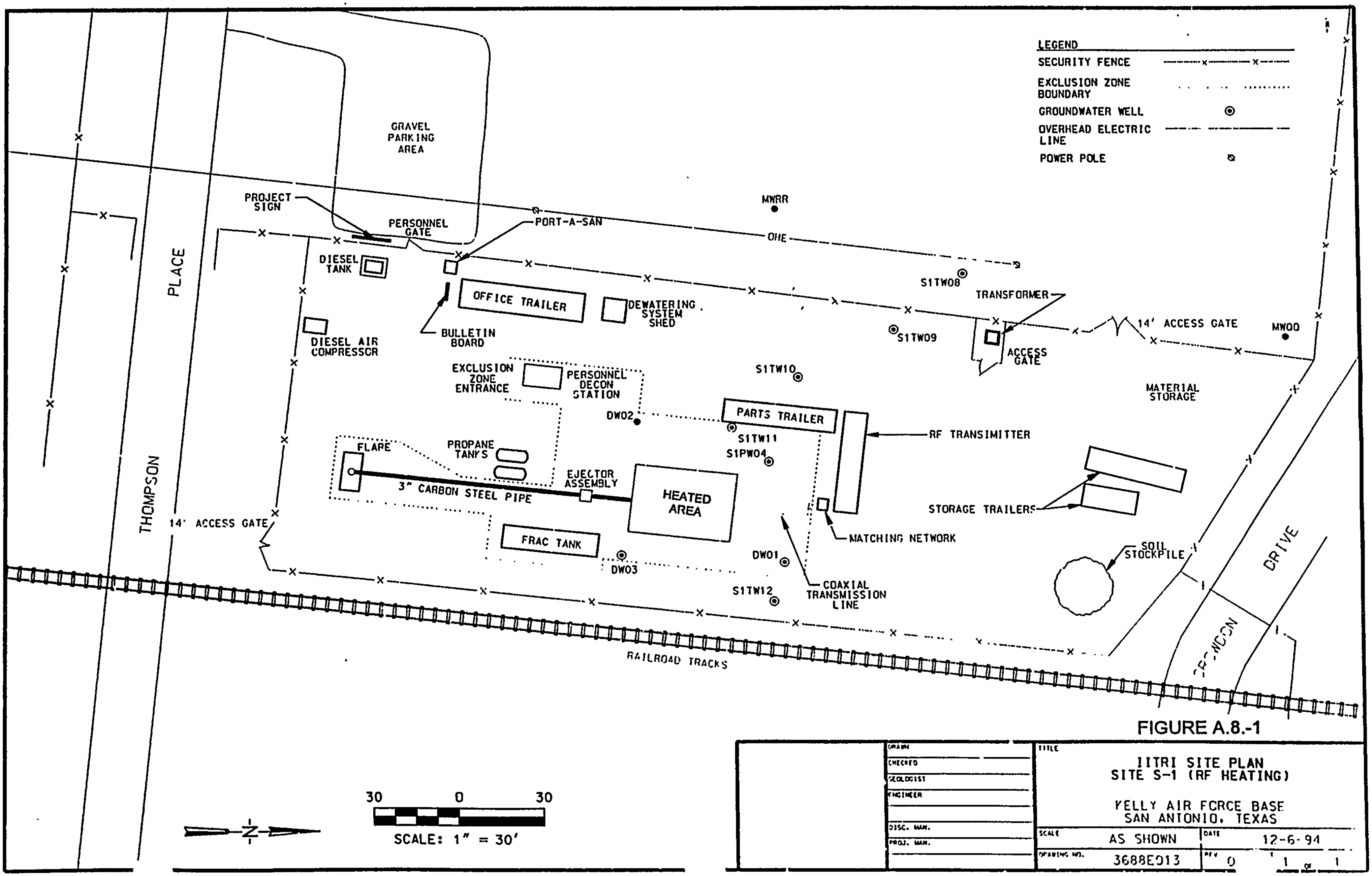

FIGURE A.8.-1

DRAWN	
CHECKED	
GEOLOGIST	
ENGINEER	
DISC. MAN.	
PROJ. MAN.	

TITLE
IITRI SITE PLAN
SITE S-1 (RF HEATING)

KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

SCALE AS SHOWN
DATE 12-6-94
DRAWING NO. 3688E013
REV 0
1 of 1

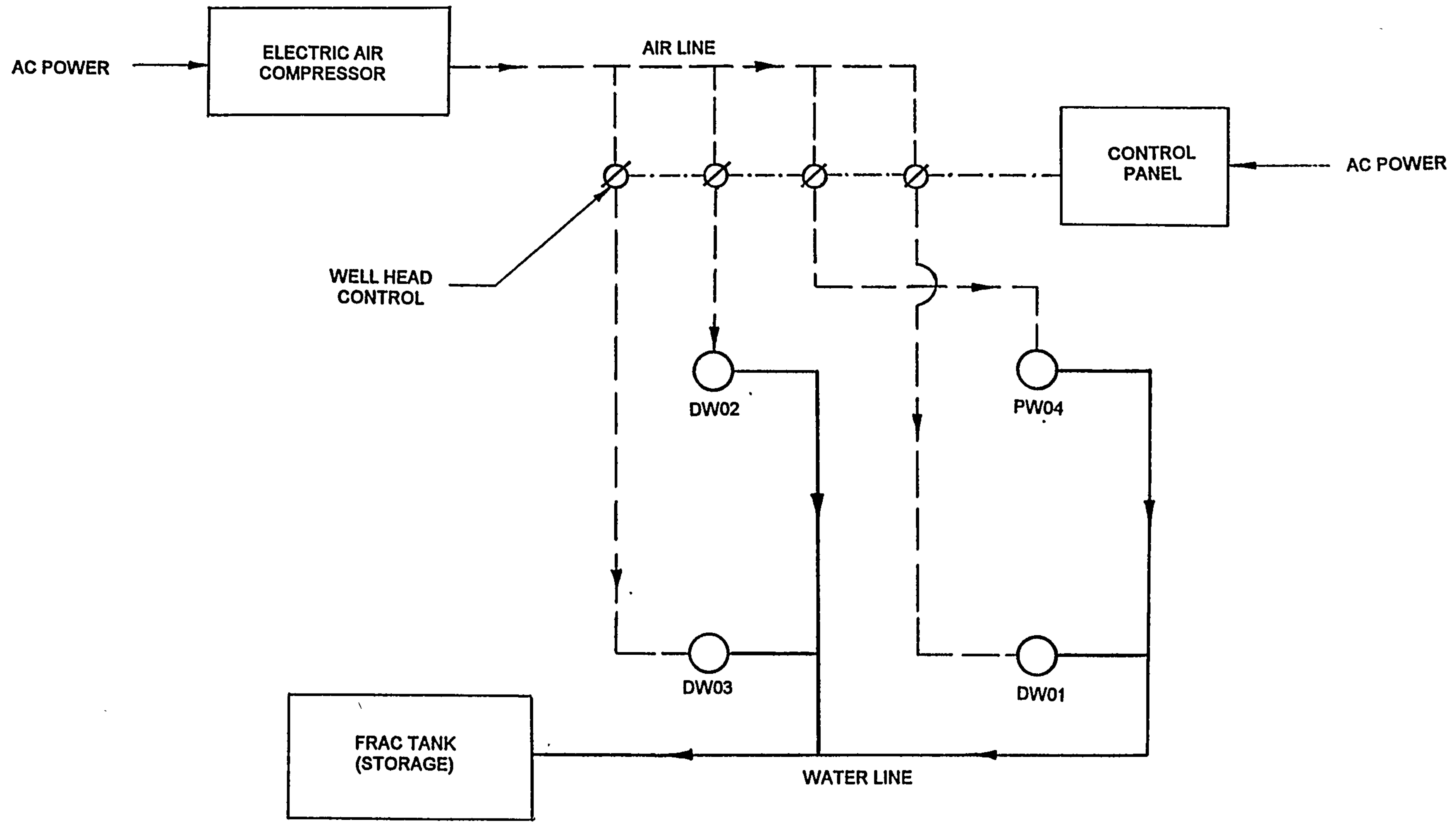

FIGURE A.8.-2
DEWATERING SYSTEM SCHEMATIC
IITRI DEMONSTRATION
SITE S-1, KELLY AFB

III. OPERATION

Dewatering began on February 2, 1993, using wells DW03 and S1PW04. Wells DW01 and DW02 came on line a few days later and the pumping levels were adjusted to match recharge in the wells. The dewatering system was turned off on February 13, 1993, to allow the aquifer to recharge to equilibrium before a test was performed to see how quickly and to what depth the water table could be lowered. Table A.8.-1 illustrates the results of the dewatering system during this test. When the dewatering system was turned off the water level at temporary well PW03 was 24.5 below the surface and rose to 22.6 feet below the surface before the system was turned on again on February 15. The dewatering system was able to lower the water table in the demonstration area 1.9 feet in twenty-four hours. PW03 was installed on January 28, 1993, to collect water levels in the demonstration area to determine the effectiveness of the dewatering system in lowering the water table. PW03 was abandoned on February 22, 1993, prior to the IITRI demonstration startup. From the results of the test it was concluded that the dewatering system would be able to keep the water table lowered 5 feet below the excitor electrodes. Water levels from PW03 and wells adjacent to the demonstration site are provided in Table A.8.-1.

Water removed by the dewatering system was collected in a holding tank at the site and transported to the Kelly AFB EPCF for treatment. Initially the water was collected in a tanker truck and transported to the EPCF in the tanker truck. Beginning in April 1993 the water was collected in a frac tank then transferred to a tanker truck for transport to the EPCF.

IV. CONCLUSIONS

Volumes of water, average pumping rates, rainfall, and water transport data during the period of the IITRI demonstration are provided in Table A.8.-2. Average pumping rates ranged from 0.79 gpm to 3.79 gpm during the demonstration. Variations in pumping rates can be attributed to various factors including precipitation, evaporation, recharge of the aquifer, and the nearby pond at the fuel tank farm to the east of the demonstration site. The dewatering system was able to draw the water table at the demonstration site down to a level of approximately 24.5 feet during a pump test in February 1993. The goal was to be able to draw the water table down to approximately 5 feet below the bottom of the exciter electrodes which was at a depth of approximately 20 feet. Actual water levels during the demonstration may have been even lower due to the continual dewatering over a longer period of time.

TABLE A.8.-1
WATER LEVELS
SITE S-1, KELLY AFB

Date	Time	Well Number								
		PW03	PW04	DW01	DW02	DW03	TW09	TW10	TW11	TW12
1/30/93	2:15 PM			23.74	22.4	23.17				
2/2/93	7:30 AM	22.47	24.63	23.80	22.58	23.28	24.39	23.80	23.66	23.92
2/2/93	9:15 AM	22.75	35.35		25.97			23.85	23.83	
2/2/93	12:30 PM	23.47	32.83		25.78			23.85	23.85	
2/2/93	1:20 PM	23.11								
2/2/93	3:20 PM	23.45								
2/3/93	6:43 PM	23.78	34.99	29.78	28.27	24.17	24.43	23.95	24.07	26.28
2/3/93	1:15 PM		34.89		27.8			23.95	24.14	26.21
2/3/93	6:30 PM	22.41	33.55		27.78			23.88	24.23	26.14
2/4/93	7:30 AM	23.7		30.02	27.75			23.96	24.4	26.09
2/4/93	12:40 PM	22.9	34.95	29.91	27.69	24.18	24.49	23.97	24.35	26.11
2/4/93	4:00 PM	23.84		29.74	28.02			24	24.54	26.08
2/7/93	1:30 PM	23.44						23.92	24.24	25.76
2/7/93	5:38 PM	23.47								
2/8/93	6:46 AM	23.6								
2/8/93	1:10 PM	23.35								
2/8/93	6:14 PM	23.46							24.67	25.39
2/9/93	8:08 AM	22.85						24.1	24.45	24.21
2/9/93	10:50 AM	22.98						24.13	24.22	24.67
2/9/93	12:50 PM	23.12							24.28	25
2/9/93	4:35 PM	23.46							24.14	25.73
2/10/93	8:35 AM	20.59						24.16	24.22	24.12
2/10/93	1:55 AM	22.08						24.1	24.27	25.52
2/11/93	8:10 AM	23.26				23.73		24.13	24.23	25.69
2/11/93	1:00 PM	23.47				25.64		24.15	24.25	25.67
2/12/93	2:00 PM	24.8							24.3	26.8
2/13/93	7:30 AM	24.5								
2/13/93	1:00 PM	24.5								25.96
2/15/93	8:30 AM	22.6								
2/16/93	8:30 AM	24.4								
2/16/93	2:00 PM	24.6								
2/18/93	7:30 AM	24.71								
2/19/93	7:55 AM	24.68								

Table A.8.-2
Dewatering Data Summary
IITRI Demonstration
Site S-1, Kelly AFB, TX

Item	Date	Quantity (gal)	Days	Gallons per day	Rainfall (in)	Average gpm
March					**2.21**	
Start-up	4/3/94	0			0.19	
Water Hauling	4/12/93	16,000	9		0.25	1.23
Water Hauling	4/19/93	16,000	7		0	1.59
Water Hauling	4/28/93	16,000	9		0	1.23
April		**48,000**	**25**	**1920**	**0.44**	**1.33**
Water Hauling	5/5/93	8,000	7		3.91	0.79
Water Hauling	5/8/93	16,000	3		0	3.70
Water Hauling	5/14/93	16,000	6		0	1.85
Water Hauling	5/18/93	5,460	4		0.06	0.95
Water Hauling	5/19/93	5,460	1		0	3.79
Water Hauling	5/25/93	18,000	6		3.01	2.08
Water Hauling	5/31/93	14,000	6		1.14	1.62
May		**82,920**	**33**	**2513**	**8.12**	**1.74**
Water Hauling	6/5/93	12,000	5		0	1.67
Water Hauling	6/10/93	18,000	5		0.28	2.50
Water Hauling	6/16/93	18,000	6		3.3	2.08
Water Hauling	6/22/93	12,000	6		1.29	1.39
Water Hauling	6/25/93	12,000	3		0.33	2.78
Water Hauling	6/28/93	12,000	3		0.73	2.78
June		**84,000**	**28**	**3000**	**5.93**	**2.08**
Water Hauling	7/2/93	12,000	4		0	2.08
Water Hauling	7/6/93	12,000	4		0	2.08
Water Hauling	7/13/93	18,000	7		0	1.79
Water Hauling	7/16/93	6,000	3		0	1.39
Water Hauling	7/23/93	6,000	7		0	0.60
Water Hauling	7/27/93	18,000	4		0	3.13
July		**72,000**	**29**	**2483**	**0**	**1.72**
Water Hauling	8/6/93	18,000	10		0	1.25
Water Hauling	8/23/93	21,000	17			0.86
August		**39,000**	**27**	**1444**		**1.00**
TOTAL		**325,920**	**115**	**2834**	**16.70**	**1.38**

APPENDIX A.9.

PRECISION ANALYTICS, INC.

N.E. 2345 Hopkins Court • Pullman, WA 99163
TEL. (509) 332-0928

May 4, 1993

SA-ALC/PKOE
1288 Growdon Road, Bldg. 1585
Kelly AFB, TX 78241-5318

Attn: JoAnn Hernandez

Laboratory Reference	Customer Reference
Samples: 3117KAB1, 3117KAB2	CALL #93-36
Report number: KAB3117	Samples: S1-3109-01, S1-3109-02

Date samples received: 4/20/93

All analyses are performed by approved methodologies whenever applicable. Deviations, modifications and/or substitutions with more stringent EPA methodologies are sometimes necessary owing to the variety of matrices being analyzed.

A *Concentration Value* of U indicates a compound could not be detected in the sample above the lower quantitation limit printed in the *Detection Limit* column.

If you have any questions regarding the enclosed laboratory results, please include the above laboratory sample and report numbers in all correspondence.

Respectfully,

Michael McMillan

Michael McMillan, Ph.D.
Chemist

Chemist: McMillan
Client Sample ID: S1-3109-01
Lab Sample Number: 3117KAB1

Date completed: 5/4/93
Sample type: Water
Method: EPA 8020

Item Number	Compound	Detection Limit µg/L (ppb)	Concentration µg/L (ppb)
1	Benzene	5	1319
2	Toluene	5	195
3	Ethylbenzene	5	41
4	Xylene I	5	15
5	Xylene II	5	48
6	Chlorobenzene	5	5747
7	1,2-dichlorobenzene	5	2700
8	1,3-dichlorobenzene	5	230
9	1,4-dichlorobenzene	5	964

Chemist: McMillan
Client Sample ID: S1-3109-02
Lab Sample Number: 3117KAB2

Date completed. 5/4/93
Sample type: Water
Method: EPA 8270

Item Number	Compound	Detection Limit µg/L (ppb)	Concentration µg/L (ppb)
1	2-Fluorophenol	$	--
2	Phenol-d$_5$	$	--
3	bis(2-Chloroethyl)Ether	660	U
4	1,4-Dichlorobenzene-d$_4$	*	--
5	2-Chlorophenol-d$_4$	$	--
6	2-Chlorophenol	660	U
7	1,3-Dichlorobenzene	660	85
8	1,4-Dichlorobenzene	660	265
9	1,2-Dichlorobenzene	660	555
10	2-Methylphenol	660	43.7
11	Phenol	660	U
12	bis(2-Chloroisopropyl)Ether	660	U
13	Benzyl Alchohol	1,300	U
14	3-Methylphenol	660	U
15	4-Methylphenol	660	16
16	N-nitroso-Di-n-propylamine	660	U
17	Nitrobenzene-d$_5$	$	--
18	Hexachloroethane	660	U
19	Nitrobenzene	660	U
20	2-Nitrophenol	660	U
21	Isophorone	660	U
22	2,4-Dimethyphenol	660	22
23	Benzoic Acid	3,300	U
24	bis(2-Chloroethoxy)methane	660	U
25	2,4-Dichlorophenol	660	U

Client Sample ID: SA-3109-02 Lab Sample Number: 3117KAB2

Item Number	Compound	Detection Limit µg/L (ppb)	Concentration µg/L (ppb)
26	Naphthalene-d_8	*	--
27	1,2,4-Trichlorobenzene	660	6
28	Naphthalene	660	84
29	4-Chloroaniline	1,300	U
30	Hexachlorobutadiene	660	U
31	2-Methylnaphthalene	660	U
32	4-Chloro-3-Methylphenol	1,300	U
33	Hexachlorocyclopentadiene	660	U
34	2,4,6-Trichlorophenol	660	U
35	2,4,5-Trichlorophenol	660	U
36	2-Fluorobiphenyl	$	--
37	2-Nitroaniline	3,300	U
38	2-Chloronaphthalene	660	U
39	Dimethyl Phthalate	660	U
40	2,6-Dinitrotoluene	660	U
41	Acenaphthylene	660	U
42	3-Nitroaniline	3,300	U
43	Acenaphthene-d_{10}	*	--
44	2,4-Dinitrophenol	3,300	U
45	Dibenzofuran	660	U
46	Acenaphthene	660	U
47	4-Nitrophenol	3,300	U
48	2,4-Dinitrotoluene	660	U
49	Diethyl phthalate	660	U
50	4,6-Dinitro-2-methylphenol	3,300	U

Client Sample ID: SA-3109-02 Lab Sample Number: 3117KAB2

Item Number	Compound	Detection Limit µg/L (ppb)	Concentration µg/L (ppb)
51	4-Nitroaniline	ND	U
52	Fluorene	660	U
53	4-Chlorophenyl phenyl ether	660	U
54	N-nitrosodiphenylamine	660	U
55	Diphenyldiazene	660	U
56	2,4,6-Tribromophenol	$	--
57	4-Bromophenyl phenyl ether	660	U
58	Hexachlorobenzene	660	U
59	Pentachlorophenol	3,300	U
60	Phenanthrene	660	U
61	Phenanthrene-d_{10}	*	--
62	Anthracene	660	U
63	Di-n-Butylphthalate	660	U
64	Fluoranthene	660	U
65	Pyrene	660	U
66	4-Terphenyl-d_{14}	$	--
67	Chrysene	660	U
68	Butyl benzyl phthalate	660	U
69	3,3'-Dichlorobenzidine	1,300	U
70	Perylene-d_{12}	*	--
71	Benzo(a)Anthracene	660	U
72	bis(2-ethylhexyl)Phthalate	660	U
73	Benzo(a)pyrene	660	U
74	Di-n-octyl Phthalate	660	U
75	Dibenz(a h)anthracene	660	U
76	Benzo(b+k)fluoranthene	660	U

Client Sample ID: SA-3109-02 Lab Sample Number: 3117KAB2

Item Number	Compound	Detection Limit µg/L (ppb)	Concentration µg/L (ppb)
77	Benzo(g,h,i)perylene	660	U
78	Indeno(1,2,3-cd)pyrene	660	U
79	Chrysene-d_{12}	*	--

$ = Surrogate * = Internal Standard

Comment: 500 ml of sample were concentrated to 1.8 ml of organic extract; hence, effective detection limits are .0036 of machine detection limits listed.

APPENDIX A.10.

Report of Analysis

JUN 1993
RECEIVED
[illegible] OFFICE

Consulting Geotechnical, Materials and Environmental Engineers
Geologists, Scientists and Chemists

Raba-Kistner
Consultants, Inc.

P.O. Box 690287, San Antonio, TX 78269-0287
12821 W. Golden Lane, San Antonio, TX 78249
(210) 699-9090

To: Halliburton NUS Corp.
800 Oak Ridge Turnpike
Jackson Plaza, A-600
Oak Ridge, TN 37830
Attn: Cliff Blanchard

Project No.: ASE93-018-00
Task No.: 5000
Assignment No.: 3893
Contract/P.O. No.:
Date Received: 5-14-93
Page 1 of 6 Date: 6-2-93

Sample Type/Sample Loc: Water/Kelly AFB
Date Collected: 5-14-93
Date Completed: 5-27-93
Collected By: Client

TEST METHODS:

TEST	PREPARATION/DATE	ANALYSIS/DATE
Semi-Volatiles	SW 846 3510/5-17-93	SW 846 8270/5-21-93
TPH		EPA 418.1/5-18-93
Volatiles	SW 846 5030/5-17-93	SW 846 8260/5-17-93

All soil and sludge results are reported on the dry-weight basis. Methods are from EPA SW 846 and EPA 600/4-79-20 or as listed.

By E Moore
Earl S. Moore
Organic Section Manager

By Edward J. Brown
Edward J. Brown
Director, Analytical Chemistry

Project No.: ASE93-018-00
Assignment No.: 3893
Page 2 of 6

BASE/NEUTRAL/ACID EXTRACTABLES	Detection Limit ug/L	3893-1 ($1W0514 931050D) ug/L
Acenaphthene	10	<10
Acenaphthylene	10	<10
Anthracene	10	<10
Benzo(a)anthracene	10	<10
Benzo(b)fluoranthene	10	<10
Benzo(k)fluoranthene	10	<10
Benzo(a)pyrene	10	<10
Benzo(g,h,i)perylene	10	<10
Benzoic acid	50	140
Benzyl alcohol	20	26
Benzidine	10	<10
Benzyl butyl phthalate	10	<10
Bis(2-chloroethyl)ether	10	<10
Bis(2-chloroethoxy)methane	10	<10
Bis(2-ethylhexyl)phthalate	10	95
Bis(2-chlorisopropyl)ether	10	<10
4-Bromophenyl phenyl ether	10	<10
4-Chloroaniline	20	<10
2-Chloronaphthalene	20	<10
4-Chlorophenyl phenyl ether	10	<10
Chrysene	10	<10
Dibenzofuran	10	<10
Dibenzo(a,h)anthracene	10	<10
Di-n-butyl phthalate	10	16
1,3-Dichlorobenzene	10	<10
1,4-Dichlorobenzene	10	<10
1,2-Dichlorobenzene	10	<10
3,3'-Dichlorobenzidine	20	<20
Diethyl phthalate	10	<10
Dimethyl phthalate	10	<10
2,4-Dinitrotoluene	10	<10
2,6-Dinitrotoluene	10	<10
Di-n-octylphthalate	10	<10
1,2-Diphenylhydrazine	10	<10
Fluoranthene	10	<10
Fluorene	10	<10
Hexachlorobenzene	10	<10
Hexachlorobutadiene	10	<10
Hexachloroethane	10	<10
Indeno(1,2,3-cd)pyrene	10	<10
Isophorone	10	<10
2-Methylnaphthalene	10	<10
Naphthalene	10	<10

2-Nitroaniline	50	<50
3-Nitroaniline	50	<50
4-Nitroaniline	50	<50
Nitrobenzene	10	<10
N-Nitrosodimethylamine	10	<10
N-Nitrosodi-n-propylamine	10	<10
N-Nitrosodiphenylamine	10	<10
Phenanthrene	10	<10
Pyrene	10	<10
1,2,4-Trichlorobenzene	10	<10
4-Chloro-3-methylphenol	20	<20
2-Chlorophenol	10	<10
2,4-Dichlorophenol	10	<10
2,4-Dimethylphenol	10	50
2,4-Dinitrophenol	50	<50
2-Methyl-4,6-dinitrophenol	50	<50
2-Methylphenol	10	14
4-Methylphenol	10	300
2-Nitrophenol	10	<10
4-Nitrophenol	50	<50
Pentachlorophenol	50	<50
Phenol	10	120
2,4,6-Trichlorophenol	10	<10
2,4,5-Trichlorophenol	10	<10

Project No.: ASE93-018-00
Assignment No.: 3893
Page 4 of 6

Test Results:

Analyte	Detection Limit (mg/L)	3893-1 ($1W0514 931050D) (mg/L)
TPH	1	5

Project No.: ASE93-018-00
Assignment No.: 3893
Page 5 of 6

Test Results:

Analyte	Detection Limit (mg/L)	3893-1 (S1W0514 931050D) (mg/L)	3893-2 (SW0514 931045C) (mg/L)
Acetone	1	2.4	12
Bromomethane	0.1	<0.1	1.3
2-Butanone	1	<1	<1
Carbon disulfide	1	<1	<1
Chloroethane	0.1	<0.1	<0.1
Chloroform	0.05	<0.05	<0.05
Chloromethane	0.1	<0.1	<0.1
Dichlorodifluoromethane	0.05	<0.05	<0.05
1,1-Dichloroethane	0.05	<0.05	<0.05
1,2-Dichloroethane	0.05	<0.05	<0.05
1,1-Dichloroethene	0.05	<0.05	<0.05
cis-1,2-Dichloroethene	0.05	<0.05	<0.05
trans-1,2-Dichloroethene	0.05	<0.05	<0.05
,2-Dichloropropane	0.05	<0.05	<0.05
Methylene chloride	0.05	<0.05	<0.05
1,1,1-Trichloroethane	0.05	<0.05	<0.05
Trichlorofluoromethane	0.05	<0.05	<0.05
Vinyl acetate	0.5	<0.5	<0.5
Vinyl chloride	0.1	<0.1	<0.1
Benzene	0.05	<0.05	0.06
Bromodichloromethane	0.05	<0.05	<0.05
Carbon Tetrachloride	0.05	<0.05	<0.05
2-Chloroethyl vinyl ether	0.1	<0.1	<0.1
1,2-Dibromoethane	0.05	<0.05	<0.05
Dibromomethane	0.05	<0.05	<0.05
1,2-Dichloroethane	0.05	<0.05	<0.05
1,2-Dichloropropane	0.05	<0.05	<0.05
1,1-Dichloropropene	0.05	<0.05	<0.05
cis-1,3-Dichloropropene	0.05	<0.05	<0.05
trans-1,3-Dichloropropene	0.05	<0.05	<0.05
Methylbutyl ether	0.05	<0.05	<0.05
4-Methyl-2-pentanone	0.50	<0.50	<0.50
Toluene	0.05	<0.05	<0.05
1,1,2-Trichloroethane	0.05	<0.05	<0.05
Trichloroethene	0.05	<0.05	<0.05
Bromoform	0.05	<0.05	<0.05
Chlorodibromomethane	0.05	<0.05	<0.05
Chlorobenzene	0.05	0.07	0.09
1,3-Dichloropropane	0.05	<0.05	<0.05
thylbenzene	0.05	<0.05	<0.05
2-Hexanone	0.50	<0.50	<0.50
Styrene	0.05	<0.05	<0.05
1,1,2,2-Tetrachloroethane	0.05	<0.05	<0.05
Tetrachloroethene	0.05	<0.05	<0.05
Total Xylenes	0.05	<0.05	<0.05

	Detection Limit (mg/L)	3893-1 (S1W0514 931050D) **(mg/L)**	3893-2 (SW0514 931045C) **(mg/L)**
Bromobenzene	0.05	<0.05	<0.05
n-Butylbenzene	0.05	<0.05	<0.05
sec-Butlybenzene	0.05	<0.05	<0.05
tert-Butylbenzene	0.05	<0.05	<0.05
2-Chlorotoluene	0.05	<0.05	<0.05
4-Chlorotoluene	0.05	<0.05	<0.05
1,2-Dibromo-3-chloropropane	0.05	<0.05	<0.05
1,2-Dichlorobenzene	0.05	<0.05	<0.05
1,3-Dichlorobenzene	0.05	<0.05	<0.05
1,4-Dichlorobenzene	0.05	<0.05	<0.05
Hexachlorobutadiene	0.05	<0.05	<0.05
Isopropyl benzene	0.05	<0.05	<0.05
p-Isopropyltoluene	0.05	<0.05	<0.05
Naphthalene	0.05	<0.05	<0.05
n-Propylbenzene	0.05	<0.05	<0.05
1,1,2,2-Tetrachloroethane	0.05	<0.05	<0.05
1,2,3-Trichlorobenzene	0.05	<0.05	<0.05
1,2,4-Trichlorobenzene	0.05	<0.05	<0.05
1,2,3-Trichloropropane	0.05	<0.05	<0.05
1,2,4-Trimethylbenzene	0.05	<0.05	<0.05
1,3,5-Trimethylbenzene	0.05	<0.05	<0.05

APPENDIX A.11.

Engineers, Geologists, Chemists, Water Planners, Hygienists and Environmental Scientists

Raba-Kistner
Consultants, Inc.

12821 W. Golden Lane
P.O. Box 690287, San Antonio, TX 78269-0287
(210) 699-9090 • FAX (210) 699-6426

December 22, 1994

Ms. Laura Witt
Brown & Root Environmental
800 Oak Ridge Turnpike, Suite A-600
Oak Ridge, Tennessee 37830

Dear Laura,

The samples submitted under chain-of-custody number 6756 were referenced as "soil" on the report dated 04-26-94. The samples submitted were actually carbon; however, our boilerplate default is "soil" for all solid matrices.

If you have any questions or need additional information, please contact me at 210-699-9090, extension 275.

Respectfully submitted,

RABA-KISTNER CONSULTANTS, INC.

AL Weilbacher
Director of Analytical Chemistry

Report of Analysis

Consulting Geotechnical, Materials and Environmental Engineers
Geologists, Scientists and Chemists

Raba-Kistner
Consultants, Inc.

P.O. Box 690287, San Antonio, TX 78269-0287
12821 W. Golden Lane, San Antonio, TX 78249
(210) 699-9090

FILE COPY

To: Brown & Root Environmental
800 Oak Ridge Turnpike
Suite A-600
Oak Ridge, TN 37830

Attn: Cliff Blanchard

Project No: ASE94-007-00
Task No: 5000
Assignment No: 6756
Contract/P.O. No:
Date Received: 04-19-94
Page 1 of 5 Date: 04-26-94

Sample Type/Sample Loc: Soil / Kelly Air Force Base
Date Collected: 04-19-94
Date Completed: 04-26-94
Collected By: R-KCI

TEST METHODS:

TEST	PREPARATION / DATE	ANALYSIS / DATE
TCLP Extraction	1311 / 04-21-94	
TCLP-ZHE	1311 / 04-21-94	
TCLP-Volatiles		8260 / 04-25-94
TCLP-Semi-Volatiles	3510 / 04-22-94	8270 / 04-25-94

By
Gang Sun, Ph.D.
QA/QC Officer

Project No: ASE94-007-00
Assignment No: 6756
Page 2 **of** 5

Analyte TCLP-Semi-Volatiles	**Detection Limit (mg/L)**	6756-1 (KSI CD 1/2-3688) **(mg/L)**
1,4-Dichlorobenzene	0.75	<0.75
2,4-Dinitrotoluene	0.013	<0.013
Hexachlorobenzene	0.013	<0.013
Hexachloroethane	0.03	<0.05
Nitrobenzene	0.02	<0.02
Pentachlorophenol	3.6	<3.6
2,4,6-Trichlorophenol	0.2	<0.2
2,4,5-Trichlorophenol	5.8	<5.8
Pyridine	0.5	<0.5
Total cresol	30	<30

Project No: ASE94-007-00
Assignment No: 6756
Page 3 **of** 5

Analyte TCLP-Volatiles	**Detection Limit (mg/L)**	6756-1 (KSI CD 1/2-3688) **(mg/L)**
Benzene	0.05	<0.05
Carbon Tetrachloride	0.05	<0.05
Chlorobenzene	10	<10
Chloroform	0.6	<0.6
1,2-Dichlroethane	0.05	<0.05
1,1-Dichloroethene	0.07	<0.07
2-Butanone	20	<20
Tetrachloroethene	0.07	<0.07
Trichloroethene	0.05	<0.05
Vinyl Chloride	0.02	<0.02

QA/QC FORM

	ORIGINAL RESULT (mg/L)	MATRIX SPIKE AMT. (mg/L)	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)	QC LIMITS (%)	RELATIVE DIFFERENCE	QC RPD	SAMPLE
1,1-Dichloroethene	10	100	117	128	61-145	9	14	Blank
Trichloroethene	10	100	100	111	71-120	10	14	Blank
Benzene	10	100	110	121	76-127	10	11	Blank
Toluene	10	100	104	115	76-127	10	13	Blank
Chlorobenzene	10	100	127	124	75-130	2	13	Blank

QA/QC FORM

	ORIGINAL RESULT (mg/L)	MATRIX SPIKE AMT. (mg/L)	MATRIX SPIKE RECOVERY (%)	MATRIX SPIKE DUPLICATE RECOVERY (%)	QC LIMITS (%)	RELATIVE DIFFERENCE	QC RPD	SAMPLE
Phenol	<10	200	32	17	5-112	17	23	Blank
2-Chlorophenol	<10	200	60	52	23-134	14	29	Blank
1,4-Dichlorobenzene	<10	100	59	51	20-124	15	32	Blank
N-Nitroso-di-n-propylamine	<10	100	62	55	D-230	12	55	Blank
1,2,4-Trichlorobenzene	<10	100	67	58	44-142	15	28	Blank
4-Chloro-3-methylphenol	<10	200	100	92	22-147	8	37	Blank
Acenaphthene	<10	100	71	64	47-145	10	28	Blank
4-Nitrophenol	<10	200	64	64	D-132	0	47	Blank
2,4-Dinitrotoluene	<10	100	88	79	39-139	11	22	Blank
Pentachlorophenol	<10	200	124	114	14-176	8	49	BLank

6756

HALLIBURTON NUS Environmental
Corporation and Subsidiaries

CHAIN OF CUSTODY RECORD

PROJECT NO.: 3688	**SITE NAME:** SITE S-1', KELLY AFB, TX
SAMPLERS (SIGNATURE): Paul F.	

P.O. #
2047-3688-
P000313

STATION NO.	DATE	TIME	COMP	GRAB	~~STATION LOCATION~~ SAMPLE NUMBER (ID)	NO. OF CON-TAINERS	TCLP VOAs & SEMI-VOAs						REMARKS
CD #2	04/19 1994	0832	X		KS1-CD1/2-3688	3	X						ONE SAMPLE IN 3 PARTS
													SEND ORIGINAL LAB REPORT
													OF RESULTS TO:
													MR. CLIFF BLANCHARD
													BROWN & ROOT ENVIRONMENTAL
													800 OAK RIDGE TURNPIKE A-600
													OAK RIDGE, TN 37830
													(615) 483-9900
													SEND INVOICE TO KAREN SHERROD AT ABOVE ADDRESS
													FAX RESULTS ASAP TO:
													CLIFF BLANCHARD (615) 483-2014 AND
													RAY BETTMENG (210) 927-1118

RELINQUISHED BY (SIGNATURE): Paul F.	**DATE / TIME:** 4/18/94 0955	**RECEIVED BY (SIGNATURE):**	**RELINQUISHED BY (SIGNATURE):**	**DATE / TIME:** 4-19-94 11:10	**RECEIVED BY (SIGNATURE):** Anna Singletary
RELINQUISHED BY (SIGNATURE):	**DATE / TIME:**	**RECEIVED BY (SIGNATURE):**	**RELINQUISHED BY (SIGNATURE):**	**DATE / TIME:**	**RECEIVED BY (SIGNATURE):**
RELINQUISHED BY (SIGNATURE):	**DATE / TIME:**	**RECEIVED FOR LABORATORY BY (SIGNATURE):**	**DATE / TIME:**	**REMARKS:**	

NUS 440 REVISED 0891

APPENDIX A.12

TABLE A.12 - 1
IITRI COST SUMMARY - PHASE II
RF SOIL DECONTAMINATION DEMONSTRATION

ITEM	UNIT COST ($)	SUBTOTALS
RF SOURCE		**$883,852**
RF TRANSMITTERS	242,000	
RF CONTROL UNIT	600,000	
ELECTRICITY	41,852	
RF APPLICATION		**$25,244**
EXCITOR ELECTRODES	11,280	
COAXIAL TRANSMISSION LINE	2,300	
GROUND ELECTRODES	11,664	
RF SHIELD		**$7,217**
DOGHOUSE	6,664	
MESH SCREEN	553	
MEASUREMENT/CONTROL		**$21,670**
THERMAL MEASUREMENT WELLS (TMW)	66	
VACUUM MEASUREMENT WELLS (VMW)	29	
THERMOCOUPLES (TCs) AND WIRE	3,437	
VACUUM/PRESSURE GAUGES	138	
GAS CHROMATOGRAPH	18,000	
VAPOR COLLECTION/TRANSFER PIPING		**$3,541**
VAPOR BARRIER	1,492	
GROUND ELECTRODE PIPING	1,188	
HORIZONTAL EXTRACTION PIPING	363	
EXTRACTION MANIFOLD	497	
VAPOR EXTRACTION/TREATMENT		**$251,700**
REGENERATIVE BLOWER	1,700	
CATOX TREATMENT UNIT	250,000	
SITE SUPPORT		**$80,050**
UTILITY TRUCK	35,000	
CELLULAR TELEPHONE	4,875	
MISCELLANEOUS ODCS	47,560	
FENCING	9,200	
GRAVEL	2,500	
CONCRETE	7,108	
WASTE DISPOSAL	7,108	
LIGHTS	1,700	
SUBCONTRACTOR SUPPORT		**$190,954**
DRILLING FOR SYSTEM INSTALL	24,664	
IN GROUND SYSTEM ABANDONMENT	23,390	
RF CONSULTANTS	100,000	
ANALYTICAL	42,900	
LABOR		**$477,389**
SITE PREPARATION/SET-UP	55,688	
TREATMENT	403,139	
SITE RESTORATION/DEMOBILIZATION	18,563	
	SUBTOTAL	**$1,941,617**
ODC MARKUP	10.60%	**$155,208**
ENGINEERING, PROCUREMENT, & PROJECT MANAGEMENT	15%	**$219,634**
CONTENGENCY	15%	**$219,634**
	TOTAL	**$2,536,093**

TABLE A.12 - 2
IITRI COST DETAILS - PHASE II
RF SOIL DECONTAMINATION DEMONSTRATION

UT PARAMETERS

ATMENT	LENGTH	44	EXCITOR TO EXCITOR (FT)	4	HEAT TIME, WKS/CELL	8
AREA (FT)	WIDTH	32	EXCITOR TO GROUND (FT)	8	COOL TIME, WKS	4
	DEPTH	20	GROUND TO GROUND (FT)	4		
			EXCITOR ELECTRODE DEPTH (FT)	20	TREATMENT TIME (WKS)	20
CELL AREA	WIDTH	16	GROUND ELECTRODE DEPTH (FT)	28	MOB/DEMOB TIME (WKS)	6
(FT)	LENGTH	32				
	DEPTH	20	VAP. BARRIER OVERLAP (FT)	10		

RF SOURCE

RF TRANSMITTERS	**$242,000.00**	CAPITAL

25kW/240V TRANSMITTERS INCLUDES TRAILER, DUMMY LOAD, CHOKES, ELECTRIC FIELD MEASUREMENT EQUIPMENT, TRANSFORMERS, MATCHING NETWORKS OR TUNERS, INSTRUMENTATION FOR ELECTRICAL/RF/TEMPERATURE DATA MANAGEMENT, AND TOOLS

100	POWER REQUIRED FOR SYSTEM (kW)
25	INDIVIDUAL TRANSMITTER POWER (kW)
$55,000.00	COST PER TRANSMITTER
$22,000.00	COST FOR TRAILER
$242,000.00	TOTAL TRANSMITTER/TRAILER COST

RF CONTROL UNIT	**$600,000.00**	CAPITAL

HOUSED IN 40' SEMI TRAILER WITH COMPUTERIZED INSTRUMENTATION FOR THE MONITORING AND CONTROL OF RF, ELECTRICAL, TEMPERATURE, VAPOR FLOW AND TREATMENT. THIS TRAILER WILL ALSO HOUSE THE SITE OFFICE AND GC LAB AREA.

$600,000.00	COST FOR CONTROL UNIT (EST/KAI)

ELECTRICITY	**$41,852.16**	DISPOSABLES

$0.07	COST PER KILOWATT HOUR
170	POWER USAGE IN KW/H DURING HEATING
3,360	HEATING HOURS (168/WK X TREATMENT TIME)
571,200	KWH USED DURING HEATING
15	POWER USAGE IN KW/H DURING COOLING/OTHER
672	COOLING/OTHER HOURS (168/WK X COOLING AND MOB/DEMOB TIME)
10,080	KWH USED DURING COOLING/OTHER
581,280	TOTAL KWH USED FOR PROJECT
$41,852.16	TOTAL COST FOR ELECTRICITY

RF APPLICATION

EXCITOR ELECTRODES	**$11,280.00**	CAPITAL

ALL ARE CONSTRUCTED OF SCH 40 COPPER PIPE WITH BOTTOM PLUGS
OUTSIDE TWO EXCITORS ARE 3" DIAM. TOPPED WITH 3"/6" COPPER ELBOWS (90) INSET 4' FROM END OF CELL
INSIDE EXCITORS ARE 2" DIAM. TOPPED WITH 2" x 6" x 6" COPPER TEES
ALL EXCITORS TIED TOGETHER BY 6" DIAM. SCH 40 COPPER PIPE
MATERIALS TO MAKE UP 2 ROWS OF EXCITORS (PIPE AND CAP) REQUIRED

12	NO. OF 2" DIAM. EXCITORS = CELL LENGTH - INSET/SPACING - NO. OF 3" DIAM. EXCITORS
240	TOTAL LF = NO. OF EXCITORS PER CELL X DEPTH X 2 ROWS
$24.00	COST PER LF FOR 2" DIAM. SCH 40 COPPER PIPE (EST.)
$5,760.00	COST FOR 2" DIAM. EXCITORS = COST PER LF X TOTAL LF
$150.00	COST FOR EACH COPPER 2"/6"/6" TEE AND BOTTOM PLUG (EST)
$1,800.00	COST FOR TEES/CAPS = EXCITORS PER CELL X COST PER TEE/PLUG
4	NO. OF 3" DIAM. EXCITORS (PER ROW = 2)
80	TOTAL LF = NO. OF EXCITORS PER CELL X DEPTH
$38.00	COST PER LF FOR 3" DIAM. SCH 40 COPPER PIPE (SAIC EST.)
$3,040.00	COST FOR 3" DIAM. EXCITORS = COST PER LF X TOTAL LF
$170.00	COST FOR EACH COPPER 3"/6"/6" TEE AND BOTTOM PLUG (EST)
$680.00	COST FOR TEES/CAPS = NO. OF EXCITORS X COST PER TEE/PLUG

COAXIAL TRANSMISSION LINE **$2,300.00** CAPITAL

CONSTRUCTED OF 6" SCH 40 COPPER PIPE IN 3 SECTIONS TIED WITH FLANGES
TIES RF SOURCE TO MID-POINT OF EXCITOR ELECTRODE ROW, EXTENDS 20' FROM GROUND ROW

$120.00	COPPER ELBOW (EST)
$200.00	COPPER TEE (EST)
$45.00	COST PER LF - 6" DIAM. SCH 40 COPPER PIPE (EST.)
42	TOTAL LF = 0.5 X GROUND ROW LENGTH + 20'
$30.00	6" DIAM. COPPER COMPATIBLE FLANGES
$2,300.00	TOTAL COST = PIPE, 6 FLANGES, 1 TEE AND 1 ELBOW

GROUND ELECTRODES **$11,664.00** CAPITAL

ALL GROUNDS ARE CONSTRUCTED OF 3" DIAM. SCH 40 ALUMINUM PIPE WITH COUPLING AND BOTTOM PLUG
ALL GROUNDS ARE TOPPED WITH 3"/2" ALUMINUM ELBOWS WITH ALUMINUM BUS BAR BRACKETS
GROUND ELECTRODES TIED TOGETHER WITH BUS BARS
MATERIALS TO MAKE UP 3 ROWS OF GROUNDS (PIPE, COUPLING, BOTTOM PLUG, AND ELBOW)

36	NO. OF GROUNDS = ROWS X 12
1008	TOTAL LF = NO. OF GROUNDS PER CELL X 1.5 CELLS (3 ROWS) X DEPTH
$8.00	COST PER LF FOR 3" DIAM. SCH 40 ALUMINUM PIPE (EST.)
$8,064.00	COST FOR 3" DIAM. GROUNDS = COST PER LF X TOTAL LF
$100.00	COST FOR ALUMINUM ELBOW, COUPLING, AND BOTTOM PLUG SET
$3,600.00	COST FOR ELBOWS/CAPS = GROUNDS PER CELL X COST PER ELBOW/PLUG

RF SHIELD

DOGHOUSE **$6,663.78** CAPITAL

CONSTRUCTED OF 0.050 CORRUGATED ALUMINUM SHEETS AND 1/8" ALUMINUM END PLATES

5.80	COST PER SQUARE FOOT OF 2.67 X 7/8 CORRUGATED ALUMINUM
905	SQUARE FEET OF ALUMINUM SHEET REQUIRED
$5,246.73	TOTAL COST FOR CORRUGATED ALUMINUM SHEETING
7.05	COST PER SQUARE FOOT FOR ALUMINUM PLATE END WALLS
201	SQUARE FEET OF ALUMINUM PLATE REQUIRED
$1,417.05	TOTAL COST FOR ALUMINUM PLATE
$6,663.78	TOTAL COST FOR DOGHOUSE

MESH SCREEN **$552.96** DISPOSABLE

EXTENDS 10' OUT FROM PERIMETER OF DOGHOUSE IN ALL DIRECTIONS

0.32	COST PER SQUARE FOOT OF ALUMINUM MESH
1728	SQUARE FEET OF ALUMINUM MESH REQUIRED
$552.96	TOTAL COST FOR ALUMINUM MESH

MEASUREMENT/CONTROL

THERMAL MEASUREMENT WELLS (TMW) **$65.70** DISPOSABLE

TMWs ARE CONSTRUCTED OF 3" DIA GREEN THREAD FIBERGLASS PIPE COMPLETED 2' AGL

6	NO. OF TMWs
180	LF OF TMWs= NO. OF TMWsX (GROUND ELECTRODE DEPTH + 2' STICKUP)
$7.30	COST PER 20 LF OF 3" DIAM. GREEN THREAD FIBERGLASS (ACT.)
$65.70	COST FOR TOTAL LF OF TMWs = TOTAL LF/20 X COST PER 20 LF

PRESSURE MEASUREMENT WELLS (PMW) **$28.80** DISPOSABLE

PMWs ARE CONSTRUCTED OF 1" DIA SCH 40 PVC PIPE COMPLETED 2' AGL

8	NO. OF PMWs
30	LF PER PMW = GROUND ELECTRODE DEPTH + 2" STICKUP LENGTH
240	LF OF PMWs= NO. OF PMWs X PMW DEPTH
$2.40	COST PER 20 LF OF 1" DIAM. SCH 40 PVC PIPE (EST.)
$28.80	COST FOR TOTAL LF OF PMWs = TOTAL LF/20FT X COST PER 20 LF

THERMOCOUPLES (TCs) AND WIRE

$3,437.12 DISPOSABLE

EVERY 3RD EXCITOR ELECTRODE IN A ROW WILL HAVE K-TYPE TCs AT 6', 12' AND 18' DEPTHS
ACH TC WILL COME WITH 10' OF WIRE, EXTRA WIRE AND PLUG/JACK FOR EACH TC REQUIRED
RE REQUIRED TO EXTEND 15' FROM TOP OF EXCITOR AT GROUND LEVEL

48	TOTAL TCs = TCs PER EXCITOR X EXACTERS PER ROW X 2 ROWS
$19.50	COST PER TC (EST.)
$936.00	TOTAL TC COST = TOTAL TCs X COST PER TC
176	LF WIRE FOR TCs AT 6' DEPTH = NO. OF 6' DC X 11 EXTRA FEET
272	LF WIRE FOR DC AT 12' DEPTH = NO. OF 12' DC X 17 EXTRA FEET
368	LF WIRE FOR DC AT 18' DEPTH = NO. OF 18' DC X 23 EXTRA FEET
816	TOTAL LF OF EXTRA WIRE
$584.00	COST PER 1000 LF OF WIRE (EST.)
$2,336.00	COST FOR WIRE = TOTAL LF (1000s) X COST PER 1000 LF
$4.30	COST OF PLUG/JACK FOR EXTRA WIRE (EST.)
48	TOTAL PLUG/JACKS = TOTAL DC
$165.12	TOTAL COST FOR PLUG/JACKS = TOTAL PLUG/JACKS X COST PER X 20% DISCOUNT (EST.)

VACUUM/PRESSURE GAUGES

$138.00 CAPITAL

MAGNAHELIC 0-10" AND 0-40" GAGES

46.00	COST PER GAUGE
3	GAUGES REQUIRED
$138.00	TOTAL COST FOR GAUGES

GAS CHROMATOGRAPH

$18,000.00 RENTAL

PORTABLE GC

3000.00	MONTHLY RENTAL RATE FOR PORTABLE GC
6.00	TOTAL MONTHS NEEDED
$18,000.00	TOTAL COST FOR PORTABLE GC RENTAL

VAPOR COLLECTION/TRANSFER PIPING

VAPOR BARRIER

$1,492.48 DISPOSABLE

3 LAYER BARRIER, TWO LAYERS OF REINFORCED PLASTIC AND ONE LAYER OF 2" INSULATION
BARRIER WILL EXTEND 12' BEYOND EDGE OF CELL IN ALL DIRECTIONS
INSULATION WILL COVER AREA UNDER SHIELD ONLY WITH NO OVERLAP

2240	PLASTIC BARRIER DIMENSIONS (SQ. FT) = (CELL WIDTH + 20') X (CELL LENGTH + 20')
1024	INSULATION DIMENSIONS (SQ. FT) = CELL WIDTH X CELL LENGTH
$0.13	COST PER SQ. FT. FOR REINFORCED PLASTIC BARRIER MATERIAL (EST.)
$0.16	COST PER SQ. FT. FOR 2" FIBERGLASS INSULATION (MCM CARR)
$1,492.48	COST FOR BARRIER = (.13/SQ. FT. X 4320 SQ. FT.) X 2 LAYERS + (.16/SQ. FT. X 1600 SQ. FT.) X 2 BARRIERS

GROUND ELECTRODE PIPING

$1,188.42 CAPITAL

FOUR GROUND ELECTRODE TIED TO 2" GREEN THREAD FIBERGLASS PIPE WITH BLACK 2" VACUUM HOSE
PIPE/ELECTRODE JUNCTION = TEE, 2 ADAPTERS, 2 COUPLING SETS, 2" BALL VALVE, AND 2' OF 2" VACUUM HOSE
EACH SECTION CONSTRUCTED IN TWO PIECES WITH A MIDPOINT FLANGE, AND END FLANGE

34.15	COST FOR 2" FIBERGLASS TEE (VEE)
5.00	COST FOR THREADED FIBERGLASS ADAPTER (VEE)
9.15	COST FOR 2" COUPLING (1 MALE/1 FEMALE) (VEE)
2.94	COST PER LV. OF VACUUM HOSE (VEE)
19.90	COST FOR 2" BRONZE BALL VALVE (ESCO)
15.50	COST FOR 2" FLANGE 15.50 (VEE)
88.23	COST FOR ONE JUNCTION (TEE, 2 ADAPTERS, 2 COUPLING SETS, BALL VALVE, AND 2' OF VACUUM HOSE
0.26	COST PER LF FOR 2" GREEN THREAD FIBERGLASS PIPE
28.00	COST FOR 2" FIBERGLASS END CAP
43.22	COST FOR PIPING ONE GROUND ELECTRODE ROW (CELL LENGTH + 10'), 2 FLANGES
$1,188.42	TOTAL COST = ((JUNCTION COST X JUNCTIONS PER ROW) + PIPING COST) X 3 ROWS

HORIZONTAL EXTRACTION PIPING

$362.97 CAPITAL

TWO SECTIONS OF HORIZONTAL PIPING PER CELL CONSTRUCTED OF 2" GREEN THREAD FIBERGLASS PIPE
EACH SECTION CONSTRUCTED IN TWO PIECES WITH A FLANGE, END CAP, AND 2 ELBOWS

28.00	COST FOR 2" FIBERGLASS END CAP
15.50	COST FOR 2" FLANGE 15.50 (VEE)
0.26	COST PER LF. FOR 2" GREEN THREAD FIBERGLASS PIPE
9.15	COST FOR 2" SLEEVE COUPLING
23.65	COST FOR 2" 90 DEG. ELBOW
26	INDIVIDUAL SECTION LENGTH (CELL WIDTH + 10')
30	LENGTH OF PIPE IN FT (INDIV. SECTIONS)
1	SLEEVE COUPLINGS PER SECTION
120.99	COST FOR ONE HORIZ. EXT. SECTION (PIPE, 2 FLANGES, 4 COUPLINGS, 2 ELBOWS, 1 END CAP)
3	HORIZ. EXT. SECTIONS
$362.97	TOTAL COST = HORIZ. EXT. SECTIONS X CELLS INSTALLED

EXTRACTION MANIFOLD

$497.13 CAPITAL

TIES TOGETHER ALL VAPOR EXTRACTION COMPONENTS FOR TWO CELLS
COMPONENTS FOR 2 CELLS INCL. 3 ROWS GROUND ELECTRODES AND 3 HORIZ. EXTRACTION SECTIONS
MANIFOLD CONSTR. WITH FLANGE DIVIDING EACH CELL AND VALVE BETWEEN EACH COMPONENT
FLEXIBLE VACUUM HOSE TIES MANIFOLD TO INDIV. EXTRACTION COMPONENTS

15.50	COST FOR 2" FLANGE 15.50 (VEE)
0.26	COST PER LF FOR 2" GREEN THREAD FIBERGLASS PIPE
34.15	COST FOR 2" FIBERGLASS TEE (VEE)
5.00	COST FOR THREADED FIBERGLASS ADAPTER (VEE)
9.15	COST FOR 2" HOSE COUPLING (1 MALE/1 FEMALE) (VEE)
2.94	COST PER LF OF VACUUM HOSE (VEE)
19.90	COST FOR 2" BRONZE BALL VALVE (ESCO)
23.65	COST FOR 2" 90 DEG. ELBOW
106	LENGTH OF PIPE = 3 X CELL LENGTH + 10' FOR MISC. SECTIONS
6	VALVES REQUIRED = 3 ELECTRODE ROWS + 3 HORIZ, EXT. SECTIONS
6	NUMBER OF 3' HOSE SECTIONS WITH 2 COUPLING SETS REQUIRED
$497.13	TOTAL COST = PIPE, 2 FLANGES, 3 ELBOWS, 6 TEES, 6-3' HOSE SECTIONS WITH COUPLINGS

VAPOR EXTRACTION/TREATMENT

REGENERATIVE BLOWER

$1,699.80 CAPITAL

HOUSED ON 40' FLATBED TRAILER WITH CAT/OX UNIT

1053.00	REGENERATIVE BLOWER COST - GAST MODEL R6350A-2
56.80	VACUUM GAUGE
109.80	MUFFLER
307.50	FILTER
172.70	RELIEF VALVE
$1,699.80	TOTAL COST FOR BLOWER AND ACCESSORIES

CATALYTIC OXIDATION TREATMENT UNIT WITH NaOH PRECIPITATION

$250,000.00 CAPITAL

HOUSED ON A 40' FLAT BED TRAILER. UNIT INCLUDES AMBIENT AIR CONDENSER, WATER SEPARATOR, CATALYTIC OXIDIZER, AND NaOH PRECIPITATION UNIT.

$250,000.00 TOTAL COST FOR TRAILER-MOUNTED TREATMENT UNIT

LABOR

GENERAL

LABOR

SITE PREPERATION AND DEMOB

	SALARY	HR RATE	
PROJECT MANAGER (ENGR)	60,000	28.85	
SR RF ENGINEER	55,000	26.44	
JR RF ENGINEER	45,000	21.63	
SR FIELD TECHNICIAN	35,000	16.83	
		93.75	
		117.19	OVERHEAD (125%)
		21.09	G&A (10%)
		232.03	CREW HOUR

OPERATION

	SALARY	HR RATE	
PROJECT MANAGER (ENGR)	60,000	28.85	
SR RF ENGINEER	55,000	26.44	
JR RF ENGINEER	45,000	21.63	
JR RF ENGINEER	45,000	21.63	
SR FIELD TECHNICIAN	35,000	16.83	
SR FIELD TECHNICIAN	35,000	16.83	
		132.21	
		165.26	OVERHEAD (125%)
		29.75	G&A (10%)
		327.22	CREW HOUR

SITE PREPARATION/SET-UP **$55,687.50** LABOR

INCLUDES FENCING, MATERIAL RECEIPT, TRAILER/SITE SETUP, ELECTRICAL, DOGHOUSE FAB., MISC. ACTIVITIES
4-MAN CREW WORKING 8 HR DAYS, 5 DAYS PER WEEK

6	TIME REQUIRED IN WEEKS
232.03	LABOR RATE FOR 4 MAN CREW (INCLUDES ALL INDIRECTS)
40	CREW HOURS PER WEEK
240	TOTAL CREW HOURS REQUIRED FOR SITE PREPARATION/SET-UP
$55,687.50	TOTAL COST FOR SITE PREPARATION/SET-UP

TREATMENT **$403,139.42** LABOR

INCLUDES RF/SVE OPERATION, PROJECT MANAGEMENT, AND REPORTING
DOES NOT INCLUDE INITIAL 4 WEEK SET-UP OR FINAL DEMOBILIZATION
2 MEN ON SITE 24 HOURS PER DAY 7 DAYS PER WEEK (=56 CREW HRS)

0.1	CONTINGENCY FACTOR FOR LOST TIME
327.22	LABOR RATE FOR 4 MAN CREW (INCLUDES ALL INDIRECTS)
56	CREW HOURS PER WEEK
20	TOTAL WEEKS OF TREATMENT
1120	TOTAL CREW HOURS REQUIRED FOR TREATMENT
$403,139.42	TOTAL COST FOR TREATMENT CREW

SITE RESTORATION/DEMOBILIZATION **$18,562.50** LABOR

2	TIME REQUIRED IN WEEKS
232.03	LABOR RATE FOR 4 MAN CREW (INCLUDES ALL INDIRECTS)
40	CREW HOURS PER WEEK
80	TOTAL CREW HOURS REQUIRED FOR SITE RESTORATION/DEMOBILIZATION
$18,562.50	TOTAL COST FOR SITE RESTORATION/DEMOBILIZATION

SITE SUPPORT

TRUCKS AND TRAILERS **$35,000** CAPITAL

ONE TON UTILITY TRUCK WITH OVERHEAD WINCH, HYDRAULIC LIFT, AND SMALL TRAILER

CELLULAR TELEPHONE **$4,875.00** SERVICES

750.00	MONTHLY RENTAL RATE
7	MONTHS NEEDED
$4,875.00	TOTAL RENTAL COST FOR CELLULAR TELEPHONE

MISCELLANEOUS ODCS

$47,559.72 DISPOSABLES

		UNIT	UNIT COST	EST. QTY
21.10	ALUMINUM FOIL	ROLL	2.11	10
39.84	BARRIER TAPE	ROLL	9.96	4
116.10	BOOT COVERS	PAIR	11.61	10
455.00	CHEMICAL TOILET	MONTH	65.00	7
204.00	COTTON GLOVES	PAIR	0.68	300
6.00	DECON TUB	EACH	3.00	2
375.00	16-GAL EYEWASH	EACH	375.00	1
205.00	DRAEGER PUMP	EACH	205.00	1
132.00	DRAEGER TUBES	EACH	33.00	4
5145.00	FRAC TANK RENTAL	DAY	35.00	147
546.20	FULL FACE RESP.	EACH	136.55	4
53.00	HARD HATS	EACH	5.30	10
4929.80	HNU DETECTOR	EACH	4,929.80	1
78.85	HPLC (4L)	4L	15.77	5
1253.00	LEL/O2 METER W/ ACC.	EACH	1,253.00	1
146.32	LIQUINOX DETERGENT	GAL	18.29	8
86.34	METHANOL (4L)	4L	28.78	3
2000.00	MILEAGE (TRUCK)	MILE	0.50	4000
84.60	MSA COMB. CARTRIDGES	EACH	2.82	30
600.00	NaOH	LB	0.15	4000
113.00	NITRILE GLOVES	PAIR	1.13	100
5046.00	OVA	EACH	5,046.00	1
28.10	PACKING TAPE	ROLL	2.81	10
74.00	PAPER TOWELS	ROLL	0.74	100
23284.80	PROPANE (CAT/OX)	GAL	0.63	36960
10.08	PIN FLAGS (BDL50)	BDL	2.52	4
209.60	SAFETY GLASSES	EACH	5.24	40
21.60	SAMPLE BOWL/TROWEL	EACH	7.20	3
74.20	SPAN GAS (HNU)	TANK	37.10	2
72.08	SPAN GAS (LEL/O2)	TANK	36.04	2
1850.00	STEAM CLEANER	EACH	1,850.00	1
43.45	SURGEONS GLOVES	BOX	8.69	5
127.00	TRASH BAGS	BOX	6.35	20
104.76	TYVEK COVERALLS	EACH	2.91	36
23.90	ZIPLOCK BAGS	BOX	2.39	10
$47,559.72	TOTAL MISCELLANEOUS ODC COST			

FENCING

$9,200.00 CAPITAL

FENCE DIMENSIONS ARE 300' BY 200', INSTALLED WITH TWO GATES

11.50	COST PER LINEAR FOOT FOR FENCING, INCLUDES GATES
800	TOTAL LINEAR FOOTAGE REQUIRED
$9,200.00	TOTAL COST

GRAVEL

$2,500.00 DISPOSABLE

USED TO REGRADE SITE DURING RESTORATION

$2,500.00	TOTAL COST FOR GRAVEL (EST)

CONCRETE

$1,400.00 DISPOSABLE

TRANSFORMER PAD

$1,400.00	8' X 8' CONCRETE PAD WITH FENCING (EST.)

LIGHTS

$1,700.00 DISPOSABLE

PERIMETER LIGHTS FOR SITE SECURITY AND NIGHT OPERATIONS

85.00	EST. COST PER LIGHT INCLUDING POST AND ELECTRICAL HOOKUP
20	NUMBER OF LIGHTS REQUIRED
$1,700.00	TOTAL COST FOR LIGHTING

WASTE DISPOSAL	**$7,107.50**	SERVICES

SLUDGE FROM NaOH PRECIPITATION UNIT, LIQUID FROM AMBIENT AIR CONDENSER, EXCESS SOIL, AND MISCELLANEOUS (PPE, USED HOSE, ETC.)

2.50	COST PER MILE FOR HAZWASTE TRANSPORT (EST)
25.00	COST FOR BULK DRUM TRANSPORT (EST)
0.40	COST FOR INCINERATION PER POUND (EST)
150.00	COST PER DRUM FOR HANDLING DURING INCINERATION PER POUND (EST)
350.00	COST PER DRUMFOR LANDFILL (EST)
300.00	COST PER DRUM FOR LANDFILL PICK-UP & HANDLING (EST)
0.25	COST PER GALLON FOR WATER TREATMENT (EST)
6,000	NaOH SLUDGE (LB) - (10 DRUMS)
$4,150	COST TO DRUM, TRANSPORT, & INCINERATE
5,000	LIQUID (GAL)
630	DECON WATER (GAL)
$1,533	COST TO TRANSPORT (50 MILES) & TREAT
3	MISC. (DRUMS)
$1,425	COST TO TRANSPORT & LANDFILL

SUBCONTRACTOR SUPPORT

DRILLING AND ABANDONMENT	**$24,664.20**	SERVICES

SYSTEM INSTALL

1.00	COST FOR 100 LB. BAG SAND BACKFILL (1 CUBIC FOOT)
10.50	COST FOR 50 LB BAG BENTONITE CHIPS (0.79 CUBIC FEET)
13.00	COST PER FOOT FOR BORING (4.25" HS AUGER)
15.00	COST PER FOOT FOR BORING (8" HS AUGER)
100.00	COST PER HOUR FOR STANDBY, SITE RESTORATION, MISC. CREW TIME
30.00	COST PER HOUR FOR DECON
250.00	MOB/DEMOB RATE EACH MOBILIZATION
30.00	COST PER BORING FOR SAMPLING
12	GROUND ELECTRODES PER ROW
3	GROUND ELECTRODE ROWS IN TREATMENT AREA
30	DEPTH OF GROUND ELECTRODE BOREHOLES
1080	TOTAL LINEAR FOOTAGE OF GROUND ELECTRODE BOREHOLES
8	EXCITOR ELECTRODES PER ROW
2	EXCITOR ELECTRODE ROWS IN TREATMENT AREA
22	DEPTH OF EXCITOR ELECTRODE BOREHOLES (8' HS AUGER)
352	TOTAL LF OF EXCITOR ELECTRODE BOREHOLES (8' HS AUGER)
6	THERMAL MEASUREMENT WELLS
180	TOTAL LF OF THERMAL MEASUREMENT WELLS (4.25' AUGER)
8	PRESUURE MEASUREMENT WELLS
127	TOTAL LF OF PRESSURE MEASUREMENT WELLS (4.25" AUGER)
1432	LF OF GROUND/EXCITOR ELECTRODE BORING
$18,616.00	DRILLING COST AT $15 PER FOOT
307	LF OF PRESSURE/THERMAL MEASUREMENT WELLS
$3,991.00	DRILLING COST AT $13 PER FOOT
12	NUMBER OF BORING REQUIRING SAMPLING
$360.00	COST FOR SAMPLING ($30 EACH)
12	REQUIRED AUGER DECONS (BEFORE EACH SAMPLE AND AT END)
1	TIME FOR EACH DECON (HRS)
$360	COST FOR DECON
501	100 LB. BAGS OF SAND REQUIRED (7 BAGS PER 20' OF BORING)
$501.20	TOTAL SAND COST
52	50 LB. BAGS OF BENTONITE REQUIRED (2 BAGS PER BOREHOLE) FOR INSTALLATION
$546.00	TOTAL BENTONITE COST

1	MOBILIZATIONS FOR ENTIRE TREATMENT AREA
250.00	COST PER MOBILIZATION/DEMOBILIZATION
$250.00	TOTAL MOBILIZATION COST

4	STANDBY HRS (EST)
$400.00	COST PER HR FOR STANDBY

SYSTEM ABANDONMENT (DISMANTLE)

$23,390.00 SERVICES

100.00	COST PER HR FOR RIG TIME
10.50	COST OF 50 LB BAG BENTONITE CHIPS (0.79 CUBIC FEET)
30.00	COST PER HOUR FOR DECON
250.00	MOB/DEMOB RATE
30.00	COST PER BORING FOR SAMPLING
2.00	TIME IN HOURS TO ABANDONE AN EXCITOR ELECTRODE (PULL & BENTONITE FILL)
2.50	TIME IN HOURS TO ABANDONE A GROUND ELECTRODE (PULL & BENTONITE FILL)
2.50	TIME IN HOURS TO ABANDONE A PMW OR TMW (PULL & BENTONITE FILL)
15.00	COST FOR EACH ABANDONMENT REPORT
5.00	CUBIC FT BENTONITE PER HOLE (EST)

10	NUMBER OF BORING REQUIRING SAMPLING
$300.00	COST FOR SAMPLING ($30 EACH)

10	NUMBER OF SOIL SAMPLE HOLES
12	AVERAGE DETPH IN FT OF BOREHOLE (8" DIA)
$1,800.00	COST OF DRILLING

16	NUMBER OF EXCITOR ELECTRODES
$3,440	COST TO ABANDONE

36	NUMBER OF GROUND ELECTRODES
$9,540	COST TO ABANDONE

14	NUMBER OF PMW's AND TMW's EXCITOR ELECTRODES
$3,710	COST TO ABANDONE

76	NUMBER OF HOLES
$3,990	BENTONITE COST

12	REQUIRED AUGER DECONS (BEFORE EACH SAMPLE AND AT END)
1	TIME FOR EACH DECON (HRS)
$360	COST FOR DECON

1	MOBILIZATIONS FOR ENTIRE TREATMENT AREA
250.00	COST PER MOBILIZATION/DEMOBILIZATION
$250.00	TOTAL MOBILIZATION COST

ANALYTICAL

$42,900.00 SERVICES

SOIL

850.00	ANALYTICAL COST PER SAMPLE FOR VOCs, SVOCs, TPH, MOISTURE, AND SIEVE
22	NUMBER OF SAMPLES TO BE ANALYZED (20 SOIL & 2 WATER)
100.00	SAMPLE SHIPPING COST PER EVENT
200.00	TOTAL SHIPPING COST
$18,900.00	TOTAL ANALYTICAL COST

VAPOR STREAM

4000.00	ANALYTICAL COST PER SAMPLE FOR VOCs, SVOCs, TPH, MOISTURE, AND SIEVE
6	NUMBER OF SAMPLES TO BE ANALYZED (20 SOIL & 2 WATER)
$24,000.00	TOTAL ANALYTICAL COST

TABLE A.12 - 3
IITRI AMORTIZATION COST DETAILS
RF SOIL DECONTAMINATION DEMONSTRATION

CAPITAL EQUIPMENT ITEM	EQUIPMENT COST	SALVAGE VALUE	ANNUAL CAPITAL COST	ANNUAL MAINTANENCE COST		ANNUAL COST
RF TRANSMITTER	$242,000	$48,400.00	$51,071	10%	$24,200	$75,271
RF CONTROL UNIT	$600,000	$120,000.00	$126,623	10%	$60,000	$186,623
COAXIAL TRANSMISSION LINE	$11,280	$564.00	$2,827	25%	$2,820	$5,647
EXCITOR ELECTRODES	$2,300	$115.00	$576	25%	$575	$1,151
GROUND ELECTRODES	$11,664	$583.20	$2,923	25%	$2,916	$5,839
RF SHIELD	$6,664	$333.19	$1,670	25%	$1,666	$3,336
VACUUM/PRESSURE GAUGES	$138	$0.00	$36	25%	$35	$71
GROUND ELECTRODE PIPING	$1,188	$0.00	$314	50%	$594	$908
HORIZONTAL EXTRACTION PIPING	$363	$0.00	$96	50%	$181	$277
EXTRACTION MANIFOLD	$497	$0.00	$131	50%	$249	$380
BLOWER	$1,700	$339.96	$359	10%	$170	$529
CATOX TREATMENT UNIT	$250,000	$50,000.00	$52,759	10%	$25,000	$77,759
TRUCKS AND TRAILERS	$35,000	$7,000.00	$7,386	10%	$3,500	$10,886
FENCING	$9,200	$0.00	$2,427	50%	$4,600	$7,027
TOTAL	**$1,171,994**	**$227,335**	**$249,199**		**$42,306**	**$375,704**

APPENDIX B

KAI DEMONSTRATION

APPENDIX B

KAI Demonstration

Section

B.1 DRAFT FINAL REPORT
B.2 FIELD LOG OF BORINGS
B.3 SVE DESIGN
B.4 OPERATING DATA, PERMEABILITY CALCULATIONS, SUBSURFACE PRESSURE ISOPACS
B.5 SUMMARY OF SOIL CONCENTRATIONS
B.6 VAPOR ANALYSIS
B.7 COST SUMMARY - PHASE II

APPENDIX B.1.

RF SYSTEM OPERATING DESCRIPTION
Appendix to final program report

FOR THE
TECHNOLOGY DEMONSTRATION OF
RADIO FREQUENCY SOIL DECONTAMINATION

AIR FORCE MATERIALS COMMAND
SA-ALC/EMR
KELLY AIR FORCE BASE, SAN ANTONIO, TEXAS 78241-5000

DECEMBER 1994 - DRAFT

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Oak Ridge, Tennessee 37830

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Contract Project No. 3688

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
ENVIRONMENTAL SERVICES OFFICE
ENVIRONMENTAL RESTORATION DIVISION (AFCEE/ESR)
BROOKS AIR FORCE BASE, TEXAS 78235-5000

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Overview

KAI Technologies, Inc. demonstrated its in-situ radio frequency heating process (RFH) at Kelly Air Force Base, San Antonio, Texas, IRP site S-1 during the spring of 1994. The technology demonstration was conducted under contract with Halliburton NUS under contract with the Armstrong Laboratory. Environics Directorate, AL/EQW, Tyndall Air Force Base in cooperation with the U.S. Environmental Protection Agency.

The primary objective of the RFH test of the KAI technology was to provide useful information to assist the Air Force in preparing for commercial scale demonstration of RFH decontamination. Other important objectives of this test were the validation of scale-up parameters for a comparison of the capacitance and antenna options of RFH Enhanced Soil Vapor Extraction Technology. Factors addressed during the program were the use of antennas for soil heating and vapor extraction, evaluation of contaminant movement through soil, and the removal of volatile organic compounds from the soil.

The KAI mobile RF system was prepared and ready to start heating within six working days of the systems arrival on site. The KAI RF heating system successfully delivered 15,549 kilowatt hours of energy to the heating zone within a total time span of 51.3 days. The RF generator developed RF power at a 19.93 kw/hr rate and was delivering this RF energy to the soil for 94.54% of the available testing period. The efficiency of RF energy transfer to the soil was measured directly during the heating period and exceeded 85% during operation. Successful impedance matching of the buried antenna occurred throughout testing and it was found that the antenna could be successfully tuned at all depths of the well. This is a significant point from a commercial system operation viewpoint. It means high coupling efficiency of RF energy to soil is maintained automatically as the antenna is moved to different heating zones during operation.

A dual antenna system was employed for this test. Measurements of mutual coupling between antennas during the heating period provided information on the removal of moisture. A significant change in the mutual coupling during heating occurred and demonstrates moisture and contaminant removal in a quantitative way. It will be an important diagnostic goal for commercial operation but will require development.

The program accomplishments summarized below are from the perspective of the RF heating system operation.

1.2 Accomplishments

- **The uniformity of soil heating within test volumes** - The heating program provided an extensive data set of temperature profiles.

  The initial heating rate of the test and several aspects of the SVE configuration produced thermal records that suggest that there are significant regions of uniformity with soil temperatures elevated well above 100 degrees centigrade (C).

There were regions, at a 3-foot radius from the antenna that exceeded 120 degrees C in the context of SVE flow influences. These infrared (IR), indirect temperature profiling measurements suggested that adjacent soils may have had localized heating temperatures for hydrocarbons at or above the 150 degree temperature goal of the program. The highest measured temperature for the program was a direct, peak measurement of 233.9 degrees C by a fiber optic temperature probe located on the outside of the heating well liner wall. The sustained high temperature readings in this region suggested a flow of a hot liquid into the volume surrounding the well liner sensor.

- **Commercial Operation** - The later portion of the heating program (21.3 days) provided operating statistics that can be used for commercial system cost and operation projections.

1.3 Modifications to Program Cost and Operation - This program was executed within the framework of several modifications. The most significant are:

- The on-site heating zone was defined as one-half of the volume originally planned as the treatment zone. This was due to the choice of a 27.12 MHz frequency to heat two smaller, 10-foot thick, adjacent volumes faster that the 13.56 MHz alternative ISM frequency. The 13.56 MHz frequency would have required more on-site heating time but would have covered the full 20-foot thick treatment zone.

- The RF heating applicators were positioned high in the well liner borehole spanning from 5 ft. down to 13 ft. within the heating zone.

- Initial delivery of 3-phase AC utility power to the RF heating system limited the RF energy generation rate. For the first 22 days of the program the system generated RF energy at an average rate of 9.42 kW/hour as opposed to the last 21.3 days of 19.93 kW/hour.

- The initial low power delivery rate did not allow the sequential heating of boreholes A1 and A2 in a manner that would allow their heating patterns to overlay as an approximation of a dual applicator, dual RF generator system.

- The design of the SVE system prevented meaningful conclusions being drawn about the measured changes in TRPH VOC and SVOC concentrations inside and outside the treatment zone as a result of RFH treatment.

1.4 Conclusions

The KAI mobile RF system performed as expected and provided significant RF energy coupling to the soil. Site set-up time was relatively fast and efficient. The applicator system (antennas) allowed for flexibility in the in-situ application of RF energy at selected depths. The coupling efficiency or energy transfer to soil was high (>85%). High efficiency is easily maintained as the applicator assumes different borehole depths for commercial scale uniform heating.

Radio frequency energy desorbs and mobilizes the contaminants more effectively than heat conduction by steam or hot air because thermal activation of the contaminant occurs at the molecular level throughout the RF treatment volume. The dipole-dipole bonding between contaminant molecule and soil particle is thermally agitated at the bonding site by the RF energy.

This result has significant implications for commercial RFH systems operating with tight soils. SVE efficiency appeared to increase substantially during the demonstration.

2.0 RF HEATING SYSTEM CONFIGURATION

KAI Technologies employed a mobile RF heating system, designated Rig #1 for this program. The system arrived on site on 28 March with all of the essential components for site setup and operation.

Figure 1 is a drawing of the mobile system with the overall dimensions of the truck and trailer combination. The trailer is a fifth wheel, gooseneck style, 28 ft. flatbed with a front mounted storage area and a removable 8 ft. x 8 ft. x 20 ft. removable steel shelter. The tow truck is a basic 1-ton pickup modified to tow the trailer as a combination vehicle with a licensed GCVW of 30,000 lbs. The truck is equipped with a roof rack suitable to carry 30-ft. applicators and tubes to the site and is an integral part of the site support strategy.

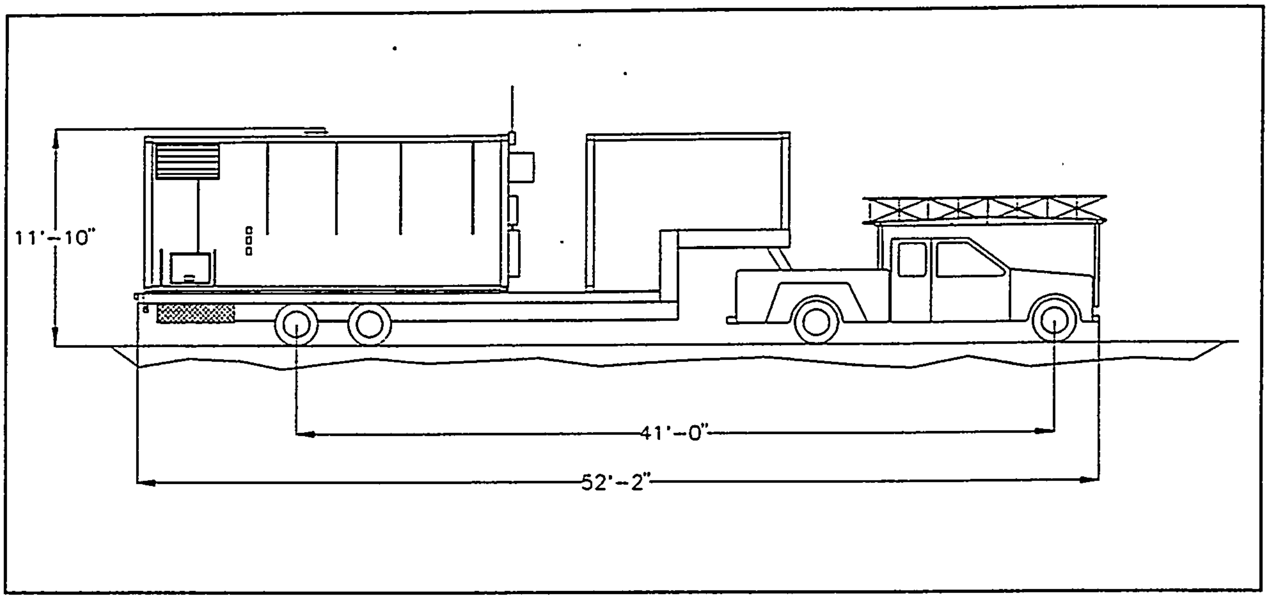

Figure 1 Dimensions of the KAI mobile RF Heating system configured for travel.

Figure 2 is a photograph of the system in-route to Kelly AFB. The RF heating applicators and transmission lines are carried in the trailer's four under-deck storage bays. Additional 20-ft. sections of RF transmission lines were carried on the roof of the shelter and the 10-ft. sections of the aluminum applicator emplacement towers were secured on the over-the-cab roof rack of the pickup truck.

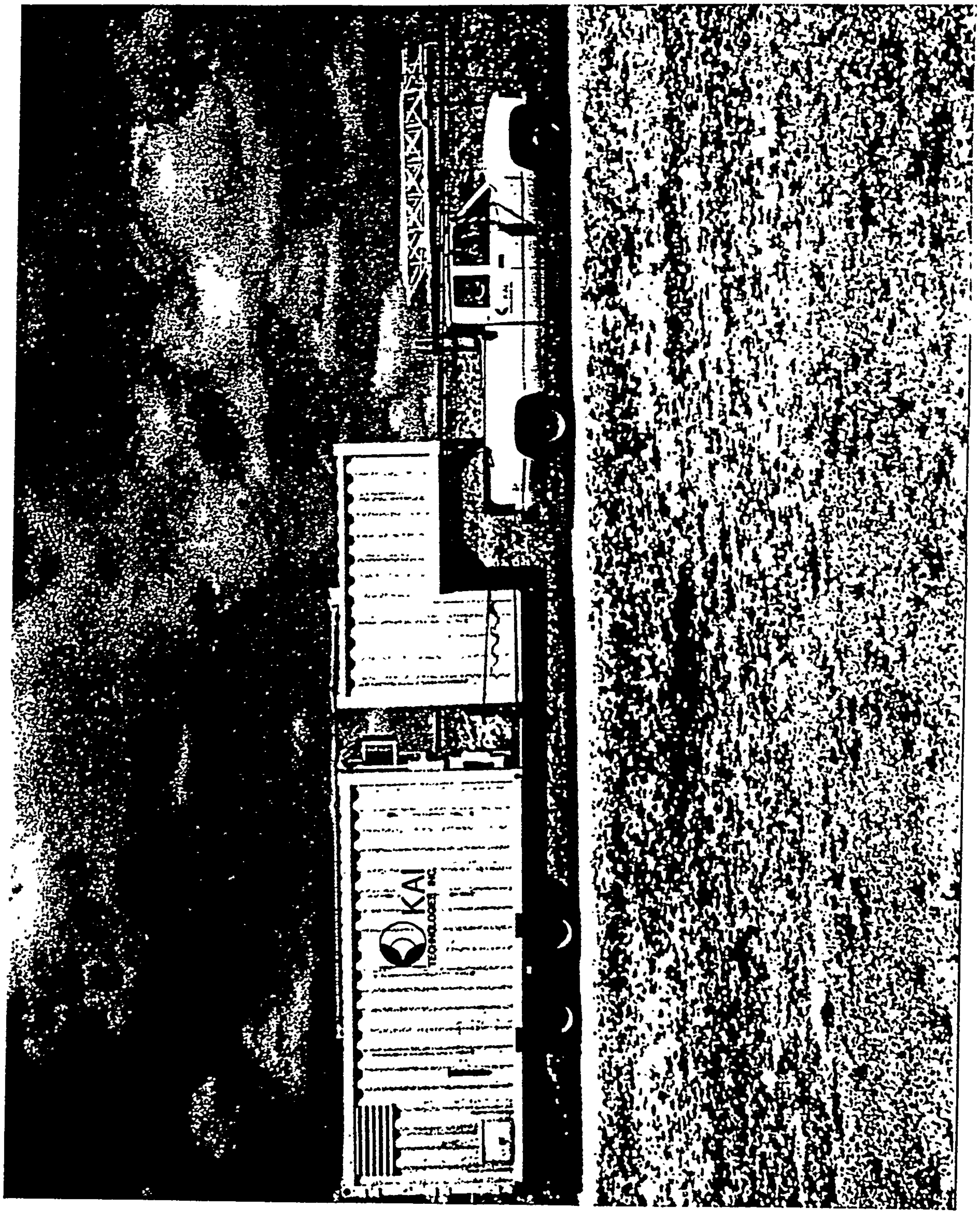

Figure 2 Photo of KAI mobile RF heating system.

2.1 Block diagram of the Basic RF Heating System - The basic RF heating system is diagramed in Figure 3 below. The figure outlines the component groups of a basic radio frequency (RF) heating system. The system power is supplied from the local utility power grid or a diesel generator through the 3-phase power distribution panel. The panel supplies power to the RF generator and a cooling blower as well as lighting, air conditioning and instrumentation. The power system also includes an uninteruptable power supply for critical instrumentation and control functions. The RF Generator supplies power through the transmission lines and the matching network to the RF heating applicator or "antenna" which typically radiates 95% of the energy it receives into the surrounding medium (soil, rock, oil). The system controller is interfaced to all elements of the system. Site environmental monitors can detect overheated components, energy leakage and component tampering. The controller is capable of transferring the complete monitoring of the system to a remote location through a phone line or a cellular telephone data link. Alarms and system status message can be set via the telephone link or messages can be sent as pre-recorded voice messages via the same UHF radio frequency communications transceiver used for site communications. On-site diagnostics instruments periodically measure the system's performance and verify operation.

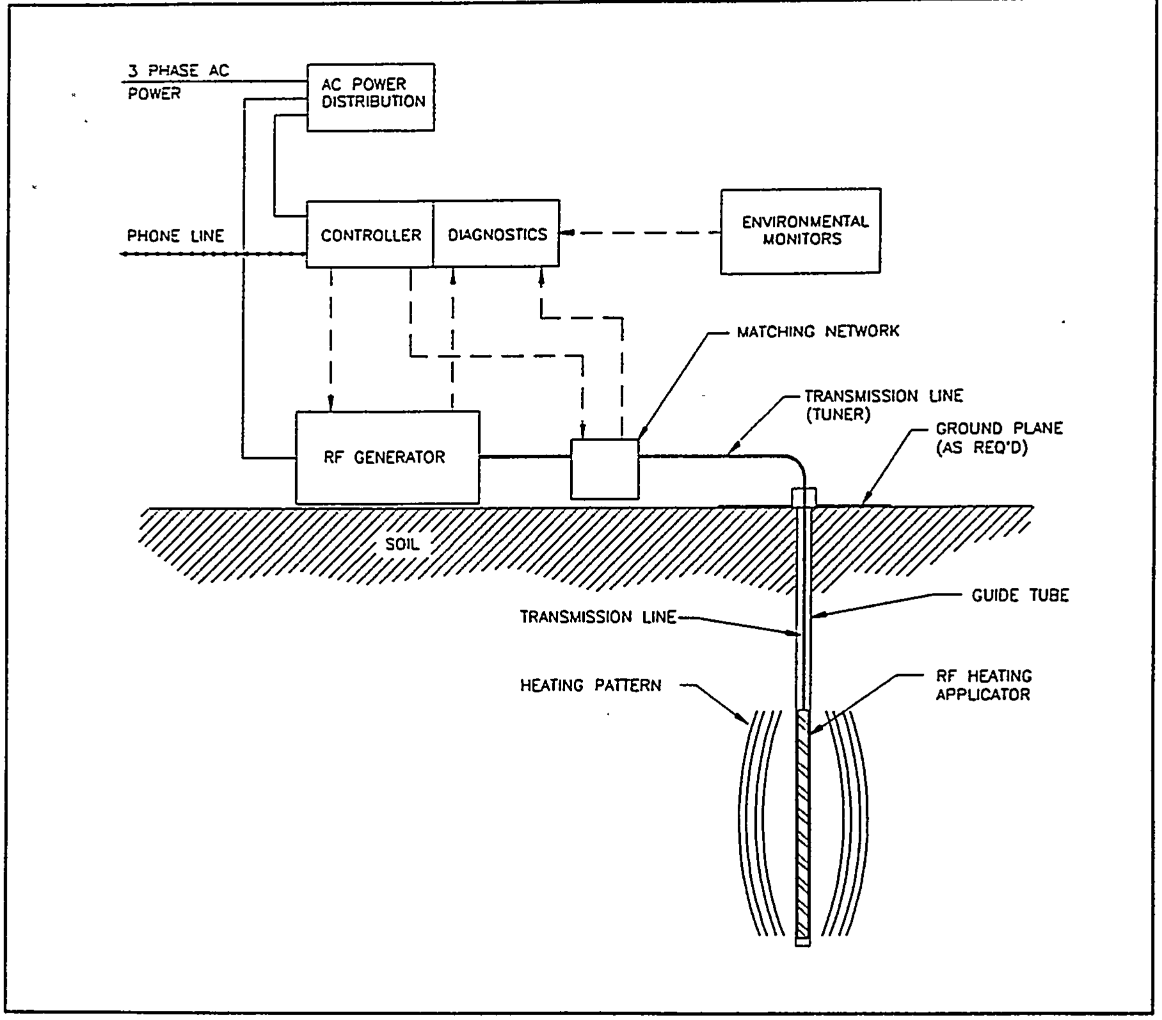

Figure 3 Block diagram of an RF heating System.

For the Kelly program the RF Generator was controlled to alternately drive one of the two applicators that it was connected to. Figure 4 shows this setup in block diagram form.

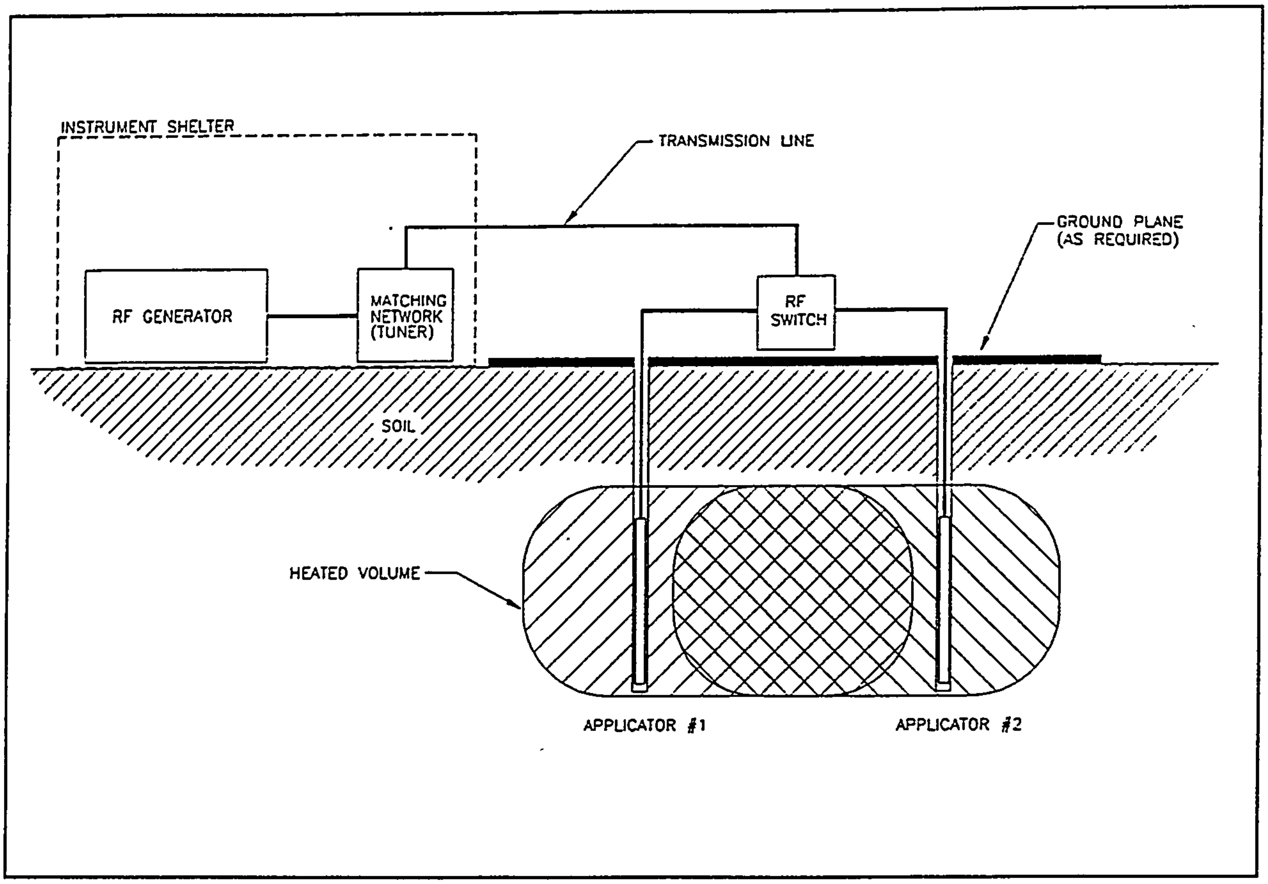

Figure 4 Block diagram of a switched, two applicator system.

Figure 5 is a detailed diagram of the high power and low power RF transmission paths within the instrument shelter. 3-phase AC power is converted to 27.12 MHz radio frequency (RF) power within the RF generator. The RF is power level is measured in directional coupler CPL #1 and is switched to either the 25 KW dummy load for system tests or to the matching network (tuner) by RF switch SW #1. The matching network is adjusted to couple the load presented by the transmission line and applicator to the output circuitry of the RF generator. The output of the matching network passes through RF SW #2 and is measured by directional coupler CPL #2 as it passes out of the instrument shelter. The transmission line from the instrument shelter is connected to RF SW #3 which directs power to either RF heating applicator #1 or #2.

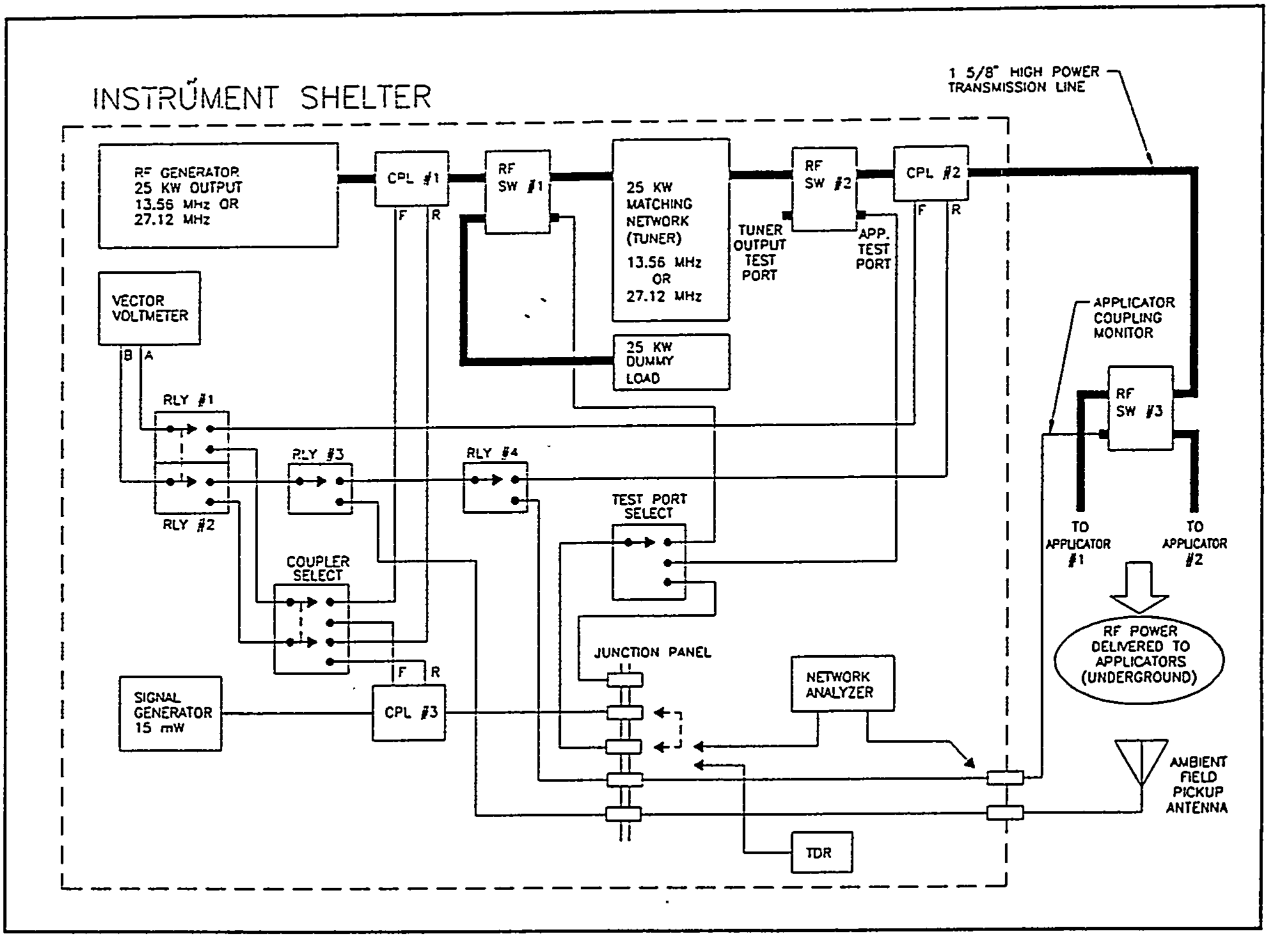

Figure 5 RF heating system transmission line paths.

The figure also details the low power measurement paths of the system that are used to control and monitor the application of the RF to the heating zone. The key instrument for real time power monitoring is the vector voltmeter. The voltmeter inputs are switched to measure the forward and reflected power at each of three directional couplers within the system. The voltmeter, which is technically a dual channel, phase discriminating, reference tuned radio receiver, is also used to measure the ambient RF emission of the heating site.

In this capacity the voltmeter serves as a safety/environmental monitor and is capable of alerting the operator of increasing RF emission at the fundamental heating frequency from the system. The voltmeter or an RF power meter (not on diagram) were also configured to measure the in-soil, incident power received by the non-heating applicator. This measurement is a real time indication of the power radiated by the heating applicator and the degree of water and contaminant removal from the heated volume between the applicators. In this mode the vector voltmeter functions as a site diagnostic tool.

The system also contains several diagnostic instruments. The signal generator is used in conjunction with the vector voltmeter and the control computer to form a stepped network analyzer. A portable network analyzer can be used to more rapidly make high resolution, swept frequency measurements of system and applicator parameters.

The junction panel and the two selector switches are used to allow a quick manual setup for measurements. The measurement paths are selected by the test port select switch. The applicator test port of RF SW #2 is the direct measurement path to the applicator for measurements of its parameters by the network analyzer, time domain reflectometer (TDR) or high voltage megger.

Figure 6 is a view of the inside of the instrument shelter. The RF Generator is visible on the right. The instrument rack is on the left. The control panel for the matching network is on the upper side of the wall.

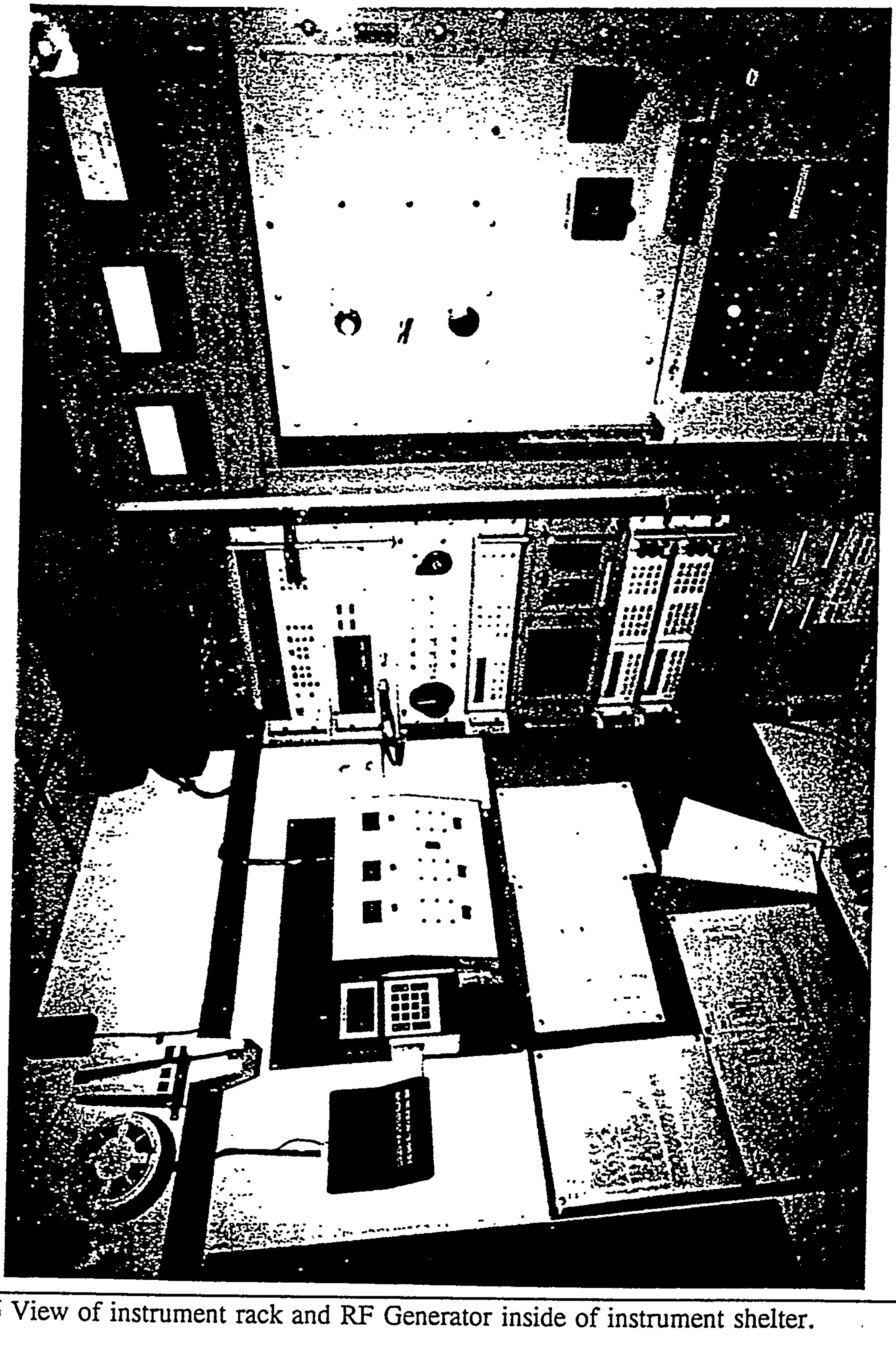

Figure 6 View of instrument rack and RF Generator inside of instrument shelter.

2.2 The RF Heating Applicator - Figure 7 is a diagram of the 3.5" diameter applicator assembly (KAI-0690-30) with the tuning dimensions used for the Kelly program. The RF Applicators are proprietary, KAI developed, devices.

The RF applicator is a dipole-style antenna with a nominal matching impedance of 50 ohms. The applicator is constructed with aluminum, stainless steel, Teflon®, ceramic, brass and copper components. The applicator is connected to the RF generator with nitrogen pressurized, 1-5/8 in. rigid copper transmission line sections. The assembly is lifted by a transmission line clamping collar and wire rope assembly that is not shown here. The 8 ft.-3 in. dimension for the radiating elements is set by interactive on-site measurements. The applicator extension arms are threaded to allow changes in length. The nominal heating span corresponds to the dipole structure formed by the extension arms. In practice the heating pattern typically extends, with lower intensity up the transmission line toward the clamping block.

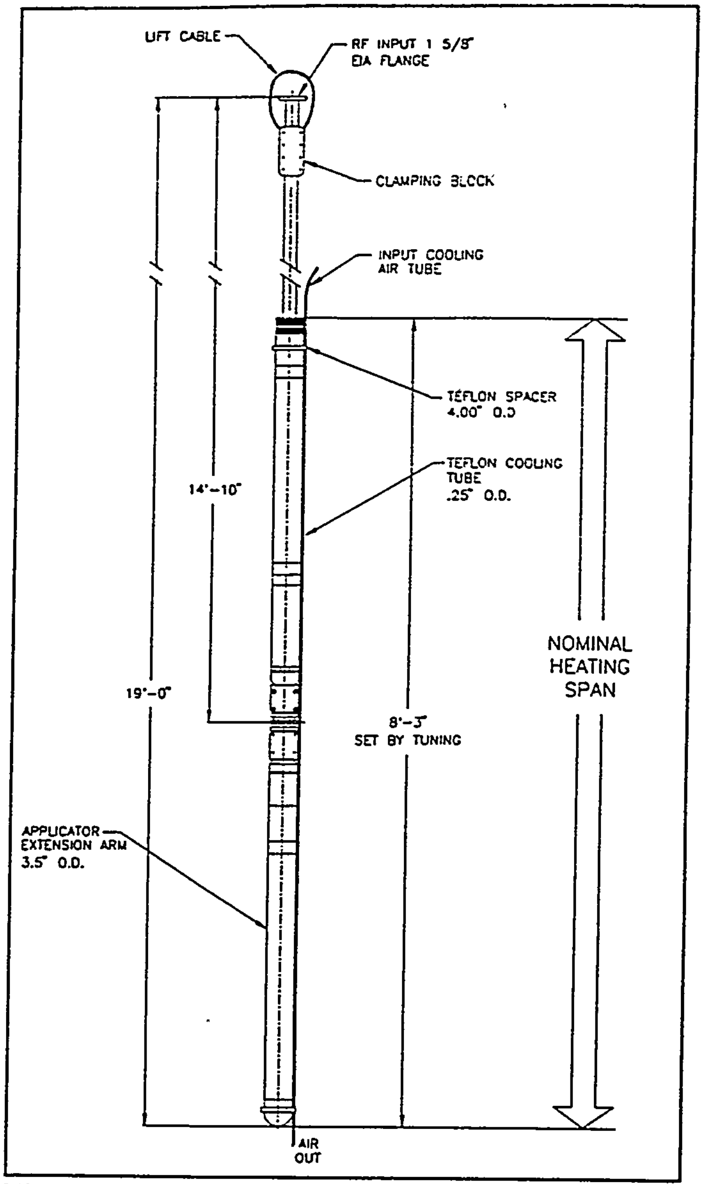

Figure 7 A 3.5 in. diameter RF Heating Applicator specifically tuned for operation at 27.12 MHz at Kelly AFB.

The 1-5/8 EIA connection flange is shown at the top of the figure. One of the four 0.25 in. diameter Teflon® cooling tubes are shown attached to the applicator by the 4 in. diameter Teflon® centering spacers. The tubes are used to cool the walls of the well liner (guide tube) with dry compressed air (e.g. well A2 for the Kelly program).

The applicator is inserted in a well liner with a nominal ID of 4.3 in. The liner is used to isolate the applicator from the surrounding contaminated soil and allow for easy repositioning of the applicator within the contaminated zone..

2.3 RF Heating Site layout - The RF system layout used for the Kelly program is shown in Figure 8. This view is limited to key components. Items such as nitrogen lines, compressed air cooling lines, fiber optic temperature monitoring cables and extended ground radials have been left out for simplicity of display. The heating and treatment zone boundary used for soil analysis is outlined.

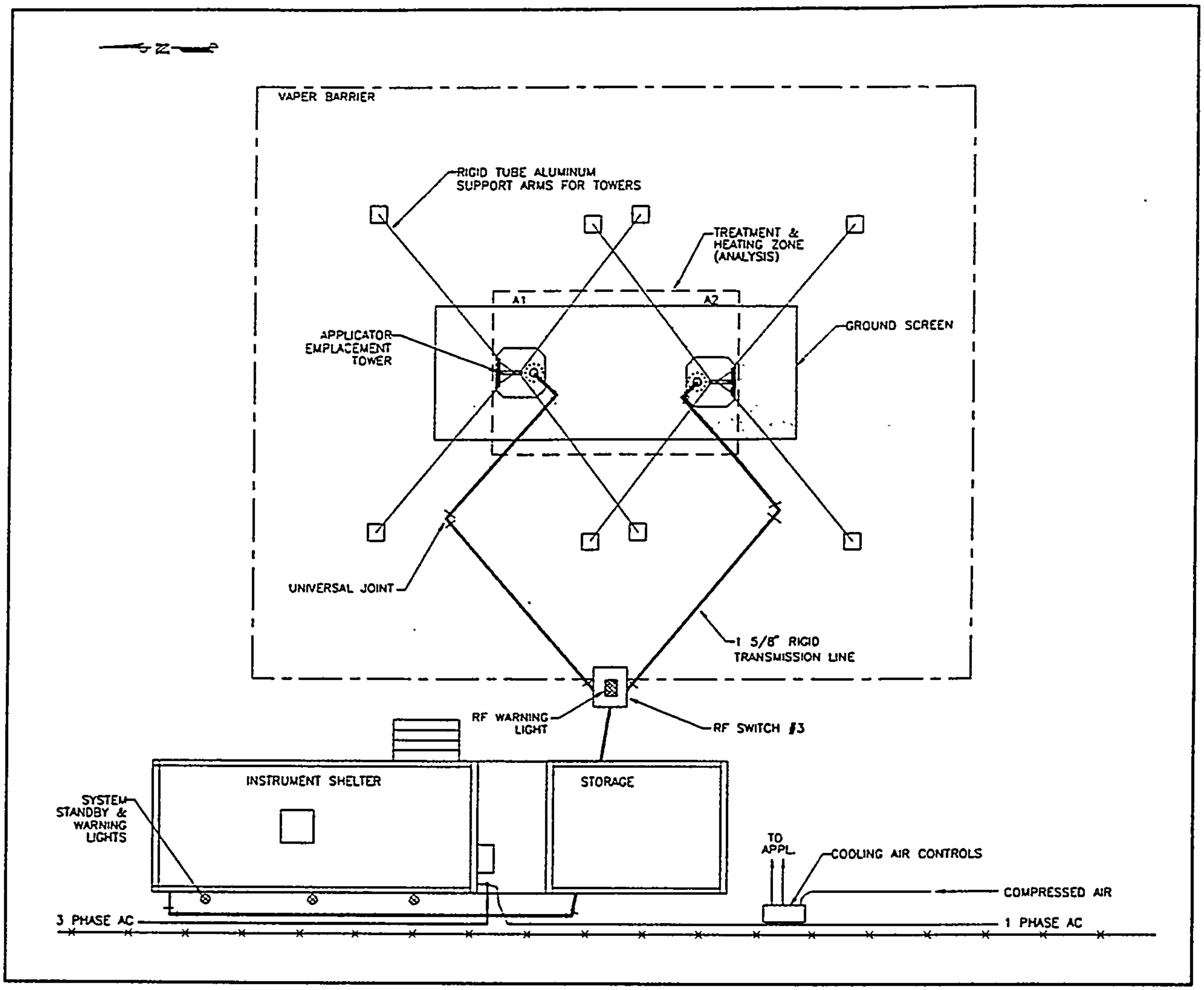

Figure 8 Plan view of RF heating site layout.

This view of the site shows the relationship of the instrument shelter to the vapor barrier and the test area. The fence line of the site is shown along the bottom of the figure where the 3-phase and 1-phase AC power feeds are shown. The well liner cooling air control panel is shown with the compressed air line from the site's diesel driven air compressor is shown. The RF transmission line from the instrument shelter feeds RF switch #3 which selects either applicator #1 or #2. The transmission lines are pressurized in zones with nitrogen or dry compressed air. The transmission lines are joined with dual right-angle connectors to create universal joints at points that require movement as the applicator position is adjusted within the well. The portable aluminum applicator emplacement towers are located above each heating well. The towers are mounted on a 3-foot x 3-foot ground plane base that is electrically connected to the ground screen and four copper clad steel ground rods. The four rigid aluminum telescoping support arms are terminated in pads that are staked with one ground rod and three 18-inch spikes. The towers were self supporting with a height of 20 feet. The towers are capable of extension to 30 feet to accomidate a wide range of applicator positioning with a single transmission line configuration.

Figure 9 is a more detailed view of the ground screen with the grounding radials shown. The grounding plane in this program is used to provide control surface electric field (E-Field) emissions and to stabilize the tuning of the applicator for heating positions located near to the surface. Figure 8 shows more details of the ground plane and its relationship to the temperature test wells.

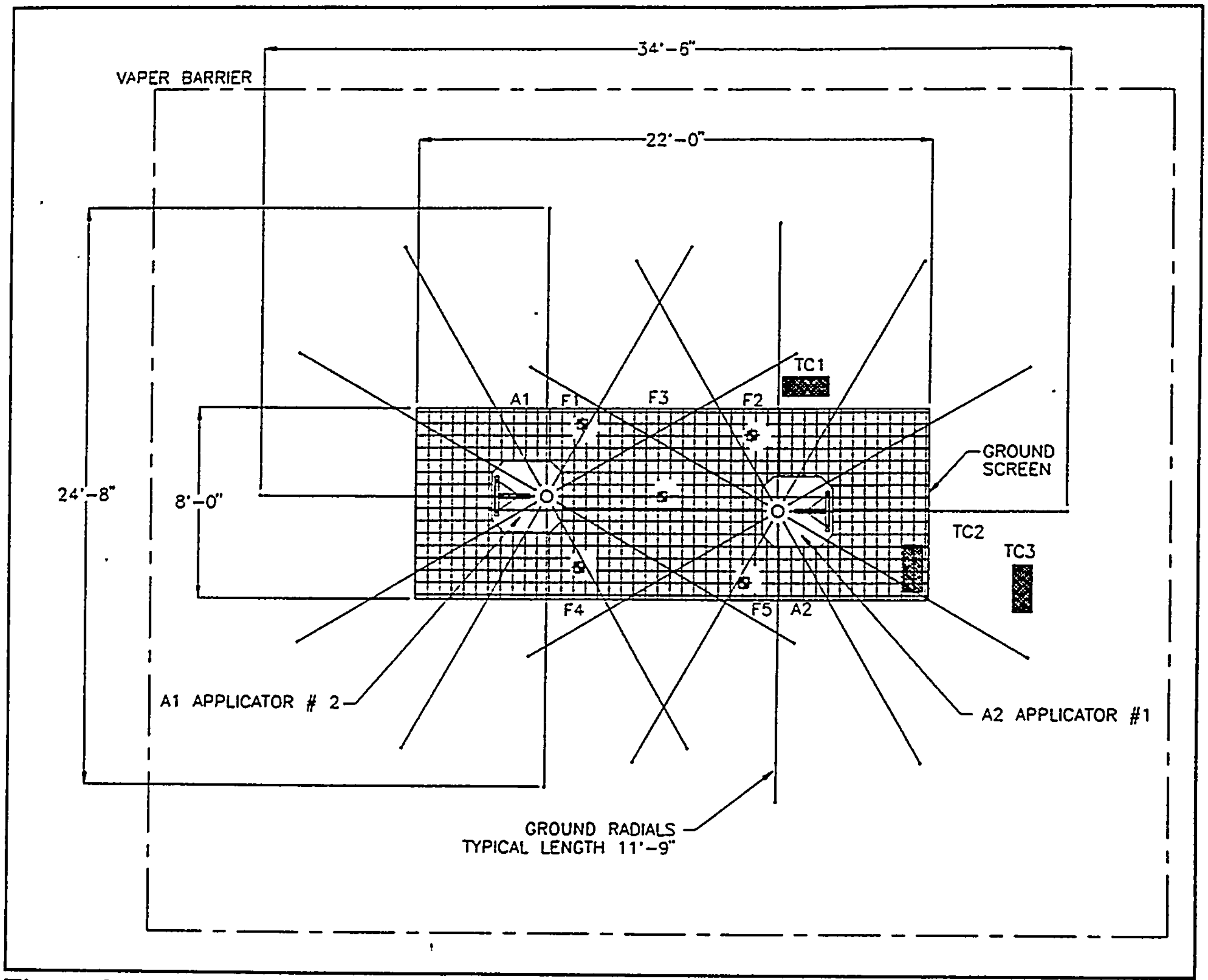

Figure 9 Detailed view of the ground plane with radials.

Figure 10 is a view of applicator #1 suspended from the 20-ft. high portable emplacement tower positioned over the A2 well entrance.

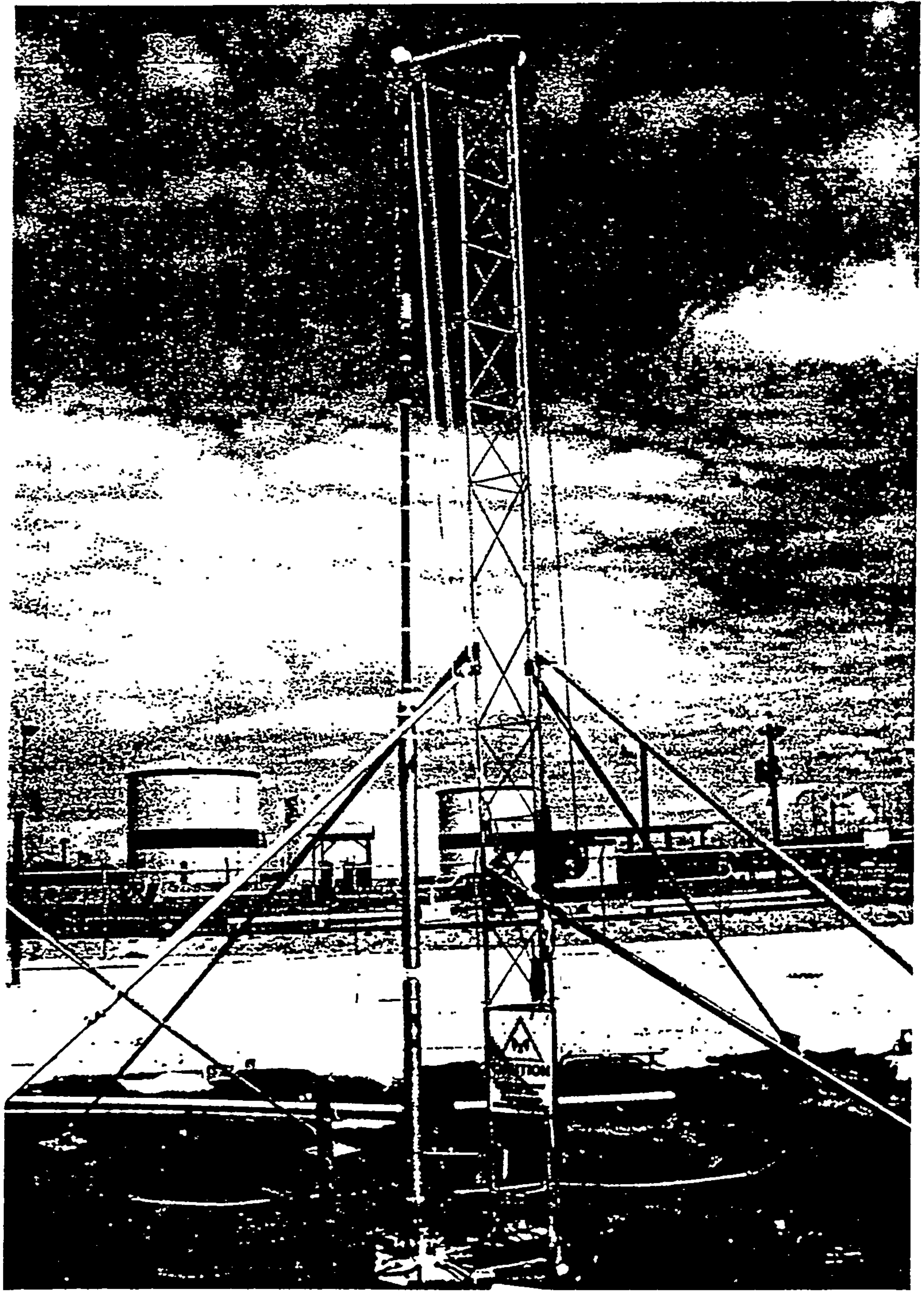

Figure 10 Applicator suspended from emplacement tower over well A2.

Figure 11 is a view of the site viewed from the Northwest corner looking to the Southwest. The SVE system and flare are visible in the upper center of the photo.

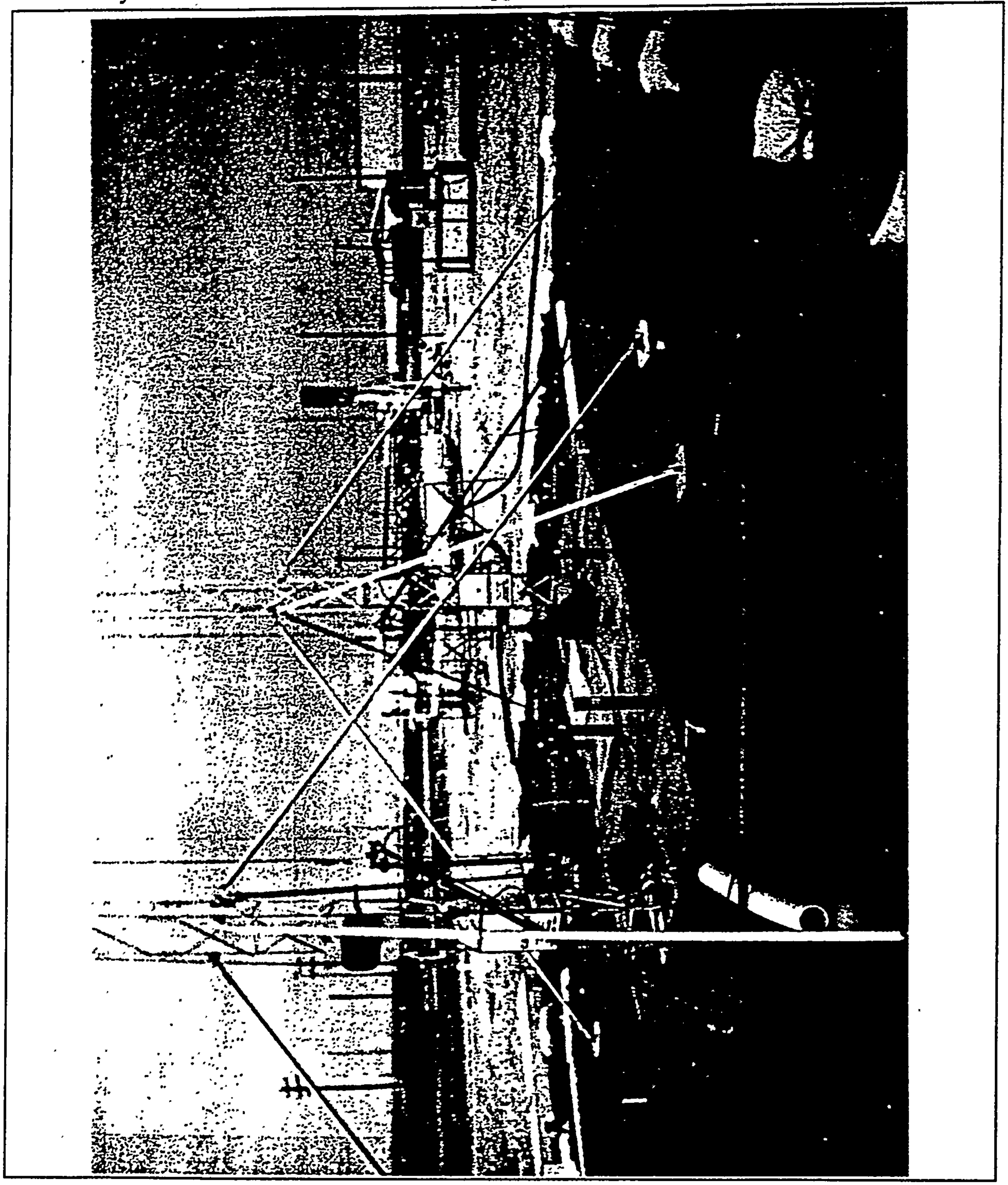

Figure 11 View of operating site with towers and transmission lines in place.

2.4 Site layout with boreholes and SVE description - The section is an assembly of drawings which integrate the details of the RF heating system, the sensor system and the soil vapor extraction (SVE) system. Figure 12 is a drawing that is based on the actual installation survey of the wells drilled at the site. The "E" wells are part of the SVE system. The "F" wells are used to record temperature profiles and magnetic field profiles of the Treatment and Heating Zone. Wells A1 and A2 are used to insert the RF heating applicators. The section lines shown on the diagram are used to define the cuts for site cross-section drawings. The drawings were used temperature analysis.

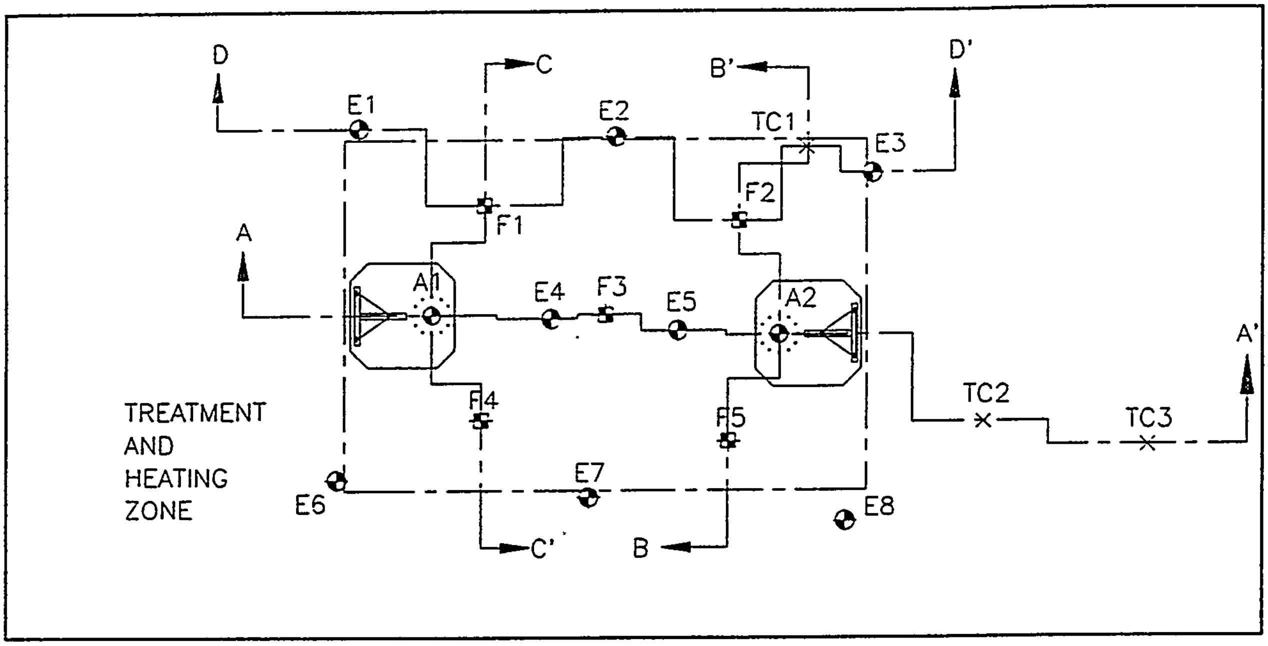

Figure 12 Actual layout of wells for site.

Figure 13 is a plot of section A-A'. In addition to the well profiles the drawing includes the locations of the five possible locations of the fiber optic sensing probes shown as "✦" points. The temperatures recorded by these probes were logged every 20 seconds by the control system computer. The FO CH 21 (fiber optic channel 21) and FO CH 22 sensors are located inside of a thin-wall Teflon tube, packed in sand and positioned on the outside of the well liner at a depth of 10.5 feet. These sensors were the primary temperature measurements for the control of the heating system. The measurements were used to determine if the heat developing in the surrounding soil was heating the liner to a damaging temperatures. The FO CH 23 and CH 24 sensors inside of the well liner were placed against the liner wall at the top of the used to monitor the effectiveness of the compressed air cooling of the inside liner wall. The FO CH 23 sensor position was used on several occasions to observe trends in the wall heating of monitor well F3.

The heating applicators are show in their operating positions in A1 and A2 within the heating zone. E4 and E5 are extraction wells used by the SVE system. The black portion of the well diagram represents the solid walled region of the extraction tube. The lower, open section was screened to allow a vacuum to be drawn on the heating zone.

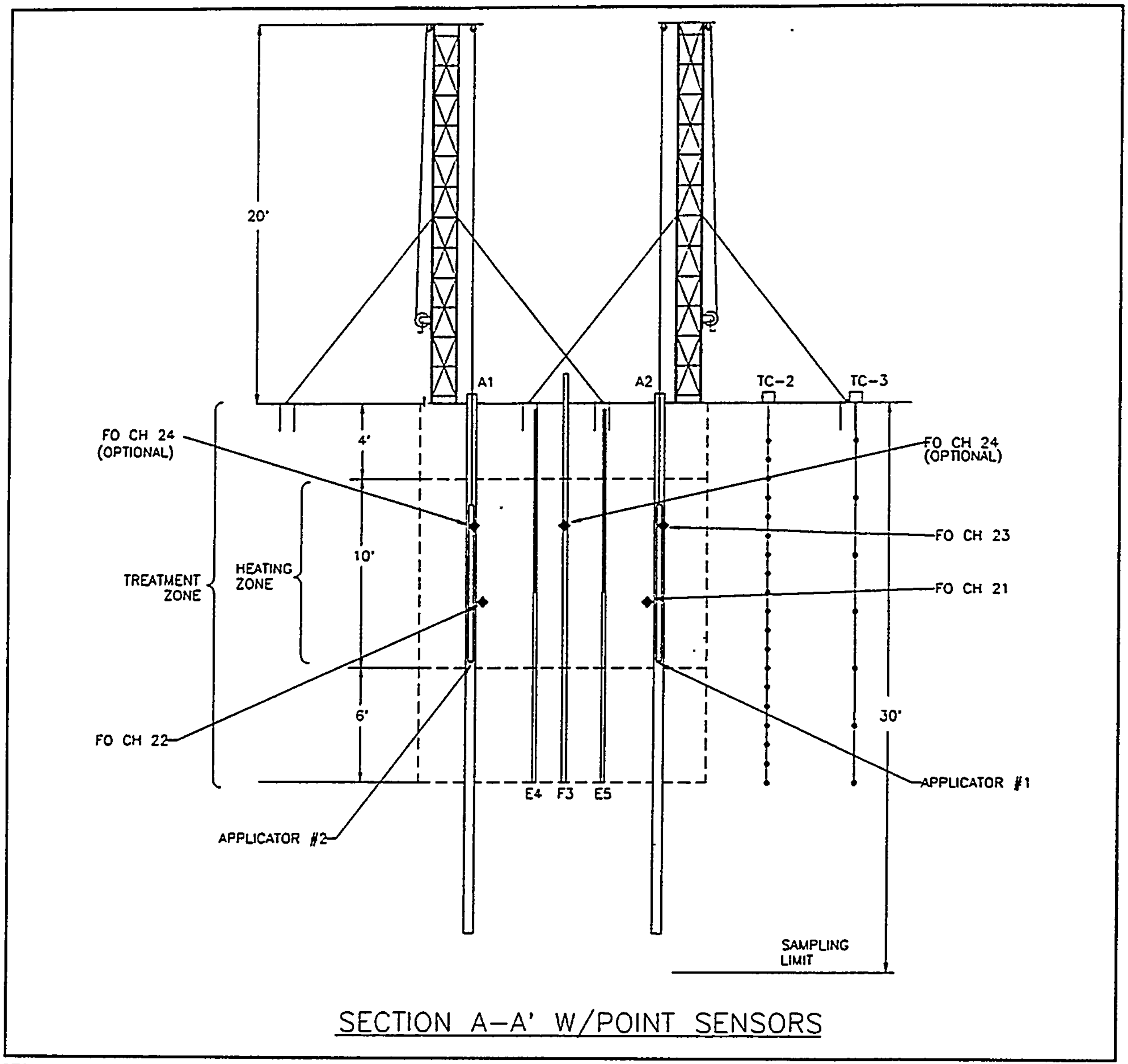

Figure 13 Site cross section A-A' with sensor positions shown.

The information in Figures 12 and 13 is brought together in a 3-D perspective drawing in Figure 14. In this figure the heating applicator wells (A1, A2) are show in relation to the measurement wells (F1 through F5) and the thermocouple strings (TC-1 through TC-3). The heating zone is shown within the treatment zone.

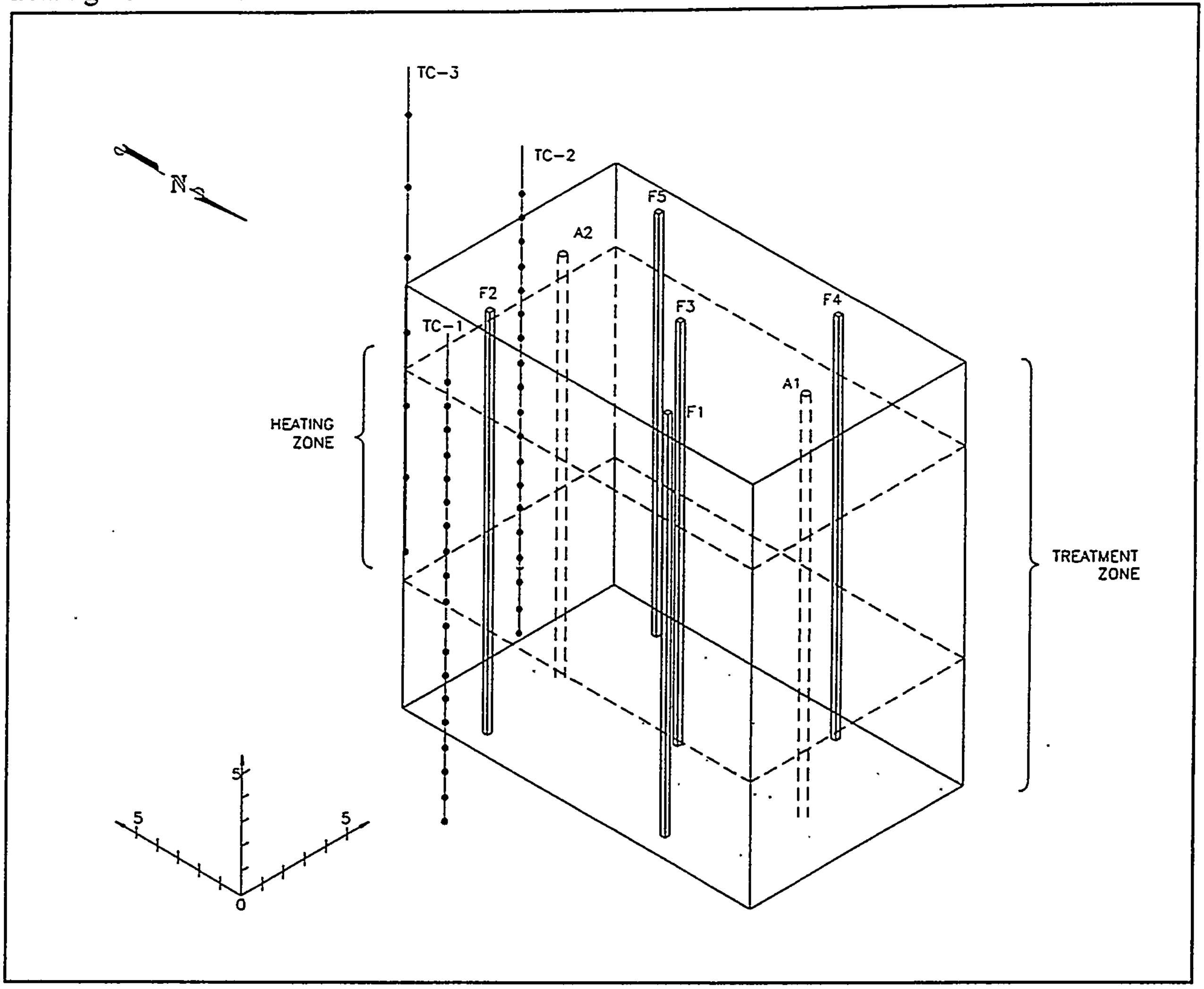

Figure 14 Isometric view of applicator and monitoring wells.

Figure 15 is an isometric view of the extraction system with its major piping features shown relative to the vapor barrier. Figure 16 is an expanded view of the treatment zone. This view allows a detailed visualization of the SVE extraction system. The clear tube areas of wells E1 through E8 are screened for air passage. The E1 through E3 wells are used generally for extraction but starting on 23 May they were used for passive injection of air. The E4 and E5 wells were used for extraction in the middle of the site. The E6 through E8 wells were used for passive injection. During most of the program only the E8 well was open to the outside air.

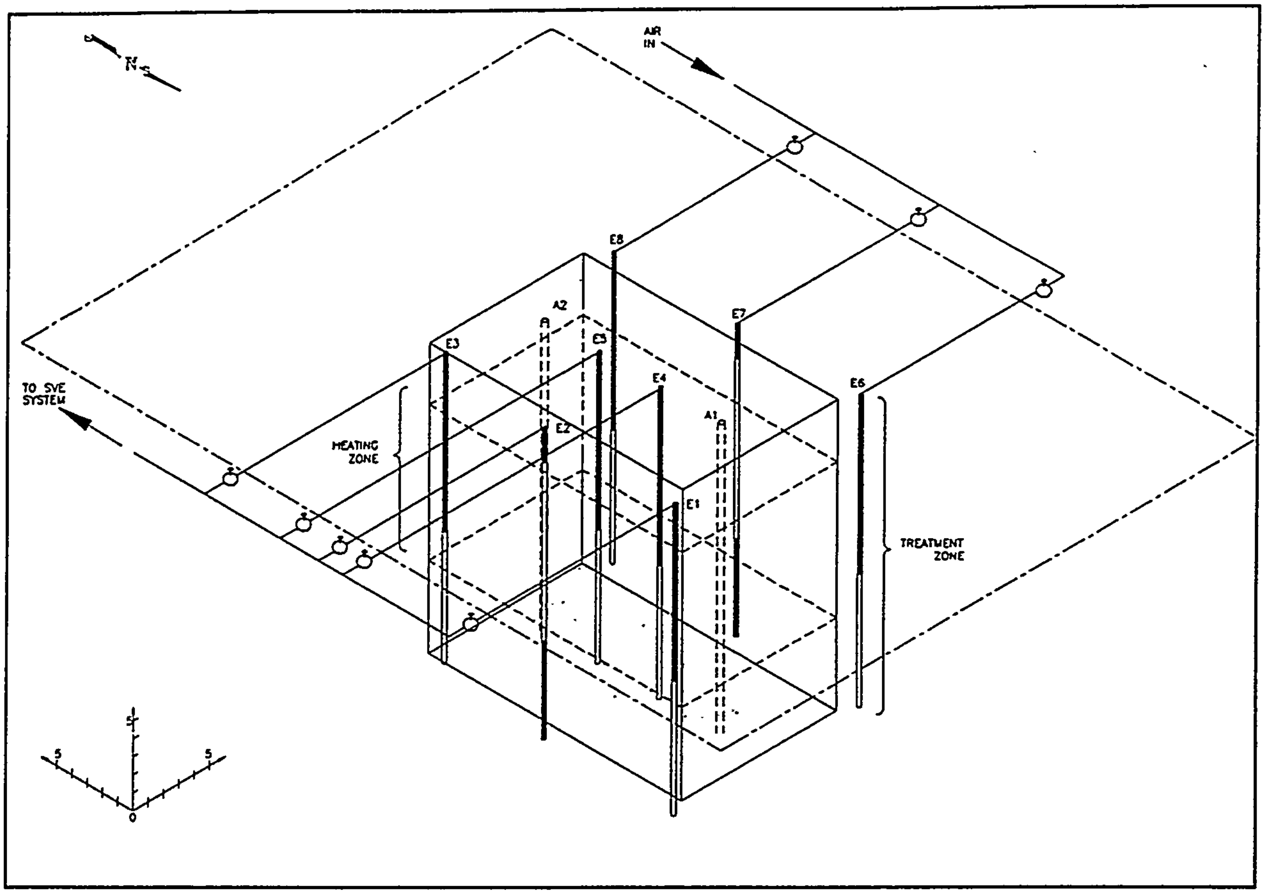

Figure 15 Isometric view of SVE wells with piping.

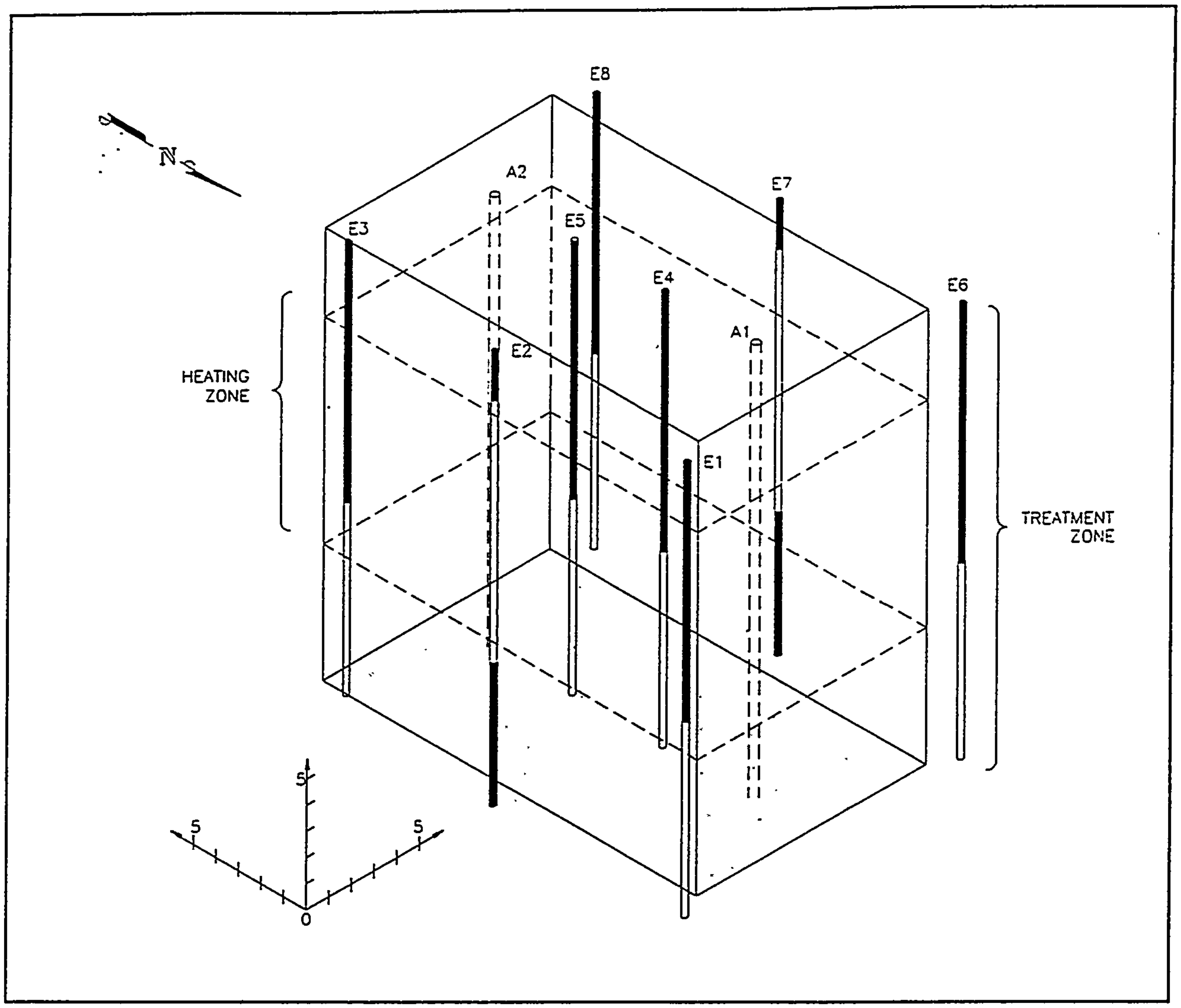

Figure 16 Enlarged isometric view of extraction wells.

2.5 Detailed RF Heating System Specifications - This section provides technical details on a number of system components that are listed in the block diagrams. Commercial equipment items are listed by make and model. The equipment grouping described here is appropriate for a full-scale pilot testing system or the master control unit for a two or four generator phased array[6] RF heating system. The diagnostic and environmental monitoring equipment can be shared among a number of systems.

2.5.1 Basic Mobile RF Heating System - This system was designed, developed and integrated by KAI Technologies Inc. of Woburn, MA and its Western Field Office in Provo, UT. The principal components, as shown in Figure 1 are:

Instrument Shelter: 8 ft. x 8 ft. x 20 ft. insulated steel utility shelter with HVAC and AC power distribution. The unit features an air-shock isolation rack configured to protect the 25 kW RF generator cabinet and an instrumentation and control rack. The shelter also has a filtered air system to cool the RF generator. The shelter was manufactured to KAI specifications by ICM of Salt Lake City UT.

Trailer: A 28-ft. flat bed trailer with neck mounted deck and steel shelter is used to transport the shelter. The trailer includes a heat exchanger tank and cooling fluid circulation system for dummy load testing of the RF generator. The under deck area also contains four 28 ft. applicator storage bays. A typically loaded trailer weighs 20,000 lbs. The basic trailer is a Hillsboro model 200, Hillsboro, KA. The storage areas and modifications were constructed to KAI specifications by ICM of Salt Lake City UT.

Truck: A heavy-duty pickup truck modified for operation with the trailer as a 30,000 lb. GCVW combination vehicle mobilizes the system. The truck frame also carries a rack system suitable for transport of applicator assemblies of up to 30 ft. in length and emplacement tower sections. The truck is used for general site support tasks during a heating program. The truck is a Chevrolet Sierra model 3500.

2.5.2 Key system components within the instrument shelter - These components are listed by generic names in the block diagrams of Section 2.1.

AC Power panel: The shelter is equipped to accept 3-phase 208 to 240 VAC power from a utility or Diesel generator source. The shelter has a 3-phase 200 Ampere power panel (WYE and DELTA feed options). The 3-phase

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[6] A phased-array system requires additional phase control equipment and fiber optic communication links between the master system and the slave generating units.

utility feed is spliced to the 0000 guage copper entrance feed lines at a weather head on the corner of the trailer. The lines are metered with two levels of transient and surge/vervoltage protection. The system also has a 1-phase 100 Ampere, 110/220 VAC panel that is powered from a 3-phase WYE service or a seperate 1-phase feed. The 1-phase power distribution system includes a 1 KVA uninteruptable power supply (UPS) to protect critical control and data acquisition functions. The 1-phase panel also controls power for the auxiliary cooling blower of the RF generator as well as for the air conditioning and lighting of the shelter.

RF Generator: RF Power Products model 25,001D generator (built to KAI specifications and with KAI operation and control modifications). Designed for operational compliance under Part 18 of FCC regulations for Industrial, Scientific and Medical (ISM) equipment.

Frequency: 27.12 or 13.56 MHz operation (crystal controlled)
Emission: A0 (CW unmodulated)
Output: 25,000 Watts, tuned output stage (harmonics suppressed)

The output is continuously adjustable from 100 to 25,000 Watts, the maximum power is set by the line voltage of the site 3-phase power service. For this test the maximum available power will be 23,000 Watts.

Details: The generator was operated at 27.12 MHz for this program. The unit is an optimized industrial design with a 3CX15000A7 ceramic vacuum tube output stage and automatic power controls. The modifications include interfaces for remote control and function monitoring.

Matching Network: (Tuner) KAI custom design with proprietary features.
Frequency: design centers of 13.56 MHz and 27.12 MHz for specified impedance transformations.
Power: > 25,000 Watts
Details: "T" network design with input and output ports using fully shielded 1-5/8" EIA connections to rigid line coax. The unit contains motorized input, shunt and output controls and interfaces to a KAI control and tuning software package.

Dummy load Coaxial Devices model 6025, 25 kW, water cooled resistive load.

CPL #1: 25 kW dual port directional coupler, 2 to 30 MHz, 70 dB coupling,

	Werlatone model C2892.	
CPL #2:	25 kW dual port directional coupler, 2 to 30 MHz, 70 dB coupling, Werlatone model C2892.	
CPL #3:	1.5 kW dual port directional coupler, 1.5 to 35 MHz, 30 dB coupling, Bird model 4266.	
RF Switch #1	25 kW transfer switch, Delta model 5730E.	
RF Switch #2	25 kW pressurized transfer switch, Dielectric model A 50000-203.	
Controller:	This is function is developed by the integration of a number of commercial components.	
	Computer:	Industrial Computer Source rack mounted system with 80386 and 80387 processors, 8 MB RAM, 240 MB hard disk with GPIB and modem interfaces.
	Software:	DOS 6.2 operating system running TBASIC V1.9 by Transera, Inc. of Provo UT. The data acquisition is a customized and proprietary package of capabilities developed from the Eyring Broadband Antenna Test System (BATS) software. The program was done by the Communications Systems Division of Eyring Corp. of Provo, UT and KAI Technologies. The remote control software for the system is Carbon Copy Plus.
	Switching:	HP 3488A switch controller with five interface modules to provide contact closures, coaxial switching and TTL sensing/logic interfaces. The unit is interfaced to the RF generator, tuner and RF switches and well as system annunciators and safety monitors.
	Comm.	Communications with the system is via a high speed error correcting FAX/modem suitable for wireline or cellular communications. The unit is capable of sending a data message to a host computer, a digital display radio pager or a FAX machine. The system also communicates via a UHF radio data voice message link to signal the operators hand held radio or scanner of a system status message.
Diagnostics:	This function is again provided by a number of commercial	

components. The items listed here are acquire data that is logged by the control computer in a data acquisition mode. Software setup files define if a channel is to be used for control processing for limit alarms warning or control actions.

Sensing:	Two HP 3457A scanning digital multimeters (DMM) with 22 channels are used to monitor system voltages, temperatures, pressures, and power levels
Temperature:	Luxtron 790 floroptic thermometer using fiber optically coupled sensor probes to monitor the Heating Zone.
AC Power:	Ohio Semitronics PC5 and MVT 3-phase Wattmeter tand Voltage transducers interfaced to the HP3457A DMM
Vector Voltmeter:	HP 8508A with frequency coverage from 0.1 to 2000 MHz with a phase locked sensing channel sensitivity of down to 10 uV (-87 dBm)
Signal Generator:	HP 8656B with coverage from 0.1 to 990 MHz and output levels of up to+13 dBm.
Network Analyzer:	HP 3577B network analyzer with 0.1 to 200 MHz coverage with an HP 35677A S-parameter test set.
TDR:	Tektronix 1503C time domain reflectometer
Megger:	Biddle model 218650CL with 500 to 5,000 VDC test voltages.

Environmental monitors:	These items are used measure site condition, above and below ground. The isotropic probe is used to monitor site safety conditions for USAF ad OSHA compliance. The spectrum analyzer is used to measure RF harmonica emissions for FCC compliance.

Spectrum Analyzer:	HP 8591E analyzer with EMC personality modules.
Biconical antenna:	EMCO 3104A calibrated antenna and insulated

	tripod. 20 to 200 MHz calibration.
Isotropic probe:	Holiday model HI-3012 with MSE and HCH probes. A foam spacer ball for 0.1 m near contact measurements (FCC defined specification).
Thermocouple readout/calibrator:	Omega CL 23 type T digital readout used for all on site temperature measurements of thermocouples.
Weather:	Davis Instrument Weather station II with dewpoint and rainfall sensors.
IR Probe:	Omega model OS36-T-240 passive IR thermocouple unit with type T output mounted on a PVE extension probe.

2.5.3 Key system components outside of the shelter - These components are listed in the diagrams of Section 2.1. The use of these components varies greatly with the site configuration. The transmission line and switching components are commercially available for AM/FM/TV broadcast applications.

Transmission lines:	1-5/8" rigid copper coaxial lines were used throughout system for system interconnections and to transfer power to the heating antennas. The transmission lines were pressurized with 15 PSI nitrogen and delivered power to either heating antenna through a computer controlled, motorized RF switch. Delivery of power to the antenna was typically >98% efficient for these components. Typical units were manufactured by the Andrew Corp. as type 561 transmission lines.
RF Switch #3	Dielectric model A 50000-203, pressurized, heated, 1-5/8" EIA flange connections. The switch is housed in a weatherprof, secure housing with adjustable legs and universal joints on each of the ports connections.
Applicators:	Two KAI 3.5" antenna assemblies designed for subsurface RF heating applications. Drawing set KAI--0690-30.

Frequency:	design centers of 13.56, 27.12 or 40.68 MHz can be configured.
Power:	25,000 Watts
Diameter:	3.5" OD w/o centralizing spacers
Length:	7.38' to 11.38' span set for soil conditions (27.12 MHz)
Feedline:	1-5/8" EIA flange

Details: The antennas are adjustable length, dipole-type, end-feed structures with 1-5/8 in. EIA feedlines. The standard design employs aluminum radiating elements with Teflon insulating components. The use of Teflon limits its to operation to an ambient temperature of 200 degrees C (392 deg. F). Operation can be extended above this temperature by the use of ceramic insulating components and localized cooling of the applicator assembly

Guide tubes: (Sleeves) The applicators were vertically emplaced in a vertical boreholes lined with 4.33 in. ID high temperature fiberglass liners. The liner wall thickness was nominally 0.25 in. The outside diameter was nominally 5 in.

Ground planes: The antenna counterpoise/ground plane at the soil surface consists a 8 ft. by 22 ft. x 0.062 in. expanded aluminum mat pattern mat, extended around and between the 3 ft. x 3 ft. x 0.25 ft. thick aluminum ground plane base plates are located around each borehole sleeve liner. An 18 ft. diameter pattern of twelve aluminum radials of #2 insulated aluminum cable extend from each base plate. The perimeter cables are terminated to form an 18' diameter aluminum radial pattern of #2 Aluminum cable terminated by 5/8 in OD x 4 ft. copper-clad steel ground rods driven about 45 inches into the soil. The radials are centrally capped by an aluminum screen mat that is bonded to the radials. The antenna transmission lines and supporting structures are bonded to the ground plane at multiple points.

Towers: The emplacement towers are mounted to the 3 ft. x 3 ft. aluminum base plates. The towers are constructed from 10' lengths of aluminum antenna mast sections. The masts are jointed to form 10 ft., 20 ft. or 30 ft. emplacement towers. The towers are supported with four aluminum extension tubes with anchored base pads suitable to make the towers self supporting without the use of guy lines. The complete tower includes a 1,500 lb. winch and two rope pulley lines. The towers were built from commercial aluminum antenna mast sections and were fabricated under KAI direction.

3.0 SITE DATA ACQUISITION

Data acquisition at the Kelly site was performed by both Brown and Root and KAI site personnel. The Brown and Root data typically consisted of 40 data point that were acquired manually, one to two times per day. The data points addressed the soil vapor extraction system, site environmental data and three spot measurements from the KAI RF heating system.

For this report, representative items from the following list are presented along with selected, same scale plotting of several items from the Brown and Root data logging of the KAI data and site temperatures and pressures. The majority of the information was acquired to assist in failure analysis or anomaly investigation. Summary records and example data are provided in Appendices A through I.

The KAI data set consists of the following:

3.1 Computer logged data sets - 23 channels of measurements were continuously logged at approx. 20 second intervals and stored every hour during the heating periods. A limited number of temperature channels were logged during the cool down period. The channels, which included real time fiber optic temperature measurements and RF system measurements are defined in detail in Appendix A. The data is logged into individual raw data files and is summarized by a data acquisition file that records that date/time of all system status messages and notes made during the acquisition cycles. The log includes all program directed connections to the cellular phone and the UHF data link to announce status messages and alarms.

The data set acquired by computer logging is described by channel in Appendix A - Site data logging. RF and AC power data is used for the Heating Summary statistics of Appendix B, the power measurement plots of Appendix C and the fiber optic temperature plots of Appendix D.

3.2 IR probe temperature scans of boreholes F1 through F5 - 17 manually acquired temperature measurements at 1-ft intervals from 0.5 ft. to 16.5 ft below the surface. The measurements were made when the applicators were removed from the boreholes for examination. The passive IR thermocouple probe was an Omega model OS36-T-240 unit with a CL23 thermometer that is designed to operate with a wide range temperature accuracy of +/- 5% of a 60 F to 310 F range. This suggests a +/-3 to +/-15 tolerance for the raw measurements (in degrees F). The measured values are also offset by the cable loss and a potential offset for the sensor.

This measurement was used to understand the thermal profile of the heated zone. The fiberglass monitoring wells provided a thermal window into the heated soil through a 1/8" wall of fiberglass and a one to three inch path of packed sand. The temperature profiles that were measured were always lower in temperature than that of the soil since the fiberglass wall was heated by an air flow. When the air flow past the tube walls was high the temperature differential between the inside well wall and the heated soil could be quite large since the air passing by included a large portion of cooler air mixed with the air in the heated region. When the air flow is low or hot liquids surround the well the temperature difference is small.

The IR probe data sets for the applicators are presented in profile form in Appendix F.

3.3 IR probe temperature scans of applicator boreholes A1 and A2 - 17 manually acquired temperature measurements acquired at 1-foot intervals from 0.8 ft above the soil surface to 15.2 ft. below the surface. The measurements were typically recorded each time the applicator was removed from the liner. *Note: The interior of the liner was continuously cooled with a 400 SCFH air flow that was used to maintain the inside liner wall below the critical thermal damage temperature of 300 deg F (148.9 C). The applicator was also surrounded by a sand pack (several inch path to the contaminated soil) and exposed to the SVE air flow. The temperatures measured inside were always lower than the ambient surrounding soil temperatures.*

The IR probe data sets are presented in time line and profile form in Appendix F.

3.4 Thermocouple temperature profile strings - Two, 19 sensor strings (TC-1, TC-2) and one 7 sensor string (TC-3) were located 5 ft., 6 ft. and 12 ft. from applicator sleeve A2 (applicator #1) at depths ranging from 2 ft. to 20 ft. below the surface. The type T sensors were manually scanned with a thermally stable rotary switch and measured with a handheld digital thermocouple calibrator/thermometer (Omega model CL23). The temperature measurements made with the thermocouples were also lower in temperature than the surrounding soil due to air flow about the sensors that were packed in sand.

The Thermocouple probe data sets are presented in temperature versus time line and temperature versus depth profile form in Appendix E.

3.5 RF System Matching Measurements - Measurements were made periodically of the transmission and reflection "S-parameters" of Applicator #1 and Applicator #2 before, during and after the heating cycle of each applicator. The S-parameters were displayed as Return loss, voltage standing wave ratio (VSWR), impedance and insertion loss between the applicators. The measurements were made with an HP 3577A/35677A network analyzer/s-parameter test system with computer controlled data acquisition by the HAQR program.

Representative measurements are provided in Appendix G. All measurements are listed in the general logging file HAQR.LOG.

3.6 RF System Emissions Measurements - Measurements were made at 3 meters, 10 meters and 300 meters at several locations about the heating site. Harmonic emission measurements (1st at 54.3 MHz through the 6th at 189.9 MHz) were made with an HP 8591E EMC calibrated spectrum analyzer and an EMCO 3104C calibrated biconical antenna to determine the absolute emission levels from the site in compliance with FCC part 18.305(b). Fundamental frequency emission levels at 27.12 MHz ISM heating frequency were measured in compliance with USAF requests.

A complete set of measurements is included in Appendix H.

3.7 Electric and Magnetic Field Measurements - Periodic measurements were made of the surface fields with a Holiday model HI-3012, portable isotropic field probe. The E-field level was checked daily at the perimeter of the heating zone and logged periodically at three distances from the active heating applicator. These distances were 3 meters, 1 meter, and 0.1 meter (near contact) from the applicator axis at a 1 meter height. Measurement were also mapped several times above the heating zone in detail in terms of E and H fields. The isotropic field measurement was also supplemented at times by an automated measurement of a vertically polarized tuned whip antenna located on the roof of the shelter to monitor ambient field emissions of the heating system at 27.12 MHz.

Representative measurements are included in Appendix H.

3.8 Time Domain Reflectometer Measurements - A Tektronix 1502C time domain reflectometer was used to characterize the transmission lines leading form the line access switch (SW#2) in the RF heating shelter to the applicator selection RF switch (SW#3) and on to each applicator. The instrument produced high resolution charts of the transmission line reflections versus distance that allowed system integrity to be verified and any line degradation to be monitored and located.

3.9 Megger Measurements - A high voltage (5 kV) megohmmeter was used to verify the insulation integrity of the RF transmission line and the applicators.

3.10 Magnetic Field Probe Measurements - Low level magnetic field probe measurements were made at well F2 as part of the tuning measurements of Applicator #1. The Applicator was driven by a low power signal generator. The field was received with a pre-amplified magnetic probe that was connected with a ferrite isolated transmission line to a battery powered spectrum analyzer (HP 8591E) on the surface. These measurements were not made at high power or after the boreholes were to hot to safely insert the magnetic probe without damage.

3.11 Applicator air flow and transmission line pressurization/flow and nitrogen tank pressure - Air flow was directed to cool the applicator within the fiberglass sleeve and was controlled to protect the liner from overheating. The transmission lines were filled with nitrogen and in the event of a leaking seal were maintained at a controlled flow rate. The nitrogen tank pressure indicated the remaining quantity of the stored gas.

3.12 Weather data station data - This data was logged automatically for the last half of the program. The measurements included outside temperature, humidity, barometric pressure, and rain.

3.13 Photographic records - The program was liberally photographed to document the setup, heating cycles, cool down and dismantling of the site. The data set was recorded on 135 mm print film with wide angle-, normal- and macro- lens photographs.

3.14 Communications program access log - This file records all communications to and from the control computer over the modem/cellular phone link.

3.15 AC power consumption - The KAI instrument shelter is supplied power through a 3-phase 208 to 230 VAC DELTA or WYE service entrance. The 120/220 VAC single phase requirements of the system can be derived from a WYE feed or from a separate service entrance. Both service entrances are metered with Watthour meters for all external power. However, when 120/220 VAC is drawn from the WYE feed internally it is not routed through the 1-phase service metering panel.

Start and finish numbers and some spot numbers were recorded for each meter. However, several changes from a single 3-phase feed to a dual feed and back during the program made this data very difficult to interpret. The data set also includes various configurations of outdoor site lighting as well as heavy air conditioning power usage.

The 3-phase AC power consumption log for the RF generator that is logged by the computer is a better time line on AC power usage. From this log the typical 24 overhead load can be added to approximate the system's power usage.

END FILE: KELLY3.A

4.0 PROBLEMS ENCOUNTERED AND LESSONS LEARNED

During the course of the program a number of technical problems were encountered that visibly influenced the data set and modified the course of some test activities. This section covers the period from 28 March (arrival on site) through 13 June (completed packing of Rig#1). None of the problems encountered were outside of the range of reasonable engineering solutions and most were solved quickly on site with minimal impact to the program.

4.1 System configuration - The items listed here are ones that specifically interacted with site's operation.

4.1.1 PROBLEM: The fiberglass well liner was considered at risk for delamination if the temperature exceeded 300 degs F. When the RF generator was set to turn off and allow cooling of the well liner, the average heating rate per hour being applied to the formation was relatively low.

> SOLUTION: Teflon tubes were attached to the outside of the applicator to flood the bottom of the liner with cool, filtered compressed air. A flow rate of 800 SCFH was used to maintain cooling of the liners. The typical flow was 400 SCFH to each liner.
>
> Note that ideally the RF generator was to switch to the other applicator as the first unit cooled down. However, the RF generator restart and control problem did not allow this mode of operation to be undertaken reliably. See section 4.3.1

4.1.2 PROBLEM: The majority of the SVE extraction wells may not have been ideally screened for extraction from the Heating Zone located in the upper half of the Treatment Zone. A large percentage of the screened wells drew air from unheated soil regions. The mixing of the cooler air with the heated air in the path to the extraction wells may have condensed some VOCs and SVOCs.

> SOLUTION A: The bottom of the Treatment Zone could have been heated first for extraction. The heating of this region should significantly enhance soil permeability in this region. Then the applicator could have been incrementally raised to heat the top half of the treatment region. This approach treats a greater volume and provides vapors with either a short path to the extraction well or a pre-heated permeable path to the extraction well.
>
> SOLUTION B: The well could be made with two concentric tubes. the outer tube would be fully screened. The inner tube could be screened to match the applicators's heating span. The inner tube would be adjusted within the well to mach the position of the applicator.

4.2 Data acquisition and measurements

4.2.1 PROBLEM: The fiber optic temperature probes demonstrated wide temperature fluctuations at or near 100 degrees C.

SOLUTIONS: Place shroud over tip (factory recommendation), and use shorter lengths of high loss probe cables. The repolishing and testing of all optical extension cables was also recommended.

EFFECT ON PROGRAM: The temperature fluctuations appeared to be due to water vapor being collected in the Teflon tube used to protect the fiber optic probe. After this water was driven out the system stabilized. The most difficult aspect of the problem was in estimating with certainty the temperature the well liner during this periods. This problem did not contribute to any operating problems.

4.2.2 PROBLEM: Some channels of the fiber optic temperature measurement system stopped operation when the probe temperature dropped below about 40 degrees C.

SOLUTIONS: The three splices in the fiber cable were not ideally matched for lowest possible loss. Ideally each probe would be a short run to a single extension cable of <250 ft. that runs directly to the instrument.

EFFECT ON PROGRAM: None since the most critical probes, channels 21 and 22 did function without this problem.

4.2.3 PROBLEM: Most of the 0.25 in. OD Teflon tubes planned for the emplacement of fiber optic probes and thermocouple scanning probes were crushed by the setting of the bentonite clay seal used to cap the site. The only usable tubes were attached to the walls of A1 and A2.

SOLUTION: The IR temperature measurement system became the primary means of characterizing soil temperatures within the heated zone. In the future a thicker wall (higher cost) Teflon tube could be used protect the fiber optic and thermocouple leads.

EFFECT ON PROGRAM: The loss of the Teflon tubes limited the number of temperature points that could be acquired for the program. The temperature measurements made with the IR probe were taken through the wall of a larger tube with significant air flow through its surrounding sand pack. Therefore the temperature measurements available to the program were from fewer points, with measurements that were generally indicating values lower than the actual soil temperatures due to SVE flow action. The channel 21 probe outside well liner A2 was blocked (crushed) and could move much lower than the 10.5 ft. position it was set at. This was a small but contributed point to the decision to position Applicator #1 at a center of 9.5 ft.

4.2.4 PROBLEM: Low temperature readings of IR and TC measurements

SOLUTION A: Monitor air flow underground with a hot-wire annometer type probe to develop a correction temperature for some locations. The cooling effect of the air flow may be used as an indicator to determine if a temperature probe is in a dead air or convective flow environment.

SOLUTION B: During the full power heating program, confine some native soil target material in a sealed container with a fiber optic probe to determine the isolated, in-situ heating rate of the soil sample within the RF heating zone. These sensors would also be used near open temperature monitoring points in the RF zone.

EFFECT ON PROGRAM: The low reading trend appears makes it more difficult to estimate the actual soil temperatures developed in the heating zone.

4.2.5 PROBLEM: The fiber optic thermometer software interface randomly dropped temperature values to a value of 1,2,3 or 4 corresponding to the channel number of the measurement probe. The effect was timing related and did not appear at previously tested sampling rates.

SOLUTION: The problem was recognized within the first few days of the data logging operation and was solved with a field programming change.

EFFECT ON PROGRAM: The recorded data shows a high density of "spikes" displaying temperature drop outs that were not real. The drop outs did cause a problem with the control system. The "drops" were recorded as 1,2,3, or 4 "degrees" by the data acquisition/control system. These low "temperatures" caused the computer to restart the RF generator before the cool down restart temperature was met.

By itself, this problem was manageable as an operational annoyance until the software was changed. However, in the context of a power line source instability at the site the computer requested RF power restarts were not reliable and often left the generator in the RF OFF position if not noted by a site observer.

4.3 Operational items - Prior to this program the generator was modified to operate at both 13.56 MHz and 27.12 MHz. The generator was run with this modification by a Diesel generator driven system for several hundred hours. The system was also upgraded to operate with a new fiber optic thermometer that had received limited testing.

4.3.1 PROBLEM: The RF generator would not restart reliably under computer control.

SOLUTION: The problem was isolated through a number of detailed troubleshooting steps. Initially it was thought that the RF Generator was the source of the problem. Later it became clear that the source impedance of the 3-phase power line was too high for the load drawn by the generator when it switched from RF OFF to RF ON. The 3-phase, 0 gauge aluminum cable[7] was replaced with 00 gauge copper cable to solve the problem.

DISCUSSION: Initially it was speculated that the problem was due to a generator instability associated with the recent modifications to operate at 27.12 MHz or 13.56 MHz. Careful troubleshooting indicated that the conversion did not cause a problem but that the 3-phase utility power was exceptionally unstable. The problem was identified to be due to several high resistance, (copper/aluminum) dry splices in the 3-phase power feed and the use of an undersized, 0 gauge, aluminum feed cable to connect the instrument shelter to the power transformer. It was found[8] that the RF generator's power control system was very sensitive to the utility line impedance when it automatically reconfigured its main power transformer from a "WYE" to a "DELTA" feed as the RF ON state was initiated by. This switching process was timed by an adjustable time-delay relay that sometimes could be adjusted to lower the probability of the RF generator not going to the ON state. However the problem remained intermittent but occurred less frequently and appeared linked to the daily variations in the utility voltages.

EFFECT ON PROGRAM: During the first several weeks of the program this problem required round-the-clock monitoring of the system by KAI personnel. The average RF power level was lower than optimum. After the splices and power feed cables were replaced the system reliability improved dramatically and the system worked smoothly under computer control.

4.3.2 PROBLEM: The 25 kW RF generator randomly tripped OFF. This was indicated with an intermediate power amplifier (IPA) annunciator light, an Overload Trip light and a system program alarm.

SOLUTION: The problem was minimized first by careful tuning and then with operation at below maximum RF power level setting. Later it was observed that the problem was related to both high power operation and the daily cycle of the 3-phase power line voltage and the available line voltage. The problem was isolated by correlating the IPA trips to transients riding on rising power line voltage levels (similar transients at lower voltages did not produce the trip).

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[7] This cable was previously used for the service trailer of a previous program. It was originally thought to be the 00 gauge AL cable that program used at 3-phase, 480 VAC.

[8] Prior to this program the RF generator was used with a number of utility and diesel generator power sources with hundred of hours of operation with each source. The RF generator field support staff indicated that this problem had not been encountered within the 10 years this product has been installed at industrial sites.

The short term solution was to retune the RF generator output stage to optimally match the power line voltage to output maximum RF. This meant temporarily setting the power output lower before the voltage trend increased for the day and then retuning it an hour or more later when the voltage stabilized at a higher value (e.g. end of main work day at Kelly AFB). This problem was also improved with the power line splices were replaced and the line replaced.

The long term solution has involved isolating the RF generator power supplys for the low voltage, bias and control voltages from the voltage swings of the 3-phase line. The upgrade has been implemented since the Kelly tests by adding an uninteruptable power supply (UPS) to the system with an interface to these RF generator circuits. This modification stabilizes the low level RF drives to the IPA stage of the generator.

EFFECT ON PROGRAM: The IPA trips required closer monitoring of the RF generator's adjustments when it was set for maximum power output after the power line was repaired. Trips did send immediate alarms to the operators and seldom accounted for more than 5 minutes of down time. Trips could be avoided by planning the tuning of the generator around the anticipated line voltage trend for the day or setting the generator approximately 1 kW below its maximum power setting.

4.3.3 PROBLEM: Applicator #2 in well A1 failed after 8.15 days of operation. The applicator initially indicated a slow nitrogen leak.

SOLUTION: The problem was based on a slow loss of the nitrogen pressurization that protects the feedline from high voltage breakdown. The line ultimately failed after we ran out of nitrogen during the Memorial Day holiday. A larger supply of nitrogen could have maintained the unit in operation until the leak could have been fixed. The damage to the applicator was repairable.

EFFECT ON PROGRAM: The power was switched back to Applicator #1 while Applicator #2 was removed and cooled. The unit was to be immediately repaired in the field by replacing the heat-distorted copper center conductor. However, it was discovered that the replacement conductor was damaged in transit. The factory supplied a repair part by an overnight package service to repair the damaged spare conductor. It was determined that the conductor could be repaired with the part and the use of a speciality welding companies services for the required high temperature copper-to-copper welding. The high temperature repair was placed on hold due to the uncertainty of the program's extension schedule. Therefore a simple mechanical repair was effected to the center conductor and Applicator #2 was placed back in low power service about one day after it was removed. The heating of Applicator #1 continued for 12.7 days till the heating period ended.

END FILE: KELLY4.A

5.0 DATA ANALYSIS

This analysis section provides samples of the data records gathered during the program. The focus is on the start and stop points of the heating cycles of applicator #1 and applicator #2.

5.1 Power delivery- The power delivery of the RF heating system is dependent on three components. The AC power input, the RF power generator, and the RF power delivery. Details of the power generation and delivery are provided in Appendices B, C and I.

5.1.1 AC power input - The system was powered by a 3-phase, WYE utility feed for the RF generator and instrument shelter. The AC voltage measured at the RF generator test points had the following characteristics:

- Nominal 3-phase line voltages were _____ **(left out for draft to review statistics)**

- The typical max to min swing for the base was ______ before the splice repair and cable change and _____ after the change.

- The estimated AC input power used for the RF generator was estimated at 26,693 KWH which was back figured from generation with a 65% conversion efficiency. It is likely that the low operating efficiency periods of the program increased this amount.

- The estimated AC power used by the site was greater than 36,053 KWH. This number assumes that the system was operating at high efficiency and was developed by back figuring against the amount of RF that was generated and a 5 kW/hr overhead rate..

5.1.2 RF Power generation - The RF power generated for the program is summarized as follows:

Applicator #1	11,201 KiloWatt hours over a 41.77 day span
Applicator #2	4,248 KiloWatt hours over an 8.15 day span
	15,549 KiloWatt hours over a 49.92 day span

The overall RF generation rate for the entire span was 12.97 KiloWatts/hr. This figure should have been in excess of 19 KiloWatts/hr. This would have increased the RF generation by the system to over 22,763 KiloWatt hours.

Additional calculations, alternate estimates and detailed tabulations are provided in Appendix B. A summary plot of the RF power trend over a day 7 to day 77 span is in Appendix I.

The RF power is generated by an industrial grade power oscillator based on vacuum tube technology. When the RF generator is optimally tuned the unit transforms 3-phase AC power to RF at 27.12 MHz with a conversion efficiency of approximately 65%. This is commonly called "cabinet efficiency" since it includes not only the efficiency of the final RF output stage[9] but the power consumed for the earlier driver stages and the systems internal cooling blowers.

The total efficiency of the power generation system involves the following typical components:

25 kW RF generator with cabinet efficiency of 65%:	38,460. Watts
External ventilation system energy requirements:	350. Watts
Control and monitoring instrumentation:	650. Watts
Instrument shelter HVAC and lighting (average):	2,500. Watts
	41,960.00

Based on a 25 kW RF output this example has a calculated efficiency of 59.5% for total system efficiency for controlled RF generation.

The RF generated for this program was often at less than this 59.5% value due to limitations in the stability of the AC utility power supplied to the instrument trailer. The non-optimum power conditions required that the RF generator be tuned for stability under these varying conditions.

5.1.3 RF Power delivery - The RF power generated is connected to a high efficiency, remote controlled "T" matching network (tuner). The output of the network is coupled to the applicators with low loss switching and rigid transmission line paths. Typical transmission efficiencies for this path is excess of 98% when the applicator is pre-matched the soil. In the case of this program the transfer from the generator to the network to the applicator was nearly ideal.

- 11,201 KWH was delivered to Applicator #1 in well A2
- 4,348 KWH was delivered to Applicator #2 in well A1
- 15,549 KWH delivered to the heating zone.

Details are provided in Appendix B.

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[9] The tube output stage alone can exceed an efficiency of 80%. Values such as this are often mistakenly used as the efficiency of the entire device that uses the tube without accounting for the overhead of support circuitry and cooling. This is also true of many semiconductor devices.

5.2 Temperature measurements - Details of the temperature measurements are provided in appendices D, E, F and I. In general, the fiber optic measurements were the most stable measurements but there positioning was limited. Most readings presented here should be considered lower than actual due to the uncertainty of the air flow and mixing of air in the vicinity of the sensors.

5.2.1 Fiber optic temperature probe - Channels 21 and 22 were the primary channels of interest. Channels 23 and 24 were largely used for well liner protection. On occasion Channel 23 was used for monitoring in monitor well F3 but little was seen due to the cooling trends of the SVE flows. Detailed samples of the data sets are contained in appendix D

- The plots showed a period where the sensor temperature was held at just below 100 degs. C while water vapor was removed.

- The fiber optic probes were used to control the temperature below 150 degs C. at the liner walls. The temperature beyond the walls was always higher in temperature than the wall. The RF energy developed heat in the region outside of the liner. The applicator and the liner themselves produced very insignificant amounts of heat from the RF energy passage through them.

- The maximum temperature recorded was 233.9 deg. C on 19 May during the heating of Applicator #1. This temperature built over six hours from 165 degrees and than dropped slowly as the energy was removed from Applicator #1 and Applicator #2 was started. The heating was stopped due to excessive temperatures on the fiberglass well liner. The temperature appeared to be due to a flow of material in the heating zone that moved into the sensor region since it did not occur within the first 100 hours of the heating cycle when susceptible materials (e.g. water and hydrocarbons) close to the liner should have heated most strongly. A plot if this event is in Appendix D.

- Maximum recorded temperatures were:

Ch 21, well liner A2	>233 deg C.
Ch 22, well liner A1	>150 deg C.

5.2.2 Infrared probe thermal scans - A complete set of scans are contained on Appendix F. The following observations can be derived from the data set.

> DRAFT NOTE: additional statistics and profile summaries are being prepared as a correction to this draft.

- Maximum recorded monitor well temperatures:

F1 near A1 East	>115 deg. C
F2 near A2 East	>95 deg. C
F3 center	>95 deg. C
F4 near A1 West	>112 deg C
F5 near A2 West	>120 deg C

  - Temperatures higher on West side of zone - perhaps due to a smaller air flow on this side since this was the side for deep passive injection of ambient air.

  - Both A1 (applicator #2 heating cycle showed higher peak temperatures. This appears to be due to the more rapid heating rate used and the delayed configuration of the SVE system.

- The measurements from monitor wells F1, F2 and F3 were most strongly affected by the SVE air flow configuration since they were on the East, extraction side of the system.

- The maximum recorded well liner scan temperatures were:

A1 (approx 1 day after heating stopped)	> 175 deg. C
A2 (29 April)	> 145 deg. C

5.3.3 Thermocouple strings and probes - A complete set of scans are contained in Appendix E. A series of probe measurements for the SVE system (e.g. SVE output temperature) is contained in Appendix I.

- Maximum recorded temperatures

TC-1, East of A2	>82 deg. C
TC-2, South of A2	>62 deg. C
TC-3, South of A2	>39 deg. C

- The bottom measurement (20 ft level) in each well showed an upward trend from approximately 22 deg.C to 32 deg. C over the span of the program

5.3 RF applicator measurements - This is a select sample of a large data set. A key to the figures of this section with a definition of return loss is provided in Appendix G. The plots presented here are provided in larger scaling and with additional supporting plots.

5.3.1 3-D scan of A2 borehole - Borehole A2 was scanned with several test dipoles prior to setting up heating applicator #1. The test dipoles were constructed from the same 3.5 in. OD aluminum extension tube sections that were used to assemble applicator #1. The test dipole differed from Applicator #1 in that its feed line was a 0.5 in. dia. flexible insulated-jacket coaxial line without a connection to the ground plane at the surface.

The test dipole was set at five element spans (74", 78", 82", 86" and 90") to evaluate the subsurface soil characteristics at four reference depths (-5,-10,-15 and -20 ft.). Figure 17 is a return loss plot of the 78 in. dipole for the four sampling depths. From this plot it can be seen that good matches (significant negative values) for this dipole occur at depths of 5, 10 and 15 feet for the 27.12 MHz heating frequency (vertical marker).

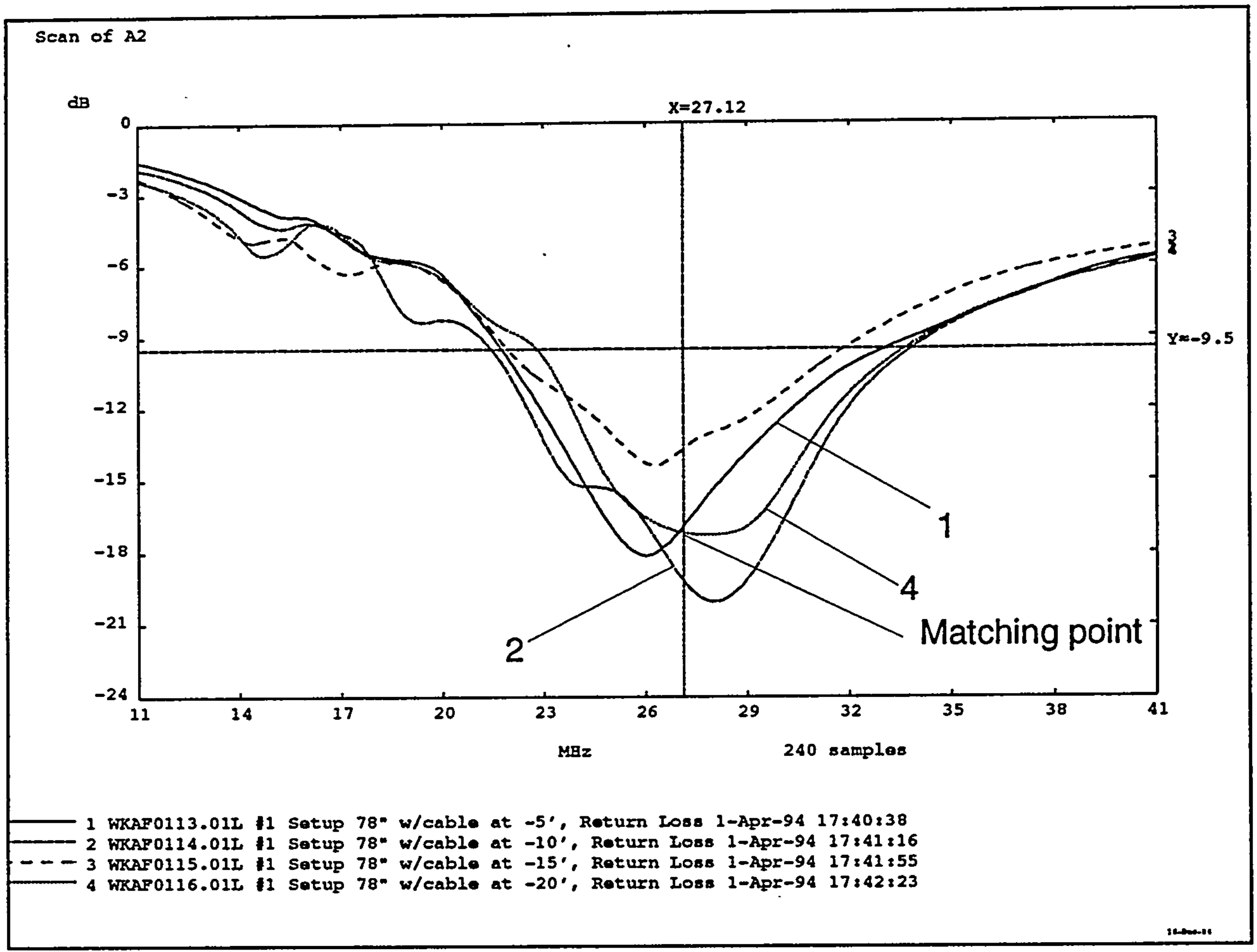

Figure 17 Overlay plot of four test dipole return loss measurements for 5 ft. to 20 ft. center depths in well A2.

This suggests that this region contained a higher density of electromagnetically lossy materials (water and hydrocarbons) than an adjacent region such as at 15 feet. Energy was strongly absorbed from the test dipole at this frequency.

Figure 18 is a 3-D display of this same data. It is important to note that these measurements represent the *average* electrical properties of a 78" vertical span of soil surrounding the well for a penetration distance of perhaps 12" to 48". Therefore the return loss measurement, for a dipole at a 20 ft. depth spans from 16.75 ft. to 23.25 ft. The measured data from these dipole measurements is of a form that can be modeled[10] with the programs NEC-3I and PAT7 to estimate a set of *average ground constants* that can then be used to plan a tuning strategy and model system performance. These average ground constants cannot be directly related to site sample analysis due to the inhomogeneous nature of the soils at the site. A complete set of scans is in Appendix G.

The applicator #1 and #2 setups differed from the test dipoles in that they were connected to the surface with sections of 1-5/8 in. dia. rigid copper transmission lines. The transmission line was radially grounded to the base plate ground plate as it exited the well. The ground plate was then connected to the ground plane screen and a set of radials. This more complex geometry does not allow for a direct translation of the test dipole data but does bracket the expected tuning setting.

The following observations can be made from the scan data:

- The physical inhomogeneity of the contaminated soil is evident in the return loss scans with a test dipole.
- Analysis of the scan data indicated that the applicator could be successfully tuned at all depths of the well.
- The well could be mechanically scanned to apply uniform heat to the entire well.

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[10] See section 6.1 on electromagnetic modeling.

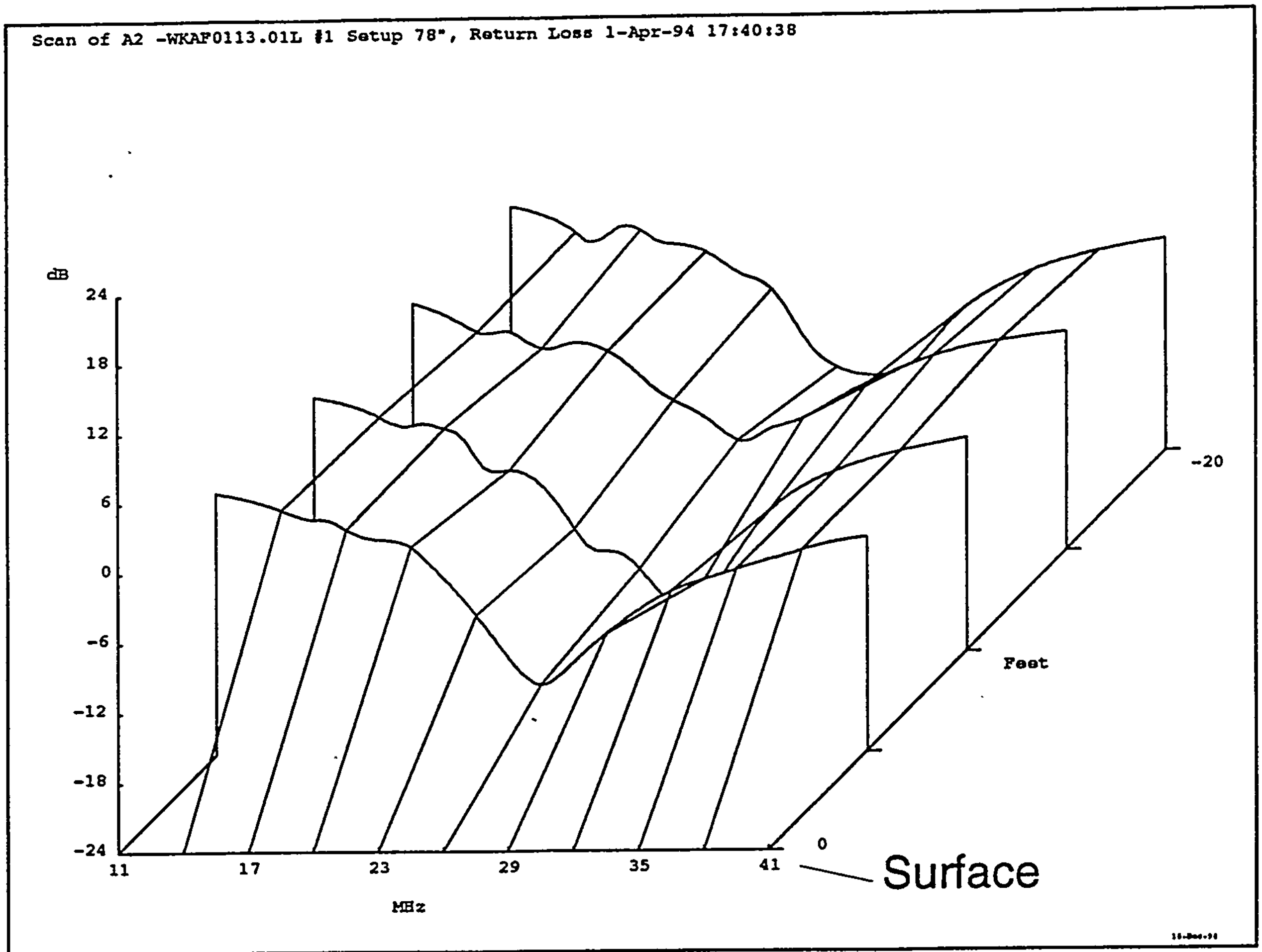

Figure 18 3-D display of dipole return loss versus depth for a scan of well A2.

5.3.2 Pre-heat measurements and applicator system tuning - Figure 19 compares the preheating return loss characteristics of Applicator #1 (in well A2) and Applicator #2 (in well A1). The applicator radiating element spans have been set to 100 inches (8.33 ft.). This long element span was selected to allow a 27.12 MHz resonance of the applicator after contaminants and water near to the applicator well liner were removed after several days of heating.

Plot line "1" for Applicator #1 shows a resonance higher in frequency than Applicator #2, plot line "2". The average soil characteristics about applicator #2 appear to be more energy absorbent. Therefore the return loss is larger and its graphic display is "deeper". These measurements were made with the HP 3577A network analyzer with a calibration point set at the center feedpoint of the applicators which is at a depth of 9.5 ft below the ground plane.

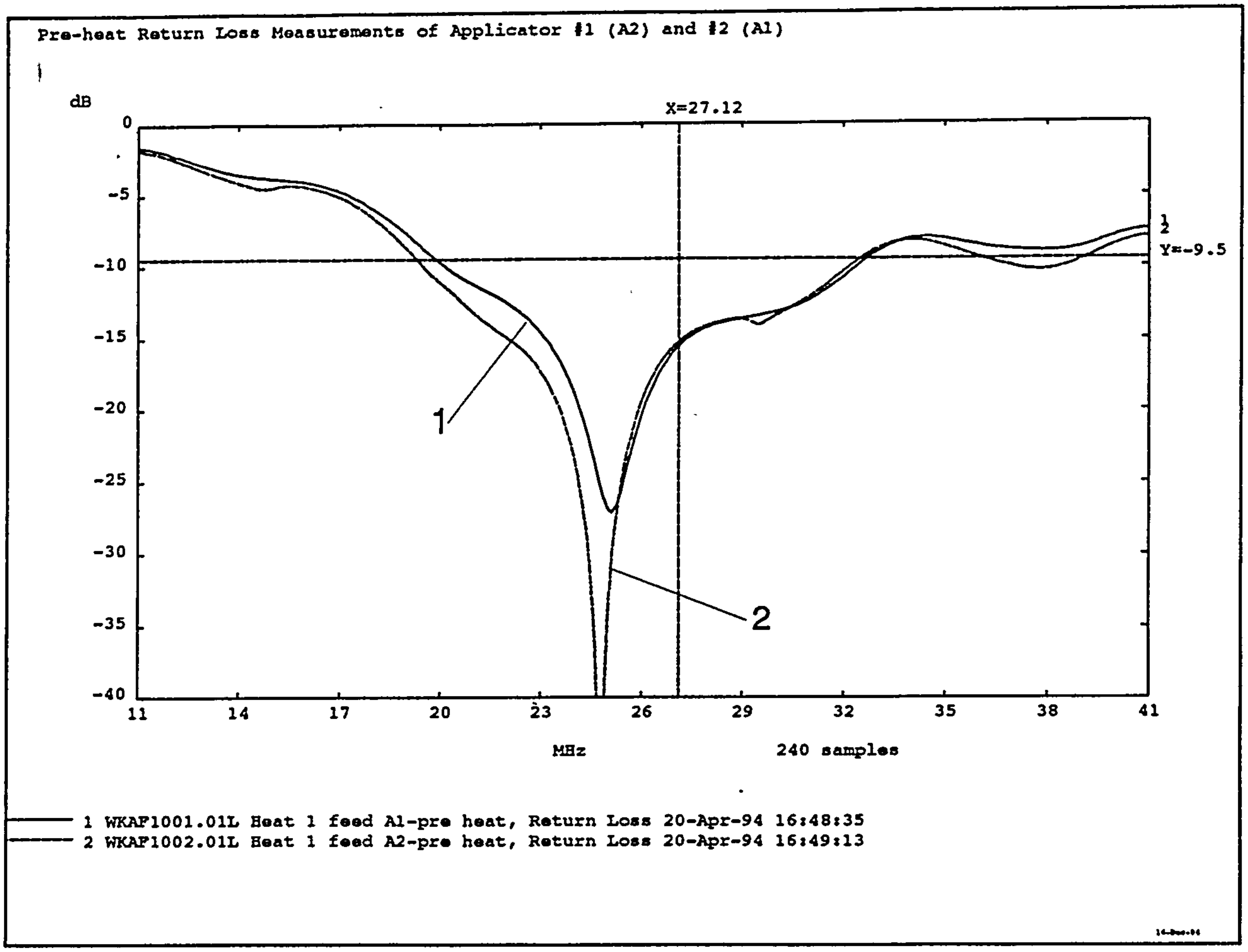

Figure 19 Comparison of pre-heat return loss measurements of Applicators #1 and #2.

Figure 20 is a return loss plot comparison of the applicators when they are matched to the RF generator by the 25 kW tuner. The measurements were calibrated to the test port of RF SW #1 at the input to the tuner. In this plot a common tuner setting was used for both applicators. The tuner matched both applicators to a resonance with a 23 dB return loss at 27.12 MHz.

Measurement applicator and tuned applicator data sets such as Figures 19 and 20 were recorded at the start and finish of each heating cycle. Initially the tuner was set for the compromise match for both applicators. However, when it became apparent, within Heating cycle one, that the energy could not be evenly applied due to the power stability problems, only one applicator was optimally tuned.

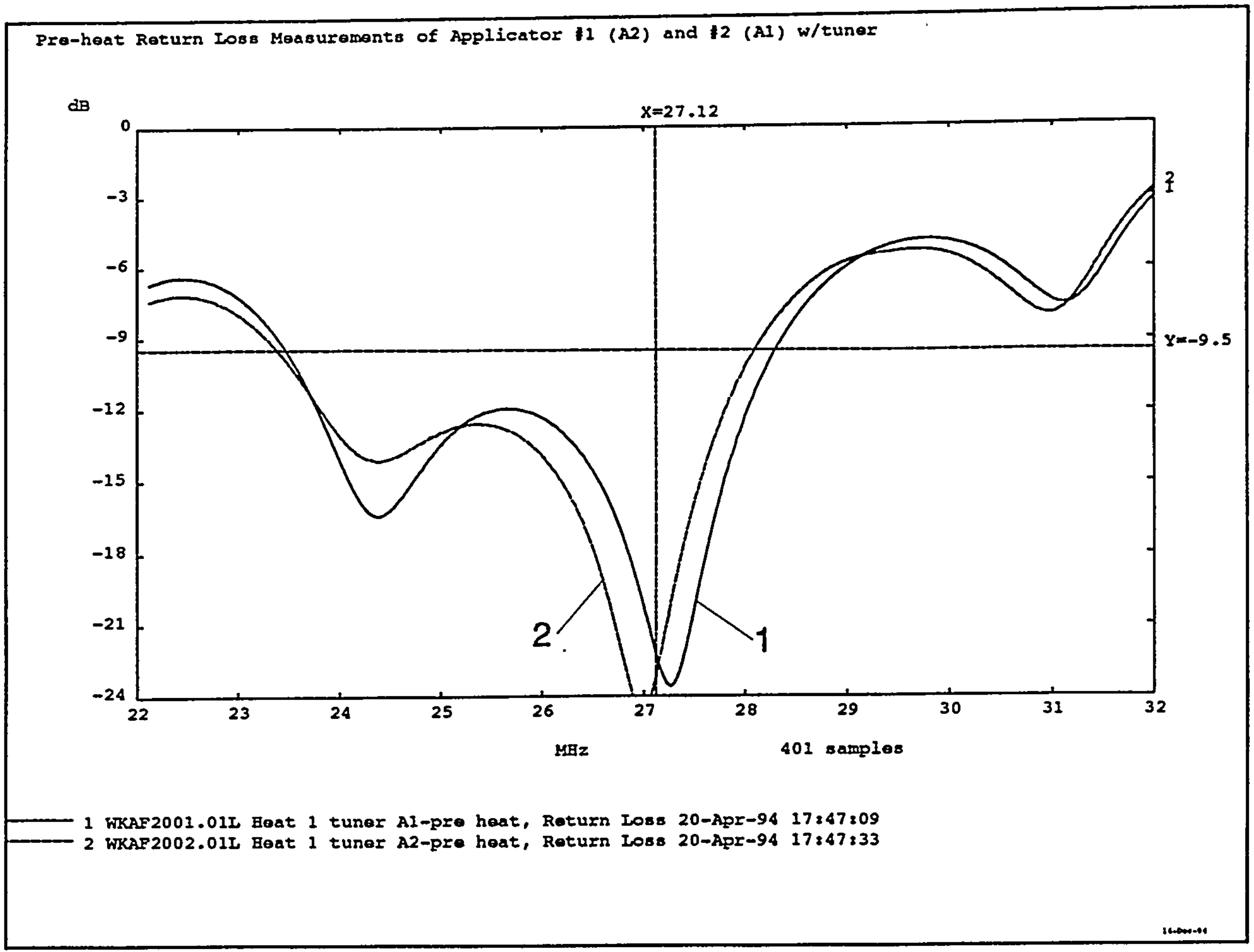

Figure 20 Return loss measurement of applicators with common tuner settings.

The observations that can be made from this data set are:

- The starting match point for the applicators was approximately 2 MHz below resonance.

- The starting match could be tuned with a common tuner setting for both applicators.

5.3.3 Applicator matching trends with heating - The RF heating applicators were initially tuned below the resonance point that was expected later in the heating cycle. Figure 21 compares a preheat baseline return loss measurement for Applicator #1 with two measurements taken within the first heating period[11]. Plot line "2" is near resonance at 27.12

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[11] Applicator #1 is labeled A1 in the plots and Applicator #2 is A2. At the time of these tests Applicator #1 was also in the well labeled A1. This was in error with site

MHz on 3 May. On 20 May the resonance has shifted to approximately 29 MHz. At this point the soil outside of the applicator was over 230 degrees C. and the applicator was turned off. Applicator #1 remained off until 30 May when it was restarted.

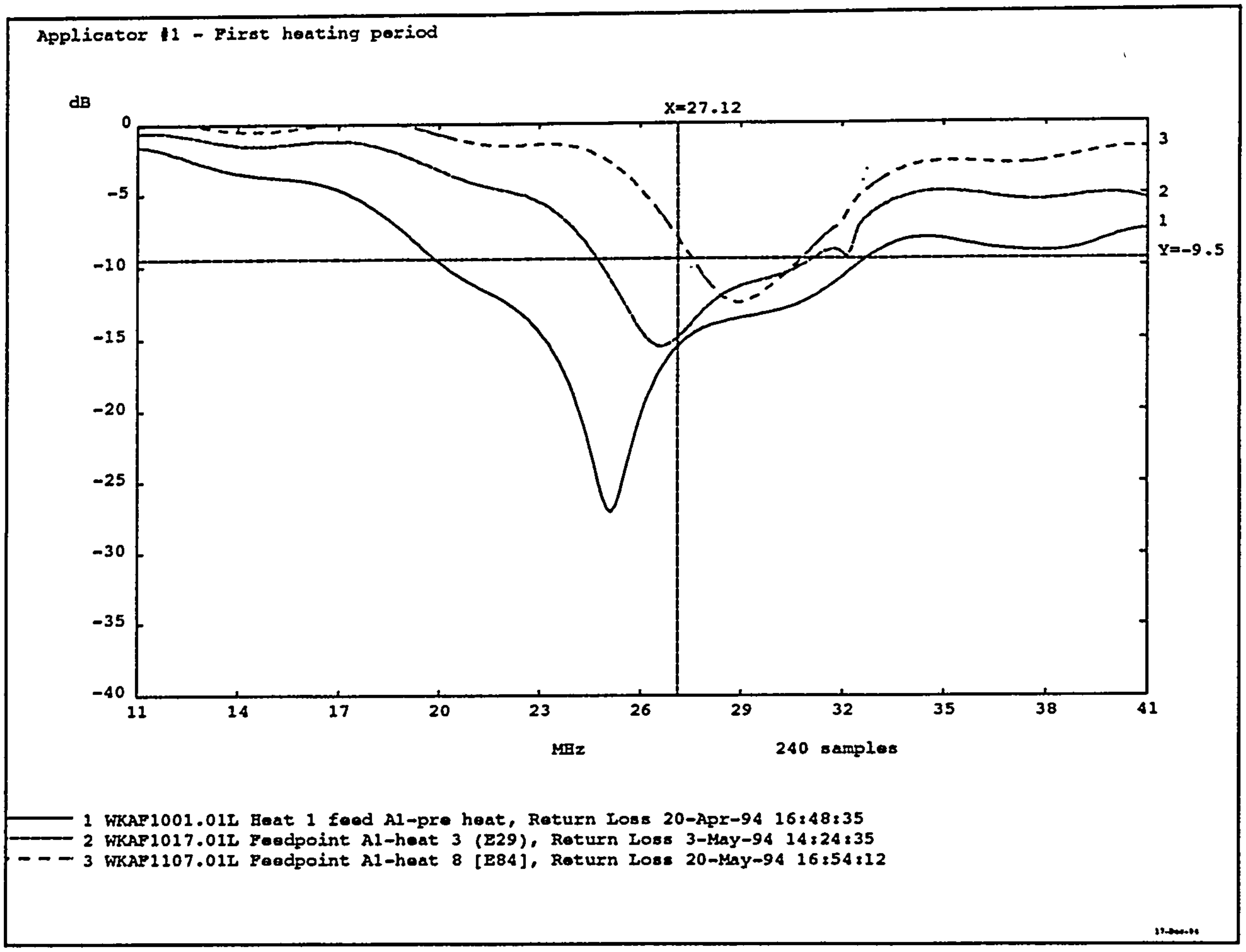

Figure 21 Return loss measurements for the first heating period of Applicator #1.

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sampling logs and has been subsequently relabeled well A2 within this report.

Figure 22 shows the return loss plot of applicator #1 in the cooling soil, prior to restart. It can be seen that the resonance point is about 26 MHz. At the end of the second heating period the applicator resonance point is just below 27 MHz and is quite sharp and deep. This sharp and deep return loss suggests that significant lossy material may have migrated[12] to the vicinity of the applicator well liner during the cooling process.

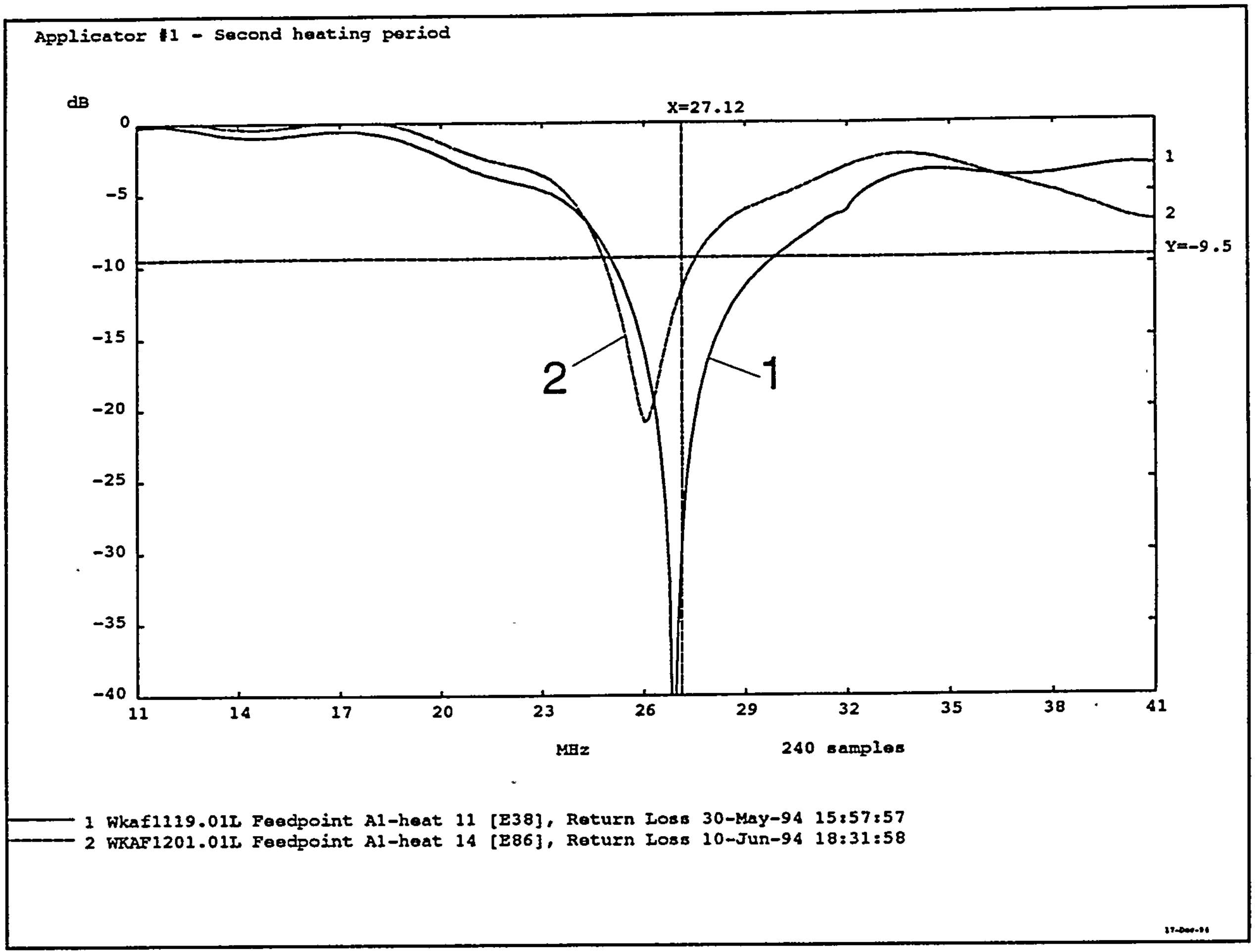

Figure 22 Return loss for the second heating period of Applicator #1.

Figure 23 is a plot of the heating period of applicator #2 which followed the first applicator #1 heating period. Approximately 8 days into the heating cycle, plot line "2" is seen with a resonance above 27.12 MHz. This shift is similar in behavior to that of applicator #1. Shortly after this measurement the applicator failed and was removed from service. The third

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[12] This is a speculation based on the idea that the 233 deg C temperature zone about the applicator at the end of heating period one was associated with the flow of a hot, high boiling point liquid. It is possible that the liquid moved into the vicinity of the heating well from an outer location and distributed itself along part of the well wall.

plot, line "3", was recorded after the applicator had cooled for about 9 days.

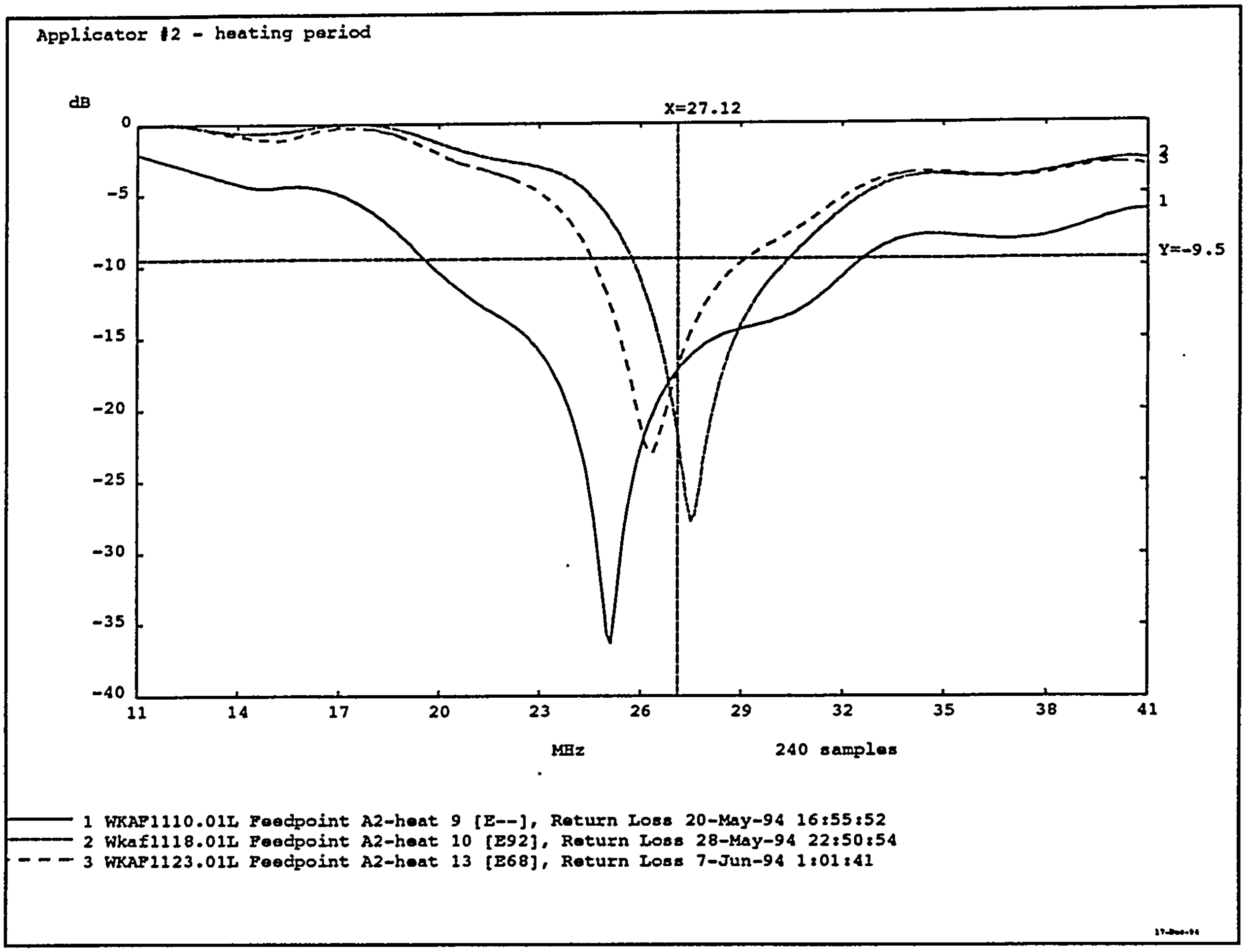

Figure 23 Return loss for Applicator #2 heating period and cool down.

The following observations can be made:

- The heating trends of applicator #1 and #2 were similar but applicator #2 shifted faster in frequency - apparently due to a higher heating rate.
- The cooling trend of Applicator #1 suggested a migration of contaminants back into the heating zone.
- The cooled resonance of the applicator #2 (7 June) heating period is very similar to the cooled resonance of Applicator #1 (30 May) after the first heating period.

5.3.4 Insertion loss trends with heating - These measurements show that as applicator #1 and applicator #2 heat the soil between them, the transmission of energy from one applicator to the other increases. The measurement is typically called the "insertion loss" of the medium between the applicators. It is measured by a network analyzer before and after the heating cycles and is recorded automatically along with the return loss measurements for each applicator. During the heating cycle this property is also measured in real time as a heating diagnostic measurement by the system's vector voltmeter. Figure 24 is a plot of the insertion loss between applicators #1 and #2 before heating. The measurements overlay identically as they should since they measure the same path with the applicators reversed.

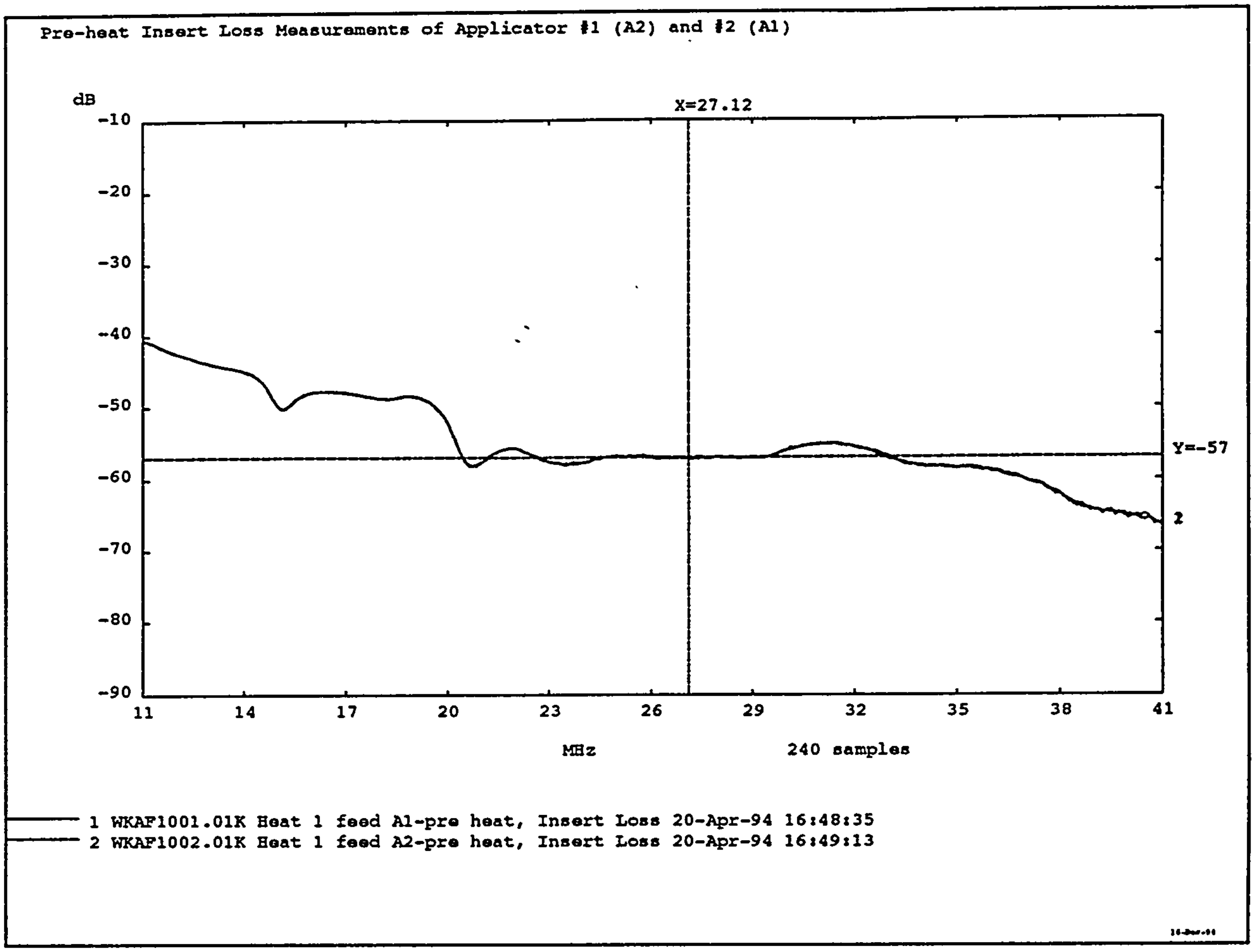

Figure 24 Baseline insertion loss measured between applicators #1 an #2.

Figure 25 shows the Applicator #1 to Applicator #2 measurement as a baseline. This baseline is accented by the -57 dB reference line which corresponds to the initial insertion loss at the 27.12 MHz marker line. This plot corresponds to the first heating period return loss measurement files of Figure 21. In this case it can be seen that there is barely any detectable insertion loss change by 3 May while a noticeable return loss resonance shift occurred. By 20 May a significant (approximately 10 dB) decrease in insertion loss occurred between the applicators.

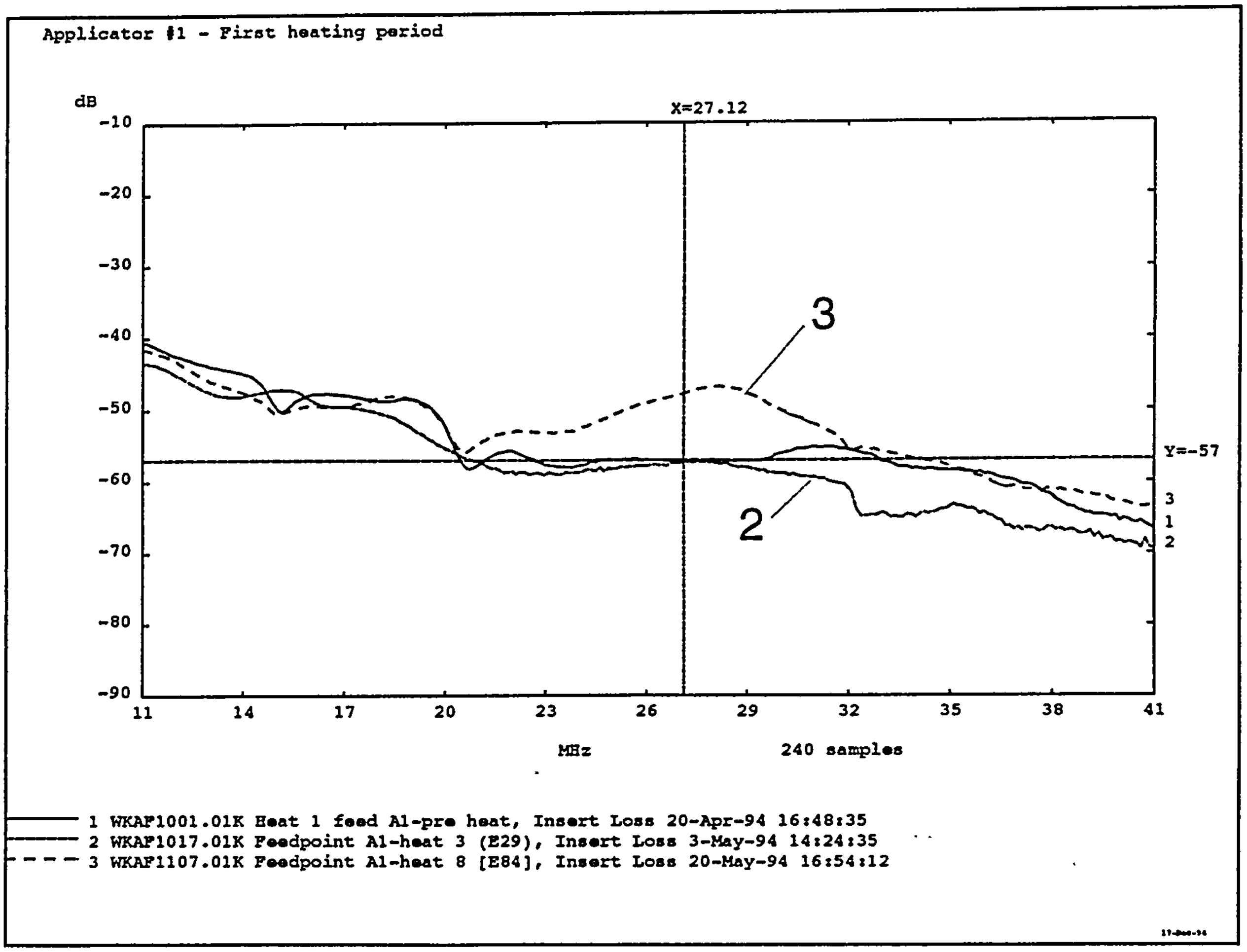

Figure 25 Insertion loss trends for first heating period.

Figure 26 provides insertion loss plots covering the entire program. The trend is continuously in the direction of decreasing insertion loss. At the conclusion of the program the corrected insertion loss decrease was 17.7 dB.

5.4 RF emission measurements- The auxiliary support instrumentation provided with the RF heating system was capable of measuring all parameters necessary to determine system compliance within both Federal Communications Commission (FCC) part 18 regulations and the USAF AFOSH Standard 161-9 which was specified for this program[11]. The detailed supporting measurements for compliance to these regulations and standards are provided in Appendix H

5.4.1 RF emission compliance under FCC part 18.305. The emissions from the site were measured with a broadband, vertically polarized, 2 meter high, calibrated biconical antenna. The antenna signal level was processed by a portable calibrated spectrum analyzer for distances of 10 meters and 300 meters (1/4 mile) from the active applicator borehole (A1 or A2). Both the initial and closing measurements were witnessed by representatives of the Kelly AFB base frequency management office. Detailed tests were logged on 3 May, 18 May, 24 May, 6 June, 7 June, 8 June and 10 June. Key observations from the data base are:

- The RF generator operated at a measured frequency of 27.1335 MHz which was 13.5 kHz below the ISM band center frequency of 27.12 MHz. This is within the FCC allowed bandwidth of +/- 163 kHz.

- The 1st through 6th harmonics of the operating frequency were measured and resolved with a 9 kHz resolution bandwidth and the signal averaging of 100 sweeps per measurement.

- Harmonics were measurable at all of the 10 meter test antenna locations. These same harmonics were unmeasurable or at the threshold of detection (noise floor) at the 300 meter location. **The part 18.305(b) harmonic emission limit for 27.12 MHz is calculated as 169 uV/m or 44.58 dBuV/m for a 300 meter distance.** *On 7 June, with 23.21 kW generated RF level, the second harmonic was detected at the 300 meter position by narrowing the resolution bandwidth of the spectrum analyzer to 200 Hz. The harmonic level was calculated as 2 uV/m or 3.9 dBuV/m.* ***This is over 40 dB below the FCC emission limit (a factor of 10,000 lower than the limit).***

- The surface emissions at the 27.12 MHz heating frequency typically ranged in the vicinity of 0.4 V/m at the 10 m measurement locations for 20 kW power levels.

- The highest surface emission measured off site at the 300 meter West location was 0.25 V/m while under similar conditions the 10 meter location measured 0.36 V/m. The RF generator output power was 23 kW during these 10 June and 8 June measurements.

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[11] Occupational Safety and Health Administration (OSHA) safety guidelines which use the IEEE Standard C95.1-1991 for enforcement of non-ionizing radiation safety.

- The highest site level measured at a 10 meter location was 1 V/m for an RF generator output power level of 23.57 kW on 6 June.

- *All RF emission measurements were easily within the compliance limits of FCC Part 18.305 regulations.*

5.4.2 Surface field strength safety measurements - The emissions from the site were measured with the calibrated electric and magnetic probes of a broadband isotropic field strength meter. Radial distances of 0.1 meter, 1 meter and 3 meters from the active heating applicator (A1 or A2) were used as measurement locations. The 10 meter distance measurements from the RF emission tests of 5.4.1 were also included in the radiation safety measurement data analysis. Twenty-three electric field measurement sets were taken at defined locations on the site on twenty-three heating days. **Safety compliance was based on maintaining the electric field exposure level for site personal below the 70 V/m calculated value[12] for the permissible exposure limit (PEL).** The PEL is defined as a 6-minute average exposure limit.

Initial measurements were witnessed by Kelly AFB site safety personnel. The isotropic field probe was constantly available for spot safety checks. Site personal were alerted to the presence of RF power delivery to the applicators by red "RF ON" warning lamps[13].

- 10 meter distance measurements at a 2 meter height reported in section 5.4.1 provided a safety cross check for the program. The maximum emitted field level measured was 1 V/m (vertically polarization only).

- 3 meter distance measurements at a 1 meter height ranged from 1 to 14 V/m over the course of the heating program.

- 1 meter distance measurements at a 1 meter height ranged from 7 to 59.1 V/m over the course of the heating program.

- 0.1 meter distance measurements, controlled by a foam spacer ball (FCC defined test fixture), ranged from 25 V/m to 132 V/m. It is important to note that these

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[12] This is calculated for the 27.12 MHz operating frequency using the formula for the 6-minute average exposure limit in AFOSH Standard 161-9, 12 February 1987. This document is contained as Appendix C of the Site Specific Health and Safety Plan for the Radio Frequency Soil Decontamination Demonstration at Site S-1, March 1993.

[13] Two red lamps were mounted on top of RF SW#3 at the edge of the vapor barrier and one red light was mounted on a mast projecting 5 feet above the instrument shelter. The warning lamps were controlled directly by the RF generator's "RF ON" power enabling circuitry. Two yellow "STANDBY" lamps mounted on masts below the red lamp are turned on to show the system is ready to go to the RF ON state under computer control.

measurements are made on the applicator transmission line surface and do not represent a risk to incidental human exposure.

- The highest measurement within 1 meter of the system at a standard height of 1 meter was 59.1 V/m on 9 June with 23 kW of generated RF power.

- *All measurements within 1 meter of the heating applicator were within the 70 V/m PEL required for the program by AFOSH Standard 161-9.*

- *All measurements within 1 meter of the heating applicator were within the 66 V/m maximum permissible exposure (MPE) allowed by IEEE C95.1-1991 Standard for enforcement of non-ionizing radiation safety.*

- An additional ambient RF measurement was logged by the control computer during some heating periods by using the system vector voltmeter. The voltmeter was connected to a calibrated monopole antenna on the roof of the instrument shelter. The received signal level was processed with alarm and warning limits that were used to alert operators in any shifts of the ambient RF that might signal a potential safety problem and shut down the RF generator. No events were recorded for this program.

- Magnetic field readings tracked the Electric field measurements for safety compliance measurements at 1 meter and 3 meter locations due to the near free space locations of the measurements. Magnetic field reading were recorded only for detailed site mapping measurements.

File: Kelly5.A

6.0 DATA ANALYSIS VS MODELING PREDICTIONS

Numerical and analytical modeling tools were used to provide a prediction envelope for the program. It was very necessary to use a series of general assumptions to setup the models since the site is a non-homogenous hydrocarbon waste dump..

6.1 Electromagnetic modeling - Two numerical codes and one analytic modeling code were used for this program. The codes were used to estimate the operating characteristics of the applicators that may be encountered as the site was heated. Ground constant measurements reported by a previous Kelly AFB test program at site S-1 varied widely and suggested stable values only above 100 degrees C. The models also used ground constant values based on the estimated water content of the soil[14].

Numerical Electromagnetic Code 3, insulated wire case (NEC-3I)[15] and a more advanced code 4 (NEC-4)[16] was used extensively to approximate the effects of the ground plane system, borehole liner, applicator spacing and applicator tuning. The goal of the pre-heating modeling was to plan the size of the ground screen, estimate the required adjustment range of the applicator tuning arms and to estimate the energy that was deliverable to the soil.

An analytic modeling code, PAT7[17] was used to quickly approximate applicator tuning trends with changes in soil dielectric constant, soil conductivity and applicator dimensions. The PAT7 models were examined in detail at specific points by the NEC codes.

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[14] *Hardened Antenna Technology, Antenna Engineering Design Handbook for Buried Linear Arrays*, Eyring Research Institute, RADC-TR-89-54, Vol 2, Final Technical Report, May 1989 - KAI Technologies was a supporting subcontractor for the production of this handbook. Appendix B of this handbook contains tables and practical information on ground constants.

[15] G.J. Burke, A.J. Poggo, *Numerical electromagnetics Code* (NEC) - *Method of Moments*, Naval Ocean Systems Center Technical Document 116, January 1981.

[16] G. J. Burke, *Numerical Electromagnetics Code - NEC-4, Method of Moments, Part I: User's Manual*, Lawrence Livermore National Laboratory, January 1992.

[17] M.B. King, R.B. Gilchrist and D.L.Faust, *Eyring Low Profile and Buried Antenna Modeling Program PAT7 User's Manual*, Eyring, Inc. Communications Systems Division, Provo, UT. June 1991. - The PAT7 code was developed to predict the communications performance and characteristics of broadband buried antenna systems. The data from this program can be interpreted to provide insight into the operation and tuning of narrowband RF heating antennas.

6.1.1 NEC modeling of the dual-applicator system for tuning - A series of models were used to approximate various aspects of the applicator tuning problem. The models considered:

- Diameter of applicator in relation to borehole diameter and average ground parameters.
- Influence of the ground plane design on the tuning strategy of the applicator when positioned near the surface. The study suggested ground plane radial lengths and expected surface electric field levels.
- Field strength within the surrounding medium as a function of antenna tuning.

The data sets developed by this approach produced guidance and trends but did not develop predictive values that matched the site's initial conditions prior to those determined by actual on-site measurements. The complete system with two applicators, transmission lines, ground plane and emplacement towers was too complicated to practically model to a predictive degree. The inhomogeneous nature of the contaminated soil added the final complication to the modeling problem.

6.1.2 NEC modeling of driving point impedance and transmission loss changes due to heating - Modeling provided a useful insight into the range of changes that were associated with the heating process. NEC-4 was used to model the change associated with the heating of applicator #1 in well A2. The NEC model was adjusted by changing the average ground constants (over 100 in. span) till the measured transmission loss value recorded at the end of the program was approximated. The result was as follows:

	Impedance (complex value) ohms	**Transmission loss measured between App #1 and App #2 dB at 27.12 MHz**
Applicator #1 (Start 20 April)	49.2 + J16.1	57.4 (measured)
NEC model (Er=14.75, σ=40 mS/m)	56.8 + J12.3	57.1 (starting model)
Applicator #1 (End 10 June)	47.0 + J23.0	39.7 (measured)
NEC model (Er - 8, σ=15 mS/m)	69.5 + J12.3	39.1 (resultant model)

The 17.7 dB transmission loss decrease associated with the heating process was modeled by shifting the average ground constants until the model matched the loss. The change in ground constants were consistent with a change in volumetric water content from 18% to 5%.

However in this case the shift is most likely due to the removal of hydrocarbon products and not a significant, 18% water content.

6.2 Thermal modeling - The thermal modeling program was used to estimate the thermal propagation characteristics of a single applicator and dual applicator heating system with the same total input power.

A finite element analysis (FEA) heat transfer code model was developed for the COSMOS FEA code developed by the Structural Research and Analysis Corporation. The energy distribution pattern used to drive the model was based on a static NEC-3I model of the RF heating applicators energy distribution for a 100 degree C starting temperature. The model developed 6 thermal calculations over a period of 30 days. Heating was started at 100°C because the electrical properties of the soil, as predicted by the previous program, remained relatively constant above this temperature.

Two cases were modeled at a 27.12 MHz frequency with 20 kW power delivery levels to the soil:

- Single applicator at 100% duty cycle,
- Two applicators spaced 10-feet apart operating at a 50% duty cycle.

6.2.1 NEC-3I configuration for thermal modeling. The single dipole was modeled in the center of a *homogenous*[18] soil volume while the dual applicators were centered on the x-y plane, 10 feet apart. The applicators were operated at their resonant length for the modeled media with the dual dipoles slightly shorter in length due to mutual coupling.

Length (m):	2.75 (9') single; 2.65 (8.7') dual
Diameter (cm):	7.62 (3")
Insulation Diameter - Air (cm):	11.81 (4.65")
εr (Soil):	8.0
σ (mS/m):	0.678
Frequency (MHz):	27.12
Feed Depth below Air/Soil Boundary (m):	14.6' single; 14.4' dual
Radiated Power (kW):	20 kW single; 20 kW (10 kW per) dual
Impedance at Resonance (Ω):	53.2 single; 38.8 dual (w/coupling)

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[18] NEC-3I requires a homogeneous medium as a modeling assumption. Below 100°C the RF heating process is much more complicated to model because both the electrical and thermal properties are changing as the temperature is raised and as the moisture is driven from the soil.

6.2.2 COSMOS FEA heat transfer configuration. The COSMOS FEA heat transfer model was run using the following values for the soil properties along with the heat flux densities generated by NEC-3I[19]. The model assumed that the soil volume was well insulated.

Dimension of heated volume:	21 ft. x 21 ft. x 21. ft
Soil volume:	343 cubic yards
Specific Heat (c):	0.22 cal/gm/°C
Density (ρ):	1.7 gm/cc
Thermal Conductivity (k):	0.25 cal/m/s/°C

6.2.3 Comparison of modeled to measured data. The heating profile data consists of 4-D color plots and a plot of the temperature versus time at a point 5-foot from the feed point of the applicator (center of antenna at depth). For the case with two applicators this 5-foot point represented the point directly between the feeds of two applicators since the applicators were 10 foot apart. The modeling data sets are provided as Appendix J of this report.

- The dual applicator model describes an ideal intended pattern for the site that may have been approximated if the system were able to alternate power between the applicators and would have been able to operate for the entire program at its optimum heating rate.

- *In general the modeling data cannot be applied directly to the heating program as it developed at the Kelly AFB site.*

- The segmented and low rate heating periods make it difficult to draw any direct ties to the time scale of the modeling with the actual program.

- The non-homogenous electromagnetic and physical nature of the soil further confounded any efforts to relate measured data to the thermal model. The 3-D return loss plot of A2 in section 5.3.1 confirms this observation from the electromagnetic view..

- The model suggests that higher temperatures should have been seen on the lower half of the applicators but they were observed to be higher on the upper half of the applicators. This could be due to the non-homogenous nature of the soil or the cooling influence of the SVE systems flow pattern.

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[19] W.C. Walton, *Principles of Groundwater Engineering*, Lewis Publishers, Inc. 1991

7.0 REVIEW OF SOIL CHEMICAL ANALYSIS

The soil chemical analysis scheme was originally based on the definition of a Treatment Zone volume of 111 cubic yards (15 ft. x 10 ft. x 20 ft.) which was compared to a control sample region bounding the sides of the volume with sample depths up to 10 feet below the region. The soil analysis for Total Recoverable Petroleum Hydrocarbons (TRPH) was based on the analysis of 40 sample pairs within this region.

Due to changes in the heating system configuration, a heating zone of 15 ft. x 10 ft. x 10 ft. was defined inside of the treatment zone. The top of the zone starts at a depth of 4 feet and ends at a depth of 14 feet. This zone was further subdivided for analysis into two a halves. The halves are centered about each of the heating boreholes (A1 and A2). The TRPH analysis if these zones, with an 80% confidence level correlates with the energy applied to the zone and the period of the applied energy (heating).

	Volume	**TRPH**	**Energy delivered**	**Days spanned**
Treatment zone	111 cu. yds.	29%	15,549 KWH	49.92
Heating zone	55.5 cu. yds	>42%	15,549 KWH	49.92
A1 heating zone	27.7 cu. yds	<40%	4,348 KWH	8.15
A2 heating zone	27.7 cu. yds	>60%	11,201 KWH	41.77 (2 spans w/cooling period)

(!!! NOTE: The above ">" items are estimated place holders, pending new calculations by SAIC, 12/14)

The A2 heating zone, driven by applicator #1 is suggestive of the anticipated recovery rate. Ideally this zone and the A1 zone would have each received 10,000 KWH in a 42 day period. It is projected that this heating would have been more effective than the slow heating period with cooling cycles that this program experienced. It is also expected that if a second generator were used the simultaneous, phased-array heating would produced an even stronger and rapid heating effect that would further improve recovery. Finally, changes to the SVE system design would also be a source of recovery improvement.

7.1 Impact of changes in the heating system configuration. - Changes in the heating program's planned operating time and its ISM operating frequency required that the heating zone be defined as approximately upper half of the treatment zone. This change occurred when an ISM operating frequency of 27.12 MHz was chosen in contrast to a 13.56 MHz frequency. The 27.12 MHz frequency was chosen to allow a faster heating of two smaller adjacent volumes within the treatment zone as opposed to a larger heating zone with a slower heating rate.

The 13.56 MHz applicator would have had a nominal heating span of 18 ft. as opposed to the 9 ft. span of the 27.12 MHz applicators and could have been positioned within the center of the treatment zone. Two, more rapidly heating, 27.12 MHz applicators were chosen to be driven in a time-multiplexed heating mode by a single 25 kW RF generator to approximate the performance of a more optimally configured dual RF generator system. This configuration allowed data to be gathered that would be predictive of how a dual RF generator phased-array[20] RF system might perform.

A additional impact of the shorter, vertical profile, heating span occurred when the applicator was fixed in the upper half of the treatment volume. This upper half favored the heating of VOCs as opposed to SVOCs in the lower half of the treatment zone.

(DRAFT NOTE) - The detailed chemical analysis commentary and data has not been fully available for review as of this time. Comments, as required by the program SOW, will be provided in review of the Final Program Report.

7.2 Other operating details with soil analysis influence - The SVE system typically operated in a "deep extraction" mode that pulled vapors down from the bottom of the heating zone into the extraction wells screened from 10-ft. to 20-ft. depths (see 3-D site setup figures in Section 2.0 and Appendix B SVE configurations listed in logging comments). The effect of this downward vapor "draw" may be responsible for some contaminant migration from the heating zone into the treatment zone and is likely to make it difficult to quantitatively evaluate contaminate concentration changes.

Several of the statistically defined TRPH sample sets[21] were complete enough at test well location to be examined as a concentration profile. A review of some TRPH sample sets suggest that materials condensed between the 0-foot and 4-foot levels where the SVE efficiency may have been low. Condensation also appears to have occurred where hot and cool extraction air mixed near an extraction well. The following data listings are of three set of soil samples. Missing depths were omitted due to the statistical sampling scheme used to distribute the 40 sample pairs..

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[20] A 2-element phased applicator array actually has a heating rate and intensity advantage over what can be produced by two, non-phase controlled applicators and RF generators. This testing approach provided data to evaluate how well the base heating rate could be predicted for the non-phased applicators. The test also demonstrated the electromagnetic field coupling levels that could be achieved between the two applicators.

[21] ***** AS OF THIS DRAFT THE VALUES PRESENTED HERE ARE PRELIMINARY AND WILL BE REPLACED BY FINAL VALUES BY SAIC.

A2 - Location of applicator #1 with the majority of applied energy - The 0 - 4 ft. locations show significant increases in concentration. The heating zone volume near the applicator shows a strong removal trend. The 10 - 12 ft. location that corresponds to the highest heating temperature profile shows significant removal.

Location A2	Pretreatment Concentration (ppm)	Post treatment Concentration (ppm)
0 - 2 ft.	2,330	8,850 [suggested condensation]
2 - 4 ft.	203	2,570 [suggested condensation]
-------- heating zone boundary -----		
4 - 6 ft.	1,530	154
6 - 8 ft.	-	-
8 - 10 ft.	-	-
10 - 12 ft.	1,290	33.3 [removal to quantitation limit]
12 - 14 ft.	622	106
-------- heating zone boundary -----		
14 - 16 ft.	-	-
16 - 18 ft.	79,700	20,800
18 - 20 ft	39,300	28,300 [removal by ambient air SVE only]

E5 - Extraction well located on center line near A2 - Extraction is enhanced in the heating zone. The 12 - 14 ft. level appears to a condensation boundary were cool air meets the downward flow of hot vapor.

Location E5	Pretreatment Concentration (ppm)	Post treatment Concentration (ppm)
0 - 2 ft.	-	-
2 - 4 ft.	-	-
-------- heating zone boundary -----		
4 - 6 ft.	2,710	673
6 - 8 ft.	1,530	587
8 - 10 ft.	-	-
10 - 12 ft.	668	330
12 - 14 ft.	739	1,450 [suggested condensation at extraction well]
-------- heating zone boundary -----		
14 - 16 ft.	-	-
16 - 18 ft.	-	-
18 - 20 ft	105,000	35,800 [removal by ambient air SVE only]

F3 - Monitor hole for IR temperature profiles centered between A1 and A2 at 5 feet. - Strong removal is suggested in the top of the heating zone where the maximum temperature profiles were recorded between 6 and 10 ft. The temperature dropped off sharply in the 10 ft. to 12 ft. zone and could be seen to match the region of increased concentration.

Location F3	**Pretreatment Concentration (ppm)**	**Post treatment Concentration (ppm)**
0 - 2 ft.	-	-
2 - 4 ft.	-	-
-------- heating zone boundary -----		
4 - 6 ft.	4,920	702 [strong removal suggested]
6 - 8 ft.	-	-
8 - 10 ft.	-	-
10 - 12 ft.	336	4,510 [suggested condensation between extraction wells screened from 10 ft. to 20 ft.]
12 - 14 ft.	-	-
-------- heating zone boundary -----		
14 - 16 ft.	-	-
16 - 18 ft.	-	-
18 - 20 ft	-	-

8.0 REVIEW OF SOIL VAPOR EXTRACTION DATA

The soil vapor extraction system flow characteristics do not appear to have been optimum to extract from the chosen Heating Zone in the upper level of the site Treatment Zone (see site setup in Section 2.0). However, it appears that they were adequate to demonstrate significant VOC removal from the Heated Zone.

The downward "draw" of the SVE system on the Heated Zone has been observed to produce a number of thermal profile measurement distortions that require careful analysis for interpretation. In general the downward flow caused the deep portions of the thermal patterns to have lower relative temperature values and truncated profile patterns with minimal lateral flow and limited "draw" from the higher levels of the zone. It is also possible that condensation occurred for some volatiles as they mixed with cooler air as they were drawn to the extraction wells.

The SVE system output temperatures, measured at the control valves next to the vacuum manifold, were generally lower than anticipated. Temperatures within the heated zone suggested that high temperature soil vapors could be estimated to range from 100 degs C to well over 180 degrees C. These vapors were mixed with a significantly larger[22] volume of cooler subsurface air that maintained the extraction well output temperatures below 100 degrees C.

The six SVE sampling periods reported Radian are identified along with the site heating conditions and SVE configuration in the comments section of the Appendix B logging summary. The SVE temperatures versus time plots are plotted in Appendix H.

(DRAFT NOTE) - The detailed SVE analysis commentary has not been fully available for review as of this time. The Radian report has been reviewed but not in the context of temperature and SVE flow profiles that are still being evaluated. Comments, as required by the program SOW, will be provided in review of the Final Program Report.

Page 5-15 of the Radian report[23] indicates that the lowest SVOC and VOC concentrations were measured on 14 June. This was 4 days after the RF system was turned off (report indicates 7 days in error). The report suggested that this measurement constituted an anomaly when

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[22] The conclusion is arrived at by estimating that the top 1/3 of each extraction well (10 ft. to 13 ft.) received hot vapors and the balance of the well (13 ft. to 20 ft.) contributed cooler subsurface air to the extracted air stream. In cases where multiple extraction wells were connected the dilution ratio would be still higher.

[23] *KAI Technologies Inc. Radio Frequency Heating Demonstration - Final Report*, Radian Corp., Austin TX, September 7, 1994.

7.0 REVIEW OF SOIL CHEMICAL ANALYSIS

The soil chemical analysis scheme was originally based on the definition of a Treatment Zone volume of 111 cubic yards (15 ft. x 10 ft. x 20 ft.) which was compared to a control sample region bounding the sides of the volume with sample depths up to 10 feet below the region. The soil analysis for Total Recoverable Petroleum Hydrocarbons (TRPH) was based on the analysis of 40 sample pairs within this region.

Due to changes in the heating system configuration, a heating zone of 15 ft. x 10 ft. x 10 ft. was defined inside of the treatment zone. The top of the zone starts at a depth of 4 feet and ends at a depth of 14 feet. This zone was further subdivided for analysis into two a halves. The halves are centered about each of the heating boreholes (A1 and A2). The TRPH analysis if these zones, with an 80% confidence level correlates with the energy applied to the zone and the period of the applied energy (heating).

	Volume	**TRPH**	**Energy delivered**	**Days spanned**
Treatment zone	111 cu. yds.	29%	15,549 KWH	49.92
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A1 heating zone	27.7 cu. yds	<27%	4,348 KWH	8.15
A2 heating zone	27.7 cu. yds	>47%	11,201 KWH	41.77 (2 spans w/cooling period)

(!!! NOTE: The above ">" items are estimated place holders, pending new calculations by SAIC as of 12/14 ---- 27% and 47% values are in question due to F3 inclusion?)

The A2 heating zone, driven by applicator #1 is suggestive of the anticipated recovery rate. Ideally this zone and the A1 zone would have each received 10,000 KWH in a 42 day period. It is projected that this heating would have been more effective than the slow heating period with cooling cycles that this program experienced. It is also expected that if a second generator were used the simultaneous, phased-array heating would produced an even stronger and rapid heating effect that would further improve recovery. Finally, changes to the SVE system design would also be a source of recovery improvement.

7.1 Impact of changes in the heating system configuration. - Changes in the heating program's planned operating time and its ISM operating frequency required that the heating zone be defined as approximately upper half of the treatment zone. This change occurred when an ISM operating frequency of 27.12 MHz was chosen in contrast to a 13.56 MHz frequency. The 27.12 MHz frequency was chosen to allow a faster heating of two smaller adjacent volumes within the treatment zone as opposed to a larger heating zone with a slower heating rate.

The 13.56 MHz applicator would have had a nominal heating span of 18 ft. as opposed to the 9 ft. span of the 27.12 MHz applicators and could have been positioned within the center of the treatment zone. Two, more rapidly heating, 27.12 MHz applicators were chosen to be driven in a time-multiplexed heating mode by a single 25 kW RF generator to approximate the performance of a more optimally configured dual RF generator system. This compared with the following 24 June measurement of comparatively higher values. Actually this shift appears to be due to the SVE configuration shift on 14 June.

The previous measurement on 7 June was made with an identical SVE configuration to the one on 14 June. Both measurements used only the deep extracting center-line wells E4 and E5. All other wells, on the perimeter of the site were used as injection wells. The SVE shift on 14 June cut off extraction form E4 and E5 and only drew from the East Wall E1, E2 and E3 wells which essentially reversed flow on part of the extraction volume.

9.0 COST EVALUATIONS

The Kelly RF Heating program was essentially executed as an investigative pilot program that addressed an number of site configuration items (e.g. SVE) in addition to the RF heating system installation and operation. The site was operated with more personnel than would normally be required for even a larger program and site conditions did not allow full automatic operation of the heating system. Therefore it is not easy to develop a set of directly scaled cost figures that apply in detail to a commercial embodiment of this system.

However, there are some cost and resource utilization number available, directly from the program data that can be used to generally characterize the application of RF heating for thermally enhanced SVE programs. These numbers were based on the last 21.3 day period[24] of the heating program. These planning numbers are:

- RF Energy Generation rate: (dependent on available 3-phase voltage level). — 19.93 kW/hour
- Cost per hour of RF generated: (based on a 19.93 kW/hr generation rate with a 58.9% system 3-phase AC power conversion efficiency plus 5 kWH overhead with a utility rate of $0.10/kWH) — $3.88/hour
- RF system operation within on site span: (includes breaks for measurements and maintenance checks over a span or 10 days or more). — 94.54%

9.1 Outline for costing of a 200 kW system - A 200 kW system could be approached by using eight 25 kW RF generators with the capability of driving either 2-element or 4-element applicator arrays. The system would employ a minimum of 16 switched applicator positions to allow continuous operation of the system as applicators are removed from heated areas and installed in new areas.

The exact definition of a 200 kW system will depend on the site characteristics. Some of the principal determinates of the system configuration would be:

- Contaminant plume thickness, extent and nominal depth defines if the preferred access would be through either vertical or horizontal drilling techniques.

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[24] This period follows the repairs to the 3-phase power system splices and replacement of the power line.

- The preferred heating dimensions of the plume will determine if the RF heating system's operating frequency should be 13.56 MHz with a nominal heating span of 18 ft. or 27.12 MHz with a nominal span of 9 ft. In some applications is possible to operate with a 6 ft. span at 40.68 MHz. In some cases the heating rate of the plume will be a factor in contrast to SVE flow requirements. An ISM heating frequency of 40.68 MHz heats the smallest volume most rapidly and 13.56 MHz heats the largest volume more slowly.

- The need or option to access large volumes of the contaminant plume also determines if the system needs large numbers of installed applicators with switching networks to allow efficient, automated operation. Alternately a limited number of applicators, with mechanical positioning equipment, can incrementally heat large volumes of the plume from a few borehole (e.g. horizontal).

9.2 A 200 kW system description - The following system would be defined as a wide coverage 13.56 MHz system configured for horizontal drilling emplacement. It would have the following components:

2	RF Master control and instrument trailers with an internally mounted 25 KW, 13.56 MHz RF generator and tuner (the units would be similar in size and design to the KAI pilot Rig #1 used for this program). Each master control trailer would also carry control and diagnostic instrumentation. The master control systems would be linked with the slave systems through fiber optic cables. Each master control system would be fully automated and respond to both local and remote control computer commands.
2	Slave RF systems with three 25 kW, 13.56 MHz RF generators and tuners per trailer. Each slave trailer would include a common cooling system and 3-phase AC power distribution system.
16	Flexible horizontal applicators with an emplacement system allowing controlled motion during heating of up to 45 ft. per setup.
8	Motorized RF switches to select between two installed applicators that are to be selected by each RF generator/tuner group.
--	Flexible and rigid RF transmission line suitable to reach 16 heating locations from the two trailer groups.
1	3-phase AC power utility or Diesel generator service capable of providing a minimum of 500 kVA for the site. Additional power requirements would dependent on the requirements of the SVE and off gas treatment systems.

A heating system of this scale and capital investment[25] can be expected to operate in the field with utility power costs, full automation, and programmed personnel support for configuration changes at a cost of much less than $100 per cubic yard over a multi-year operating period. This figure is exclusive of horizontal drilling costs, SVE system installation, off gas treatment and non-RF site operating costs.

9.3 Recommendations on system strategies - The costing of RF thermally enhanced SVE programs is very dependent on the use of the following key strategies:

- Select the ISM heating frequency based on the optimum heating rate, soil penetration depth, and contaminant thickness.

- Select a drilling technique (vertical, slant or horizontal) that provides the most access to the contaminated zone for each borehole position and applicator heating span.

- Use each heating applicator in multiple positions along the length of the guide tube or slowly "scan" the heating zone with the applicator's heating span.

- Use each RF generator to sequentially drive two or more applicators.

- Use multiple RF generators in groups of two or four as phased arrays to focus and steer heating pattern.

- Use automated and remote control operation to minimize the need for highly skilled on-site labor.

The application of RF thermal enhancement also needs to be characterized in terms of the time savings it represents over conventional treatment projections using non-thermal SVE technique at the same site (assuming the targeted contaminants are removable by non-thermal methods). Key points for consideration are:

- RF thermal enhancement can be applied as a rapid response tool for stopping the migration of contaminant plumes at depths of over 750 feet.

- RF thermal enhancement may be selectively applied to high concentration regions within a general site remediation strategy of passive SVE.

- Thermally enhanced SVE may allow extraction of contaminates from some sites that normally would require excavation.

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[25] Assuming a 5 year pay pack period.

Data Appendices

A - Site data logging - TAQR program channel listing and channel details.

B - Heating Summary - Site statistics and heating cycles with log comments

C - Power Measurements - AC and RF power plots

D - Temperature Plots - Fiber optic probes

E - Temperature Profiles - Thermocouple measurements

F - Temperature Profiles - Infrared probe measurements

G - RF System Matching Measurements - return loss and insertion loss.

H - RF System Emission Measurements - RF emission compliance under FCC part 18.305 and surface field strength compliance under (IEEE standard C95.1-1991).

I - Plots of SVE and Heating System - displayed on the RF heating system time line.

J - Thermal Modeling Data - One and two applicator models.

APPENDIX A - Site data logging

The typical 23 channel data accusation and control screen for the KAI RF Heating control and monitoring system is shown below. Description of the channel groups and screen display features and program capabilities follow. The typical TAQR[21] data acquisition screen looks like this:

```
18-May-94 18:49:21.2  TKEL0824.46   Elapsed= 47:59:42   Remain= 0:00:18
Transmitter:  RF ON     (Steady)        X=Xmit Q=quit Sky ON
 1  Gen. AC input PWR                                          30.07 kW
 2  Gen. RF PWR Incident                   S                   19.35 KW
 3  Gen. RF PWR Reflected                  SHX                 145.25 Watts
 4  Gen FWD cpl VVM 27.12MHz                                   109.2 dBuV
 5  App FWD cpl VVM 27.12MHz                                   109.2 dBuV
 6  App REV cpl VVM 27.12MHz                                   100.4 dBuV
 7  App REFL cpl VVM 27.12MHz                          -0.1804 -0.3151
 8  SW#3 REF FWD CPL 27.12MHz                                  109.7 dBuV
 9  S3 P B 27.12MHz                        HX                  108.1 dBuV
10  S3 R PB 27.12MHz                                   0.2701 0.7867
11  Gen. O.L. RESET ALARM=0                LX                  1
13  VAC ch 1 (BLU-RED)                                         210.56 VAC
14  VAC ch 2 (RED-BLK)                                         211.43 VAC
15  VAC ch 3 (BLK-BLU)                                         209.43 VAC
16  VAC 1-phase(wye BLU-N)                                     121.65 VAC
17  INPUT AIR TEMP                                             29.48 deg C
18  OUTPUT AIR TEMP                        H                   79.11 deg C
19  TUNER AIR TEMP                         HX                  34.41 deg C
20  App. manifold                          L                   12.44 PSI
21  APP#1 WALL @10.5'(s)                   SHX                 110.53 deg C
22  APP#2 WALL @10.5'( )                   HX                  24 deg C
23  App#1 EL at 6.5'(s)                    HX                  141.97 deg C
24  F3 center at 6.5'(s)                   SHX                 67.76 deg C
```

The header block is described as follows:

```
18-May-94 18:49:21.2  TKEL0824.46   Elapsed= 47:59:42   Remain= 0:00:18
```

This line carries the start time of the data acquisition file group TKEL08*ch.cc* where *ch* is the last channel acquired and *cc* in the continuation number that increments with each file set storage. The elapsed time is from the start time and the remaining time is based on the total number of hours selected for this data run.

```
Transmitter:  RF ON     (Steady)        X=Xmit Q=quit Sky ON
```

This line indicates that the RF generator output is set for a steady output level (as opposed to a pulsed or D/A controlled level). X=Xmit and Q=Quit are reminders to operator for the access of hidden menus in the display and Sky ON indicates that the system will report Status and Alarm conditions to the SkyPager over the cellular phone link.

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[21] TAQR or "Timed Acquisition" is a specialized program written in the TBASIC® language by the Communications Systems Division of the Eyring Corporation of Provo, Utah for KAI Technologies Inc. The core program has been evolved by KAI for specialized RF heating tasks.

The typical definitions of the channel groups and individual channels for this program follow[22]. Note that each channel is stored in typically 180 sample groups every hour.

Detailed Channel Descriptions for KELLY AFB tests using TKEL08 setup example:

1 Gen. AC input PWR 30.07 kW

This is a measurement by a true RMS AC Watt transducer located inside of the RF Generator cabinet that is scanned by the HP 3457A voltmeter. This is an absolute measurement of the energy being supplied to the RF Generator by the 3-phase power line. However, it is not a measurement of the total system energy input which includes the RF generator stepup blower, air conditioning, heat exchanger pump, lighting, instrumentation, and communications. Typically these items add another 8 to 15 kW to the system's energy requirements.

2 Gen. RF PWR Incident S 19.35 KW
3 Gen. RF PWR Reflected SHX 145.25 Watts

These channels record the output power (Incident) and reflected power of the generator as sensed by the RF generator's internal directional coupler that is used for automatic power control. These transducer channels parallel the readings of the analog meters on the top left side of the RF Generator cabinet. The transducers are scanned by the HP 3457A voltmeter. The voltages recorded here are scaled and table processed by the TAQR program using lookup table MEAS25 and MEAS26. NOTE: at this time the fit is not perfect and additional interpolation points must be added. This measurement is estimated to be accurate on the order of +/- 4%.

The "S" before the reading indicates that this value is a channel that is used to compose the SKYPAGER status message for remote monitoring of the system. The "HX" indicates that this channel is monitored for a high level alarm that will shut down the RF generator ("X").

4 Gen FWD cpl VVM 27.12MHz 109.2 dBuV
5 App FWD cpl VVM 27.12MHz 109.2 dBuV

These channels record the same forward power information as channel 2 but at two other points in the system using -70 dB directional couplers monitored by an HP 8508A vector voltmeter. Channel 4 is measured at Coupler #1. This is at the output of the RF generator before the transmission line segment to RF switch #1 that selects either the input to the applicator tuning network or the dummy load. Channel 5 is measured at Coupler #2 which is located after the applicator tuning network and in the transmission line path to the heating applicator.

The measurements are recorded in the native scale of the vector voltmeter and are scaled to dBm or Watts by post processing of the data files. This measurement is a more accurate measurement of power output than that of channel 2.

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[22] Note that some channels were added during the startup of the program. Not all channels were continuously recorded. In some cases the definitions were changed to reflect configuration changes (typically fiber optic probe selections or locations).

6	App REV cpl VVM 27.12MHz		100.4 dBuV
7	App REFL cpl VVM 27.12MHz		-0.1804 -0.3151

Channels 6 and 7 are paired with the channel 5 forward measurement to derive a reflected power measurement and a complex reflection coefficient. Both signals are post processed for analysis. Note that the difference between channel 5 and 6 in dB is return loss.

8	SW#3 REF FWD CPL 27.12MHz		109.7 dBuV
9	S3 P B 27.12MHz	HX	108.1 dBuV
10	S3 R PB 27.12MHz		0.2701 0.7867

Channels 8, 9 and 10 are measurements used to determine the transmission characteristics that exist between the heating applicator and the monitoring applicator. Note that channel 8 is corrected by 70 dB and channel 9 by 20 dB to derive the relative transmission loss of 51.6 dB in this case.

11	Gen. O.L. RESET ALARM=0	LX	1

This is a channel to track the status of four overload sensors within the RF generator.

13	VAC ch 1 (BLU-RED)		210.56 VAC
14	VAC ch 2 (RED-BLK)		211.43 VAC
15	VAC ch 3 (BLK-BLU)		209.43 VAC
16	VAC 1-phase(wye BLU-N)		121.65 VAC

These four channels monitor the 3-phase and 1-phase power voltages used by the system. Channels 13, 14 and 15 are derived from AC to DC voltage transducers located within the RF generator cabinet. Channel 16 is monitored at the RF switching and interlock junction box and also indicates that power is available to operate the remote RF SW#3.

17	INPUT AIR TEMP		29.48 deg C
18	OUTPUT AIR TEMP	H	79.11 deg C

These channels monitor the cooling air and exhaust air for the RF generator. The sensors are thermistors that are directly processed to temperature by the HP 3457A system voltmeter.

19	TUNER AIR TEMP	HX	34.41 deg C

This channel monitors the upper cabinet air temperature inside of the matching network (tuner).

20	App. manifold	L	12.44 PSI

This channel monitors the nitrogen pressure the RF power transmission lines.

21	APP#1 WALL @10.5'(s)	SHX	110.53 deg C

This is a fiber optic sensor located 10.5' below the surface of the test site on the outside of the fiberglass borehole liner. The probe is inside of a 0.25" ID Teflon tube. The sensor is located on well liner A2 used for applicator #1.

The depth indicated here is referenced to the base of the aluminum plate above each borehole. The ice bath calibration of this sensor suggests a correction of +1.5 degrees to the reading. This sensor has a factory calibration accuracy of +/- 2 degrees.

22 APP#2 WALL @10.5'( )	HX	24 deg C

This is a fiber optic sensor located 10.5' below the surface of the test site on the outside of the fiberglass borehole liner. The probe is inside of a 0.25" ID Teflon tube. The sensor is located on well liner A1 used for applicator #2, 10 ft. from Applicator #1.

The ice bath calibration of this sensor suggests a correction of +3.0 degrees to the reading. This sensor has a factory calibration accuracy of +/-2 degrees.

23 App#1 EL at 6.5'(s)	HX	141.97 deg C

This is a fiber optic sensor located 6.5' below the surface of the test site on top of the aluminum radiating element of Applicator #1. It represents the "integrated" temperature of the borehole liner as it is heated by the surrounding soil. The probe is inside of a 0.1875" OD Teflon tube. The sensor is bowed away from the applicator to touch the borehole liner wall.

The ice bath calibration of this sensor suggests a correction of -2.7 degrees to the reading. This sensor has a factory calibration accuracy of +/-2 degrees.

24 F3 center at 6.5'(s)	SHX	67.76 deg C

This is a fiber optic sensor located 6.5' below the surface of the test site in fiberglass monitoring borehole F3. The probe is inside of a 0.1875" OD Teflon tube that is coiled to position the sensor against the wall facing Applicator #1.

The ice bath calibration of this sensor suggests a correction of -3.6 degrees to the reading. This sensor has a factory calibration accuracy of +/-2 degrees.

NOTE: This channel is also used for Applicator #2 during its specific heating cycle the same as channel 23.

END FILE: KELLYA.A

APPENDIX B - Site S-1 Heating Summary

The following items are included within this appendix:

- Site statistics
- Comparison of the planned program to actual statistics
- Observations on actual site operation
- Site heating cycles with log comments
- Summary of RF Heat Generation and Delivery to Applicators - Table

Site Statistics

● Antenna #1, Applicator position A2[23]	
Energy applied for first heating period (28.9 day span, both low, medium and high power)	6,482. KWH
Energy applied for second heating period (12.87 day span, high power)	4,719. KWH
Total for 41.77 day span	11,201. KWH
● Antenna #2, Applicator position A1	
Energy applied for only heating period (8.15 day span at medium to high power)	4,348. KWH
○ Total RF energy applied to the heating zone (using 90% delivery efficiency of generated RF energy or a 58.5% conversion efficiency of 3-phase AC to delivered RF energy)	15,549. KWH
● Estimated 3-phase AC input power required (back-calculated using a 65% conversion efficiency from AC to RF)	26,693. KWH
● Estimated total site AC energy usage (5 kW/hr avg. energy overhead for 78 days + RF total)	36,053. KWH
● Total span of KAI on-site support at Kelly AFB (28 March - 13 June system packing)	78. Days
● Total span of heat application (21 April - 10 June RF system shut down)	51.3 Days
● Total span of continuous measured SVE operation (13 April - 24 June SVE system shut down)	72.3 Days

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[23] Note that in some data sets and in all site photographs the applicator sleeve A2 is identified as A1. Housing A2 was used with antenna #1 (RF heating applicator).

Comparison of the planned program to actual statistics

• Planned span of heat application (by orig. SOW)	42. Days
• Comparison to planned heat application time	122.% of planned

- Energy delivery based on planned 42 day span 20,098. KWH
  (using actual 19.93 KW/hr best estimated delivery rate w/94.54% ON time operating efficiency)
- Comparison to planned energy delivery 77.3% of planned

Observations on actual site operation

- The earliest date RF heating could have started was by 6 April
- USAF Frequency management allowed medium power operation on 21 April
- USAF authorization for full power operation was granted on 25 April.
  NOTE: It is estimated that 19 Days of possible high power operation was lost due to this administrative delay.

- The RF System was operated below its full power and with limited control capability until 20 May.
  NOTE: 30 Days of high power operation with full automatic control was lost due to faulty CU/AL splices and an under-sized 3-phase power feed line. The average RF generation rate increased from a low of 9.42 kW/hr to 19.93 kW/hr[24] after the repair and retrofit operations.

- UNDER EXPECTED SITE CONDITIONS AND WITHIN THE SAME ON SITE OPERATION SPAN: The System could have operated at full power with an operating period of 15 + 51.3 = 66.3 days. The RF system, if operating at the actually site-documented rate delivery rate of 19.93 kW/hr, could have placed 31,712 KWH of energy into the soil of the heating zone or 200% of what was delivered in this span. This energy could have been distributed throughout the total treatment zone by movement of the applicators.

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[24] The 19.93 kW/hr rate is includes normal system OFF and down time for about a 21 day operating period documented on the site from 20 May to 10 June. It also represents a 94.54% RF ON time.

Site heating cycles with log comments
Update: 3 December 1994 analysis

Format for detailed summary of data logging for RF heating program

File name, Title of test, purpose of test
File continuation number span
Start date/time, Day # from 13 April 12:00 AM = Day 0.0
End date

- Hours of data logging represented by this span (from XY file scan of CH 2)
- Heating value, average power generated (CH 2) over entire logging span
- Hours of heating application (CH 2 above 10 kW level), average value.
- KWH generated (heating hours x average value for application)
- KWH delivered to heating soil zone (estimated w/efficiency and calibration correction of 90%)

COMMENTS: general

1. specific numbered items. Including: special site conditions, power outages, repairs, SVE configurations.

SVE SYSTEM STARTED with periodic measurements (by Brown & Root personnel)

Reference time set = 0.00 at start of day
Initial start of continuous SVE measurements, 11:35 Wednesday, 13 April 1994
Note: The SVE system was turned on briefly for system testing before this date and for the initial baseline soil vapor measurements by Radian on 8 April 1994.
COMMENTS:

1. Radian SVE measurement #1 on 8 April, Day -4.5

TKEL00, EM - Applicator #1 in well liner A2, low power short heating tests.

Continuation numbers 01-06
Start 15:44 Thursday, 21 April 1994, Day 8.65
18:45 Thursday, 21 April 1994, Day 8.78
3.01 hours of logging
1.38 kW average power over logging period
0.12 heating hours (above 10 kW) with average value of 13.07 kW
1.5 KWH generated
1.4 KWH delivered
COMMENTS: No heating value for this period.

1. Biconical Antenna for calibrated EM measurements arrives 14:45, 21 April
2. Power tests authorized at 12 KW level by USAF.
3. SVE Extraction wells: E2 (2'-12'), E4 (10'-20' CL), E5 (10'-20' CL)
4. SVE Passive injection: no wells open, draw from surface.

TKEL01 (not used)

TKEL02, EM Test 2 - Applicator #1 in well liner A2, low power and short duration tests.

Continuation numbers 01-07
Start 10:50 Friday, 22 April 1994, Day 9.45
19:36 Saturday, 23 April 1994, Day 10.81
8.77 hours of logging
10.11 kW average power over logging period
5.23 heating hours (above 10 kW) with average value of 12.95 kW
67.72 KWH generated
60.96 KWH delivered
COMMENTS: Some heating value during period

1. First line voltage problem noted as causing control problem for RF Generator.
2. SVE Extraction wells: E2 (2'-12'), E4 (10'-20' CL), E5 (10'-20' CL)
3. SVE Passive injection: no wells open, draw from surface.

TKEL03, EM Test 3 - Applicator #1 in well liner A2 - **Start of heating cycle**

Continuation numbers 01-85
Start 23:19 Sunday, 24 April 1994, Day 11.97
11:28 Thursday, 29 April 1994, Day 16.5
108.16 hours of logging
9.99 kW average over logging period
58.88 heating hours (above 10 kW) with average value of 15.73 kW
926 KWH generated
833 KWH delivered
COMMENTS:

1. Formal start of heating period
2. Power line stability measurements during this period

3. USAF authorizes full power operation during this period.
4. Difficulty in getting RF Generator to cycle ON/OFF under computer due to power line voltage drop problem (AL/CU splice and 00 AL line later found as problem).
5. Data framing problem puts false "low temp" spikes into temperature data, values are Luxtron channel number as 1,2,3 or 4 deg. C.
6. Test of compressed air to cool borehole liner started at approx 20:00 on 28 April
7. Heavy Rain on 28 April about 11:00
8. Heavy rain storms slowed progress from 29 April till 1 May
9. SVE Extraction wells: E2 (2'-12'), E4 (10'-20' CL), E5 (10'-20' CL)
10. SVE Passive injection: no wells open, draw from surface.

TKEL04, Test 4 - Applicator #1 in well liner A2

Continuation numbers 01-47

Start 22:39 Sunday, 1 May 1994, Day 18.94
22:34 Wednesday, 4 May 1994, Day 21.94
71.91 hours of logging
16.46 kW average over logging period
58.28 heating hours (above 10 kW) with average value of 18.18 kW
1,059 KWH generated
953 KWH delivered

COMMENTS:

1. Test started with two 0.25 ID Teflon cooling tubes added to applicator to cool borehole.
2. Continuous operation leads to high temp scaling of output inductor. Inductor pulled and scaled. Later unit was replaced by a 1-turn copper tube unit.
3. RF generator drifts in adjustments, 18.5 kW max power with instability.
4. IPA trips and fluctuations in RF power and RF drop outs without OL trips - later corrected by transformer tap changes and changes to factory settings over tests 5 and 6 (later solved by power line repairs).
5. Cellular phone blockage at: 21:04, 26 April
6. SVE Extraction wells: E2 (2'-12'), E4 (10'-20' CL), E5 (10'-20' CL)
7. SVE Passive injection: no wells open, draw from surface.

TKEL05, Test 5 - Applicator #1 in well liner A2

Continuation numbers 01-39
03:10 Thursday, 5 May 1994, Day 22.13
18:39 Friday, 6 May 1994, Day 23.77
39.48 hours of logging
12.92 kW average
26.67 heating hours (above 10 kW) with average value of 18.23 kW
486 KWH generated
437 KWH delivered

COMMENTS:

1. Cellular phone blockage, 18:45 5 May.
2. Radian SVE measurement #2 on 6 May 1994, Day 23
3. SVE Extraction wells: E2 (2'-12'), E4 (10'-20' CL), E5 (10'-20' CL)
4. SVE Passive injection: no wells open, draw from surface.

TKEL06, Test 6 - Applicator #1 in well liner A2

Continuation 01-99
Start 19:42 Friday, 6 May 1994, Day 23.82
09:45 Wednesday, 12 May 1994, Day 29.40
134.01 hours of logging
14.87 kW average
75.49 heating hours (above 10 kW) with average value of 19.46 kW
1,469 KWH generated
1,693 KWH delivered

COMMENTS:

1. Cellular phone blockages at 23:01 6 May, 23:01 9 May, 10:01 10 May, 18:05 11 May, 19:07 11 May, 7:01 12 May,
2. 9:08 7 May RF OFF but RF ON due to tuning adjust for voltage fluctuations, later transformer tap changed and returning of osc. stage.
3. 0.5" flow meter and higher capacity liner cooling flow installed on 7 May
4. 12BY7A osc. tube V1 replaced (later found to voltage stability problem)
5. System OFF for 3-phase "black" phase line overheating on evening of 20:18 on 10 May during Cont. No. 76.
6. System restart at Cont. No. 77 at 8:56:46 11-May-94 after 3-phase splice change.
7. SVE Extraction wells: E2 (2'-12'), E4 (10'-20' CL), E5 (10'-20' CL); add E3 (10'-20').
8. SVE Passive injection: no wells open, draw from surface

TKEL07, Test 7 - Applicator #1 in well liner A2

Continuation 01-94

12:27 Thursday, 12 May 1994, Day 29.51
16:57 Monday, 16 May 1994, Day 33.70
100.5 hours of logging
19.65 kW average
94.98 heating hours (above 10 kW) with average value of 19.81 kW
1,881 KWH generated
1,693 KWH delivered

COMMENTS:

1. Restart after power outage to replace bad 3-phase power line splices.
2. System off for approx. 4 hours on 13 May after close lighting hit dropped one phase of 3-phase feed from base power grid. 2" of Rain.
3. Cellular blockage 8:01 15 May, 13:01 15-May, 10:01 16 May
4. SVE Extraction wells: E2 (2'-12'),E3 (11'-20), E4 (10'-20' CL), E5 (10'-20' CL) till Friday, 13 May then close E4 and E5 well on center line (CL) of heating axis in morning.
5. SVE Passive injection: no wells open, draw from surface and surrounding volume till sometime before 17:00 on Thursday 12 May when E8 (10'-20') is opened to air.

TKEL08, Test 8 - Applicator #1 in well liner A2

Continuation 00-86

Start 18:49 Monday, 15 May 1994, Day 32.78
13:38 Wednesday, 20 May 1994, Day 37.67
93.82 hours of logging
15.66 kW average
69.66 heating hours (above 10 kW) with average value of 19.85 kW
1,382 KWH generated
1,244 KWH delivered

COMMENTS:

1. First sign of slow nitrogen leak on applicator #1 (in liner A1) at 18:22 20 May.
2. Cellular blockage 17:00 17 May, 23:01 17 May, 7:01 18 May, 8:01 18 May, 10:01 18 May, 12:01 18 May, 13:00 18 May.
3. 9:09:16 20-May-94 -> shutdown Xmit for power line change.
4. Applicator #1 outside liner temp over 231 deg. C. cannot apply more heat with out possible damage to liner.
5. Applicator #1 heating discontinued to allow start of Applicator #2
6. SVE Extraction wells: E2 (2'-12'), E3 (10'-20'); Tuesday, 16 May E5 (10'-20' CL) is added before 12:00.
7. SVE Passive injection: E8 (10'-20')

TKEL09, Test 9 - Start of to Applicator #2 in well liner A1

Continuation 00-93

Start 18:33 Wednesday, 20 May 1994, Day 37.77
19:22 Sunday, 24 May 1994, Day 41.80
96.81 hours of logging
21.09 kW average
94.21 heating hours (above 10 kW) with average value of 21.49 kW
2,024 KWH generated
1,822 KWH delivered

COMMENTS:

1. Start of applicator 2 heating.
2. Spare Nitrogen tank to external manifold for App#2 isolation. Tank #1 is to low to charge line with reserve.
3. SVE Extraction wells: E2 (2'-12'), E3 (10'-20'), E5 (10'-20' CL); Thursday, 21 May E2 and E3 are listed in summary as closed with only E5 open (not confirmed by site log of 21 May or 22 May); Friday, 22 May E1 (10'-20') and E4 (10'-20' CL) added to group of E1 through E5 wells; Saturday, 23 May E1, E2 and E3 are removed from extraction and only E4 and E5 are used for extraction.
NOTE: the E2, E3 and E5 wells are selected around A2. The extraction starts about A1 when the E1 and E4 wells are selected.
4. SVE Passive injection: E8 (10'-20'); Friday, 22 May E6 (10'-20') and E7 (2'-12') are added; Saturday, 23 May E1, E2, E3 are used as injection wells.

TKEL10, Test 10 - Applicator #2 in well liner A1

Continuation 00-92

Start 21:27 Sunday, 24 May 1994, Day 41.89
22:18 Saturday, 28 May 1994, Day 45.42
96.81 hours of logging
20.98 kW average
94.14 heating hours (above 10 kW) with average value of 21.17 kW
1,992 KWH generated
1,793 KWH delivered

COMMENTS:

1. On Saturday, 28 May, Nitrogen pressure seal at applicator feedpoint started a high leakage rate and exhausted nitrogen supply available on site over Memorial day holiday. Operation continued at risk. Low VSWR of applicator at time of seal failure provided an initial safety margin for continued operation.
2. SVE Extraction wells: E4 (10'-20' CL), E5 (10'-20' CL)
3. SVE Passive injection: E1, E2, E3, E6, E7, E8.

TKEL11, Test 11 - Applicator #2 in well liner A1

Continuation 00-38

Start 23:22 Saturday, 28 May 1994, Day 45.97
15:18 Monday, 30 May 1994, Day 47.63
39.93 hours of logging
20.45 kW average
39.13 heating hours (above 10 kW) with average value of 20.82 kW
814 KWH generated
733 KWH delivered

COMMENTS:

1. Normal heating operation continued until between 14:00 and 15:00 hours on Monday, 30 May (Memorial Day) the rising VSWR caused a sustained HV discharge within the transmission line near the applicator feed point. The center conductor heated beyond the systems thermal expansion capability and shorted the applicator. Confirmed by TDR.
2. SVE Extraction wells: E4 (10'-20' CL), E5 (10'-20' CL)
3. SVE Passive injection: E1, E2, E3, E6, E7, E8.

TKEL12, Test 12 - Applicator #1 in well liner A2, Restart

Continuation 00-93

Start 16:24 Tuesday, 30 May 1994, Day 47.63
00:15 Saturday, 4 June 1994, Day 52.01
103.85 hours of logging
20.09 kW average
94.42 heating hours (above 10 kW) with average value of 20.85 kW
1,968 KWH generated
1,771 KWH delivered

COMMENTS:

1. Restart without difficulty. Ambient RF levels measured by CH 9 test channel to base loaded whip antenna.
2. Radian SVE measurement #3 on 31 May 1994, Day 48
3. SVE Extraction wells: E4 (10'-20' CL), E5 (10'-20' CL)
4. SVE Passive injection: E1, E2, E3, E6, E7, E8.

TKEL13, Test 13 - Applicator #1 in well liner A2
Continuation 00-68
Start: 00:24 Saturday, 4 June 1994, Day 52.01
12:43 Tuesday, 7 June 1994, Day 55.02
72.32 hours of logging
21.64 kW average
70.08 heating hours (above 10 kW) with average value of 22.14 kW
1,551 KWH generated
1,396 KWH delivered
COMMENTS:
1. SVE Extraction wells: E4 (10'-20' CL), E5 (10'-20' CL)
2. SVE Passive injection: E1, E2, E3, E6, E7, E8.

TKEL14, Test 14 - Applicator #1 in well liner A2
Continuation 00-88
Start: 02:10 Tuesday, 7 June 1994, Day 55.09
20:15 Friday, 10 June 1994, Day 58.84
90.09 hours of logging (continuing)
19.43 kW average
86.09 heating hours (above 10 kW) with average value of 20.03 kW
1,724 KWH generated
1,552 KWH delivered
COMMENTS: Test concluded the heating program
1. Applicator lowered to new heating zone but limited to 1.87 ft. by an unidentified jamming point.
2. Temp. logging continued several hours after RF power off.
3. Radian SVE measurement #4 on 7 June 1994, Day 55
4. SVE Extraction wells: E4 (10'-20' CL), E5 (10'-20' CL)
5. SVE Passive injection: E1, E2, E3, E6, E7, E8.

TKEL15, Test 15 - Applicator's removed, Cool down period.
Continuation 00-12, (in progress)
Start: 01:24 Saturday, 11 June 1994, Day 59.05
23:21 Saturday, 11 June 1994, Day 59.97
22.14 hours of logging (continuing)
COMMENTS: No heating at this time, only SVE
1. Note that logging time of computer was offset in archive processing error. File dates indicate 10 June when they should be 11 June.
2. Temperature of A1, Channel 21 has dropped 0.74 degrees C in 22.14 hours.
3. Logging of channels 21 and 22 for borehole cooling rate estimates.
4. SVE Extraction wells: E4 (10'-20' CL), E5 (10'-20' CL)
5. SVE Passive injection: E1, E2, E3, E6, E7, E8.

SVE SYSTEM OPERATION ONLY (by Brown and Root personnel)
COMMENTS
1. Radian SVE measurement #5 on 14 June 1994, Day 62
2. SVE Extraction wells: E4 (10'-20' CL), E5 (10'-20' CL); 14 June change to E1, E2 and E3 with E4 and E5 closed (after Radian measurements ?).
3. SVE Passive injection: E1, E2, E3, E6, E7, E8; 14 June changed to E6, E7 and E8 only.

SVE SYSTEM OPERATION CONCLUDED (by Brown & Root personnel)

Stop: Friday, 24 June approx Day 72.5

COMMENTS

1. Radian SVE measurement #6 on 24 June 1994, Day 72
2. SVE Extraction wells: E1, E2 and E3
3. SVE Passive injection: E6, E7 and E8.

Table summary of RF generation and energy delivery to heating zones

Comments on the table information:

1. The DATA SET FILE NAMES are those used by the TAQR data logging program as prefixes for the 23 channels of logged data. The DATA LOGGING START and STOP points cover the time the system is logging.

2. The ELAPSED TIME SUMMARIES summarize either the Start and Stop hours for a logging interval (RF START and HEATING) or the total number of hours for the logging interval (LOGGING, RF OUT GENERATED). The last column is unique in this group since it reports the Average RF output power level for the adjacent columns RF OUT generator hours.

3. The ENERGY SUMMARY columns outline the totals for each logging period. The RF Gen KWH (1) column is based on a multiplication of the RF OUT GENERATED HRS x AVERAGE RF FOR GENERATOR HOURS. The RF ENERGY DELIVERED KWH (2) is 90% of the RF GENERATED KWH (1).

The 90 % value is a composite correction listed in the upper right hand corner of the chart. The 90% is based on a 98% RF transmission line efficiency, a 95% applicator to soil delivery efficiency and a 97% system correction. Note that the system correction is based on a correction for the system power metering.

4. The COLUMN TOTALS sum the values from the individual logging periods. The ENERGY SUMMARY columns provide a summary of the RF energy generated and the estimated amount delivered to the soil.

5. The SYSTEM PERFORMANCE INDICES are calculated to provide indicators for describing system performance.

    Logging time / total hours from start - Indicates what percent of time the logging system was recording system performance from the 21 April start date to the 10 June stop date.

    RF OUT / total hours from RF start - Indicates the percent of time RF was generated

    Heating period / total hours form RF start - Indicates the percentage of the hours from RF start that were for figured into the heating period.

    RF OUT / heating period - Indicates the percentage of the heating period that the RF was output.

6. Impact of required repairs and weather delays on RF generation efficiency

    RF OUT / heating period (24 April) to the 12 May 3-phase power splice repair; The AVERAGE RF GENERATION for this period is on the same line.

    RF OUT / heating period (24 April) to the 20 May 3-phase power line replacement point; The AVERAGE RF GENERATION for this period is on the same line.

    RF OUT / heating period from 20 May to the 10 June, after the repairs; The AVERAGE RF GENERATION for this period is on the same line.

Summary of RF Heat Generation and Delivery to Applicators.									
Kelly AFB site S-1									Efficiency
Update: 10 June 1994									& Cal. Corr
									0.9
Data	**Data logging**		**Elapsed time summaries**					**Energy summary**	
Set	**Start and**	**Stop points**	**From**	**From**	**System**	**RF OUT**	**Average**	**RF**	**RF Energy**
File			**RF Start**	**Heating**	**Logging**	**Gen.**	**RF for**	**Gen.**	**Delivered**
Name	**Date**	**Time**	**Hours**	**Hours**	**Hours**	**Hours**	**Gen. hrs**	**KWH (1)**	**KWH (2)**
TKEL00	21-Apr-94	03:44:00 PM	0.0						
	21-Apr-94	06:45:00 PM	3.0		3.01	0.12	13.07	1.57	1.41
TKEL02	22-Apr-94	10:50:00 AM	19.1						
	23-Apr-94	07:36:00 PM	51.9		8.77	5.23	12.95	67.73	60.96
TKEL03	24-Apr-94	11:19:00 PM	79.6	0.0					
	29-Apr-94	11:28:00 AM	187.7	108.2	108.16	58.88	15.73	926.18	833.56
TKEL04	01-May-94	10:39:00 PM	246.9	167.3					
	04-May-94	10:34:00 PM	318.8	239.3	71.91	58.28	18.18	1059.53	953.58
TKEL05	05-May-94	03:10:00 AM	323.4	243.9					
	06-May-94	06:39:00 PM	362.9	283.3	39.48	26.67	18.23	486.19	437.57
TKEL06	06-May-94	07:42:00 PM	364.0	284.4					
	12-May-94	09:45:00 AM	498.0	418.4	134.01	75.49	19.46	1469.04	1322.13
TKEL07	12-May-94	12:27:00 PM	500.7	421.1					
	16-May-94	04:57:00 PM	601.2	521.6	100.50	94.98	19.81	1881.55	1693.40
TKEL08	15-May-94	06:49:00 PM	579.1	499.5					
	20-May-94	01:38:00 PM	693.9	614.3	93.82	69.66	19.85	1382.75	1244.48
TKEL09	20-May-94	06:33:00 PM	698.8	619.2					
	24-May-94	07:22:00 PM	795.6	716.1	96.81	94.21	21.49	2024.57	1822.12
TKEL10	24-May-94	09:27:00 PM	797.7	718.1					
	28-May-94	10:18:00 PM	894.6	815.0	96.81	94.14	21.17	1992.94	1793.65
TKEL11	28-May-94	11:22:00 PM	895.6	816.1					
	30-May-94	03:18:00 PM	935.6	856.0	39.93	39.13	20.82	814.69	733.22
TKEL12	30-May-94	04:24:00 PM	936.7	857.1					
	04-Jun-94	12:15:00 AM	1040.5	960.9	103.85	94.42	20.85	1968.66	1771.79
TKEL13	04-Jun-94	12:24:00 AM	1040.7	961.1					
	07-Jun-94	12:43:00 AM	1113.0	1033.4	72.32	70.08	22.14	1551.57	1396.41
TKEL14	07-Jun-94	02:10:00 AM	1114.4	1034.9					
	10-Jun-94	08:15:00 PM	1204.5	1124.9	90.09	86.09	20.03	1724.38	1551.94
TKEL15									
COLUMN TOTALS			**1,205**	**1,125**	**1,059**	**867**	**- NA -**	**17,351**	**15,616**
System Performance indicies									
Logging time/total hrs from RF star			**87.96%**						
RF OUT/total hrs from RF start			**72.01%**						
Heating period/hrs from RF start			**93.39%**						
RF OUT/heating period			**77.11%**						
Impact of required repairs and weather on RF generation efficiency									
RF OUT/heating up to 5/12 (splice)			**52.41%**		Average RF generation rate (kW/hr)				**9.42**
RF OUT/heating up to 5/20 (cable)			**62.50%**		Average RF generation rate (kW/hr)				**11.73**
RF OUT/heating from 5/20 - 6/10			**94.54%**		Average RF generation rate (kW/hr)				**19.93**

APPENDIX C - Power Measurements

AC and RF Power plots

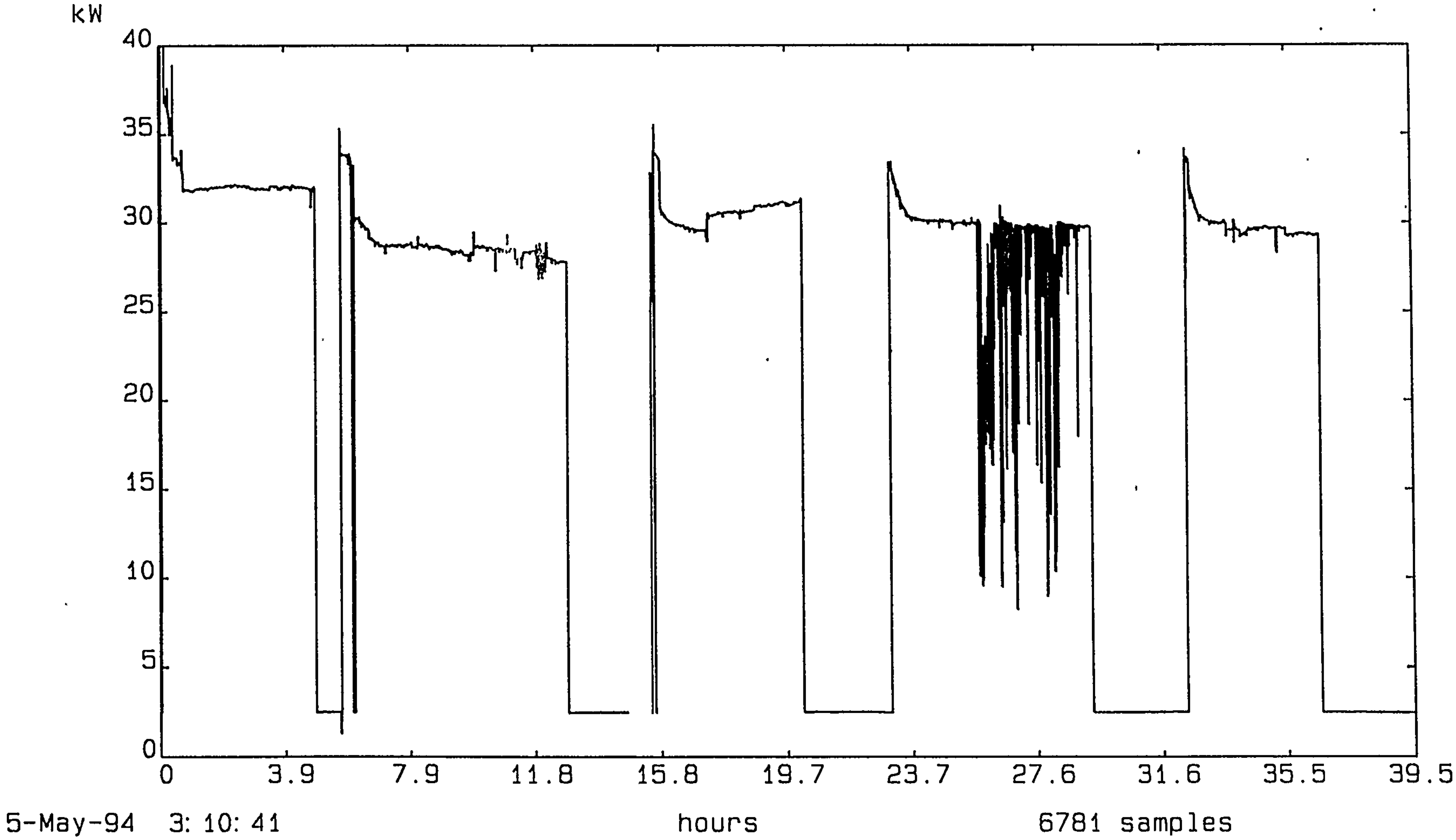
DRAFT NOTE: These are samples of the data base. The final report will have sections of these plots in 120 hours segments.

- Examples of 3-phase AC input power to the system - before splice repair and cable replacement.
  - 5 May 03:10, 39.5 hrs
    - (unit is also being held off to control temperature, black area at time 27.6 was due to autorestart attempts.
  - 6 May 19:42, 134 hrs

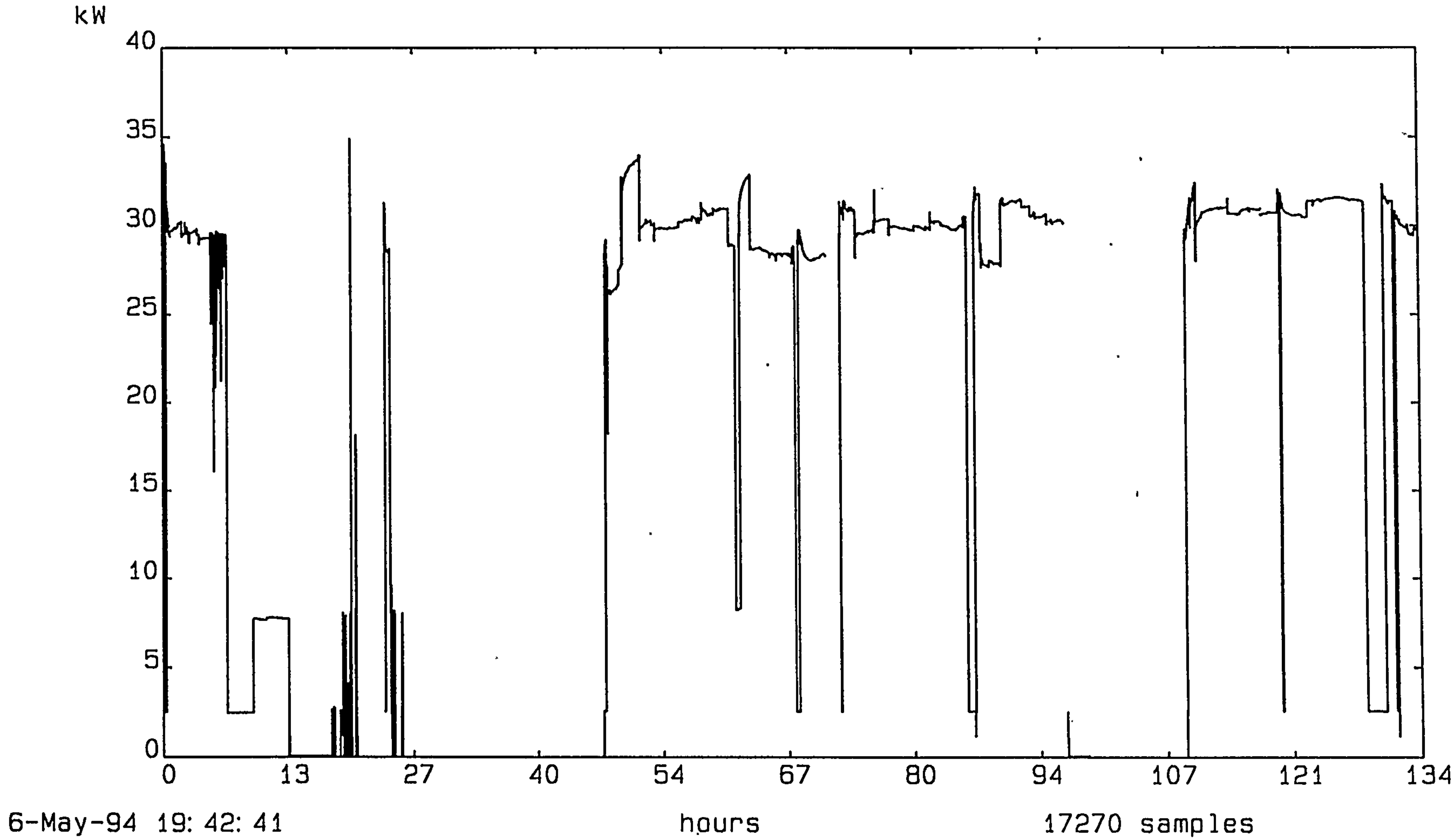
- Examples of 3-phase AC input power after line repair and replacement
  - 20 May 18:33, 48 hrs
    - (the broad break at 24 hours was used to make temperature profile measurements.
  - 04 June 00:24, 13 hrs

- Examples of RF generator power output
  - 01-May 22:39, 71.9 hrs
  - 20-May 18:33, 96.8 hrs
  - 24 May 21:27, 96.8 hrs

END FILE: KELLYC.A

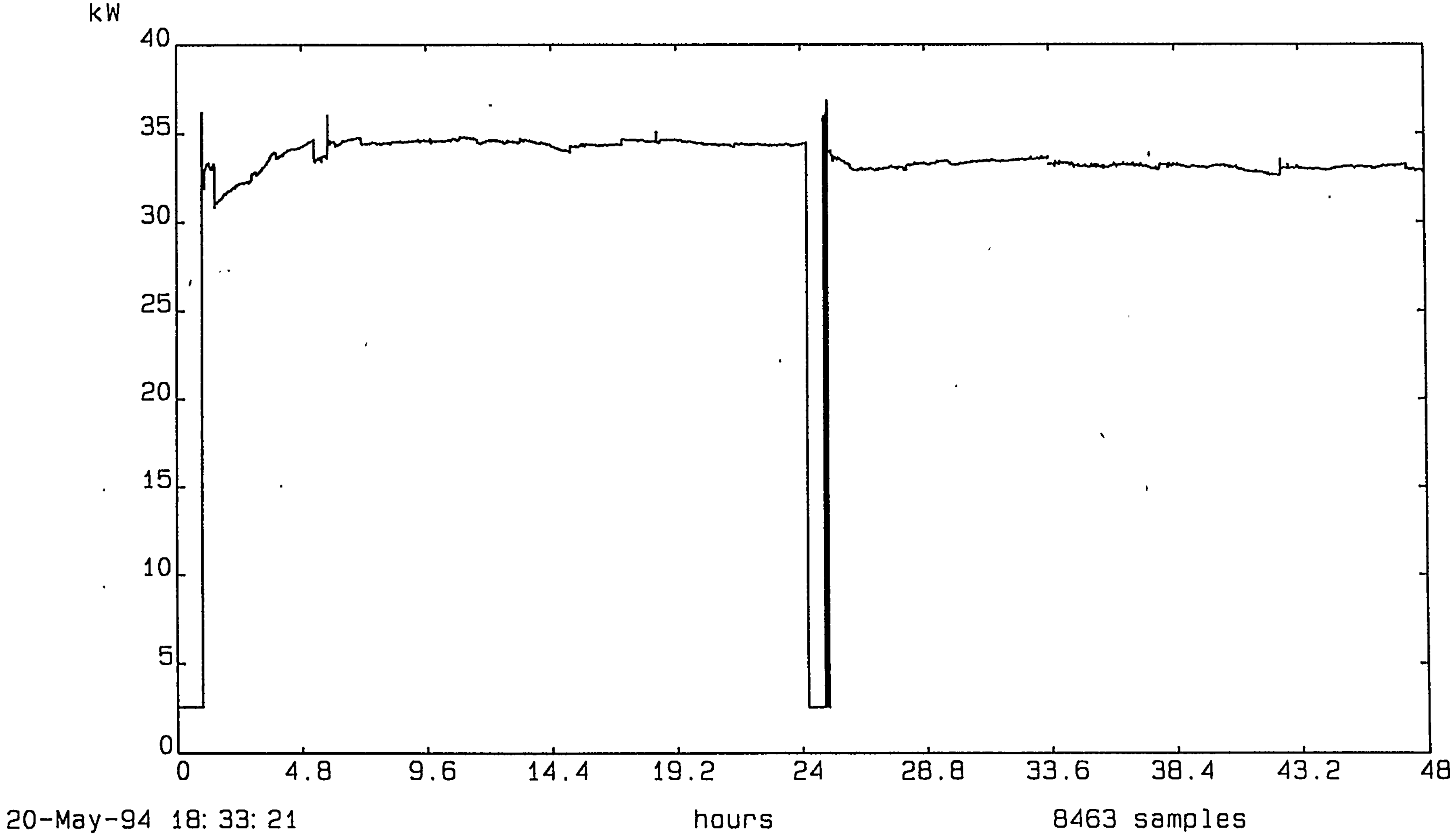


TKEL0501.01W Test 5 Gen. AC input PWR 5-May-94 3: 10: 41
tkel0501.01w ... tkel0501.39W

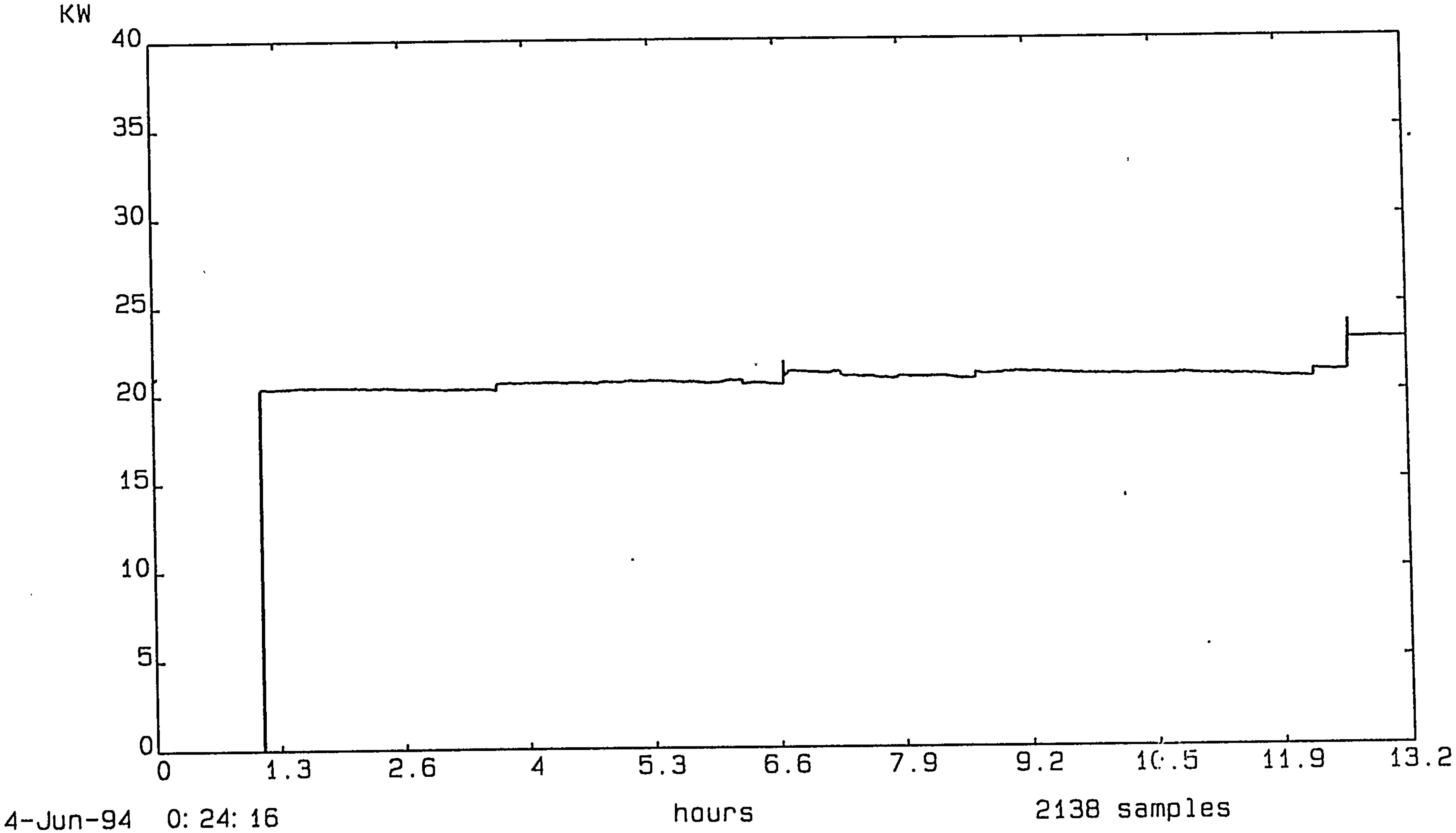


TKEL0601.01W Test 6 Gen. AC input PWR 6-May-94 19: 42: 41
tkel0601.01W ... tkel0601.99W

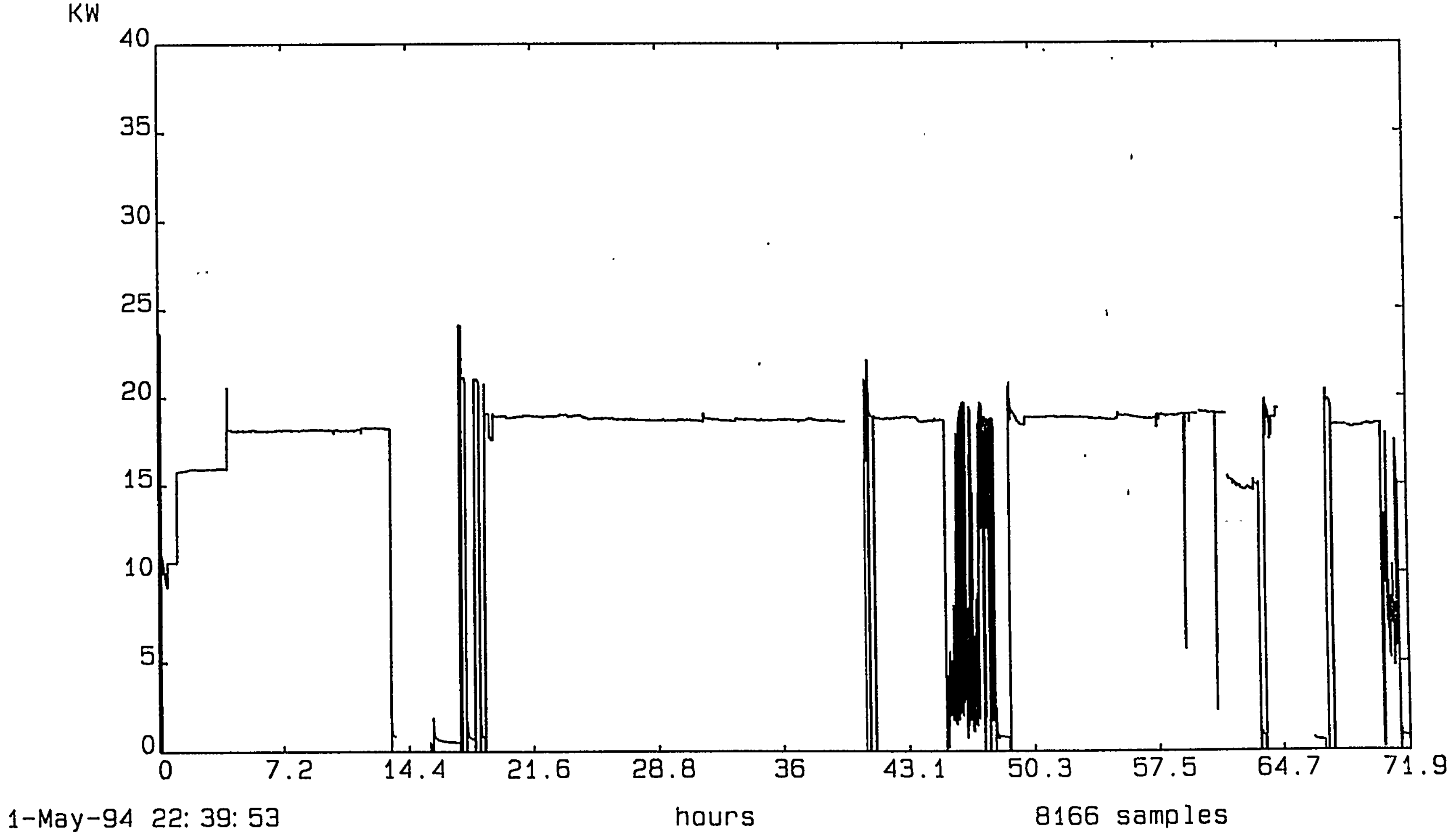
13-May-94



TKEL0901.00W Test 9 Gen. AC input PWR 20-May-94 18:33:21
tkel0901.00W ... tkel0901.47W

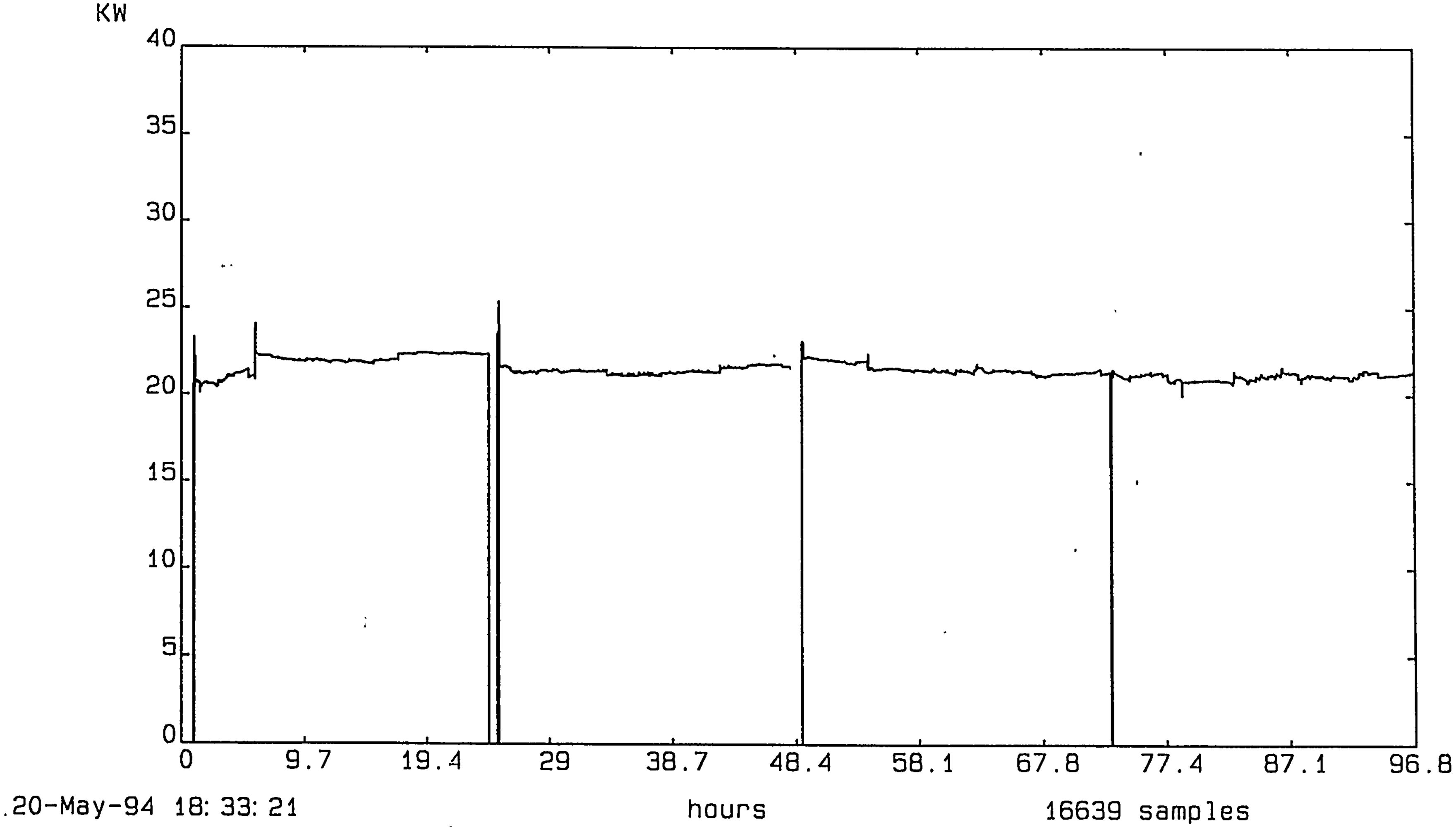


TKEL1302.00W Test 13 Gen. RF PWR Incident 4-Jun-94 0: 24: 16
tkeL1302.00W ... tkeL1302.12W



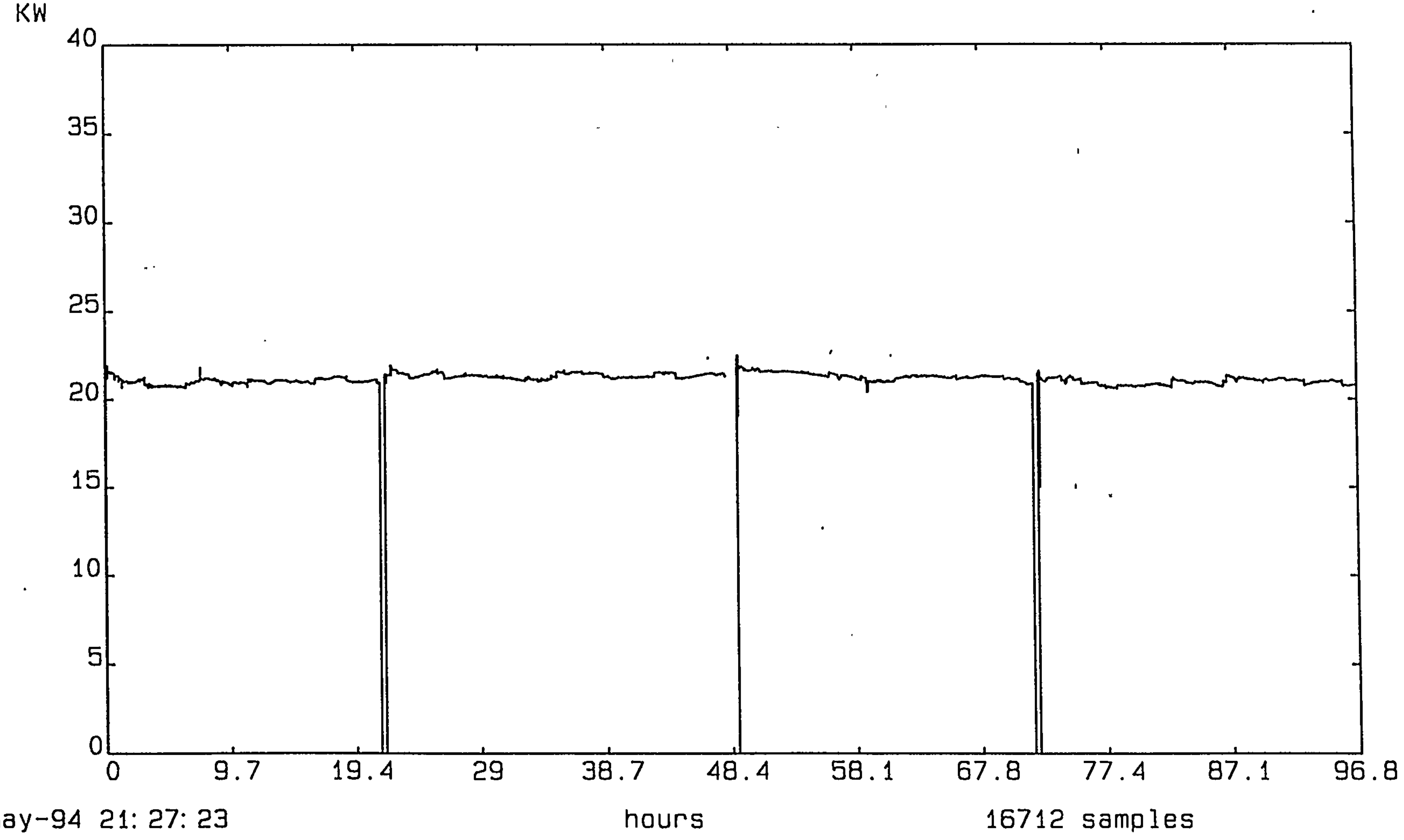
TKEL0402.01W Test 4 Gen. RF PWR Incident 1-May-94 22: 39: 53
tkel0402.01w ... tkel0402.47w

6-May-94



TKEL0902.00W Test 9 Gen. RF PWR Incident 20-May-94 18: 33: 21
tkel0902.00W ... tkel0902.93W

25-May-94



TKEL1002.00W Test 10 Gen. RF PWR Incident 24-May-94 21: 27: 23
tkel1002.00W ... tkel1002.92W

y-94

APPENDIX D - Temperature Plots Using Fiber Optics

Fiber optic probe measurements

The fiber optic temperature measurement we recorded by the data logging system as channels 21, 22, 23 or 24.

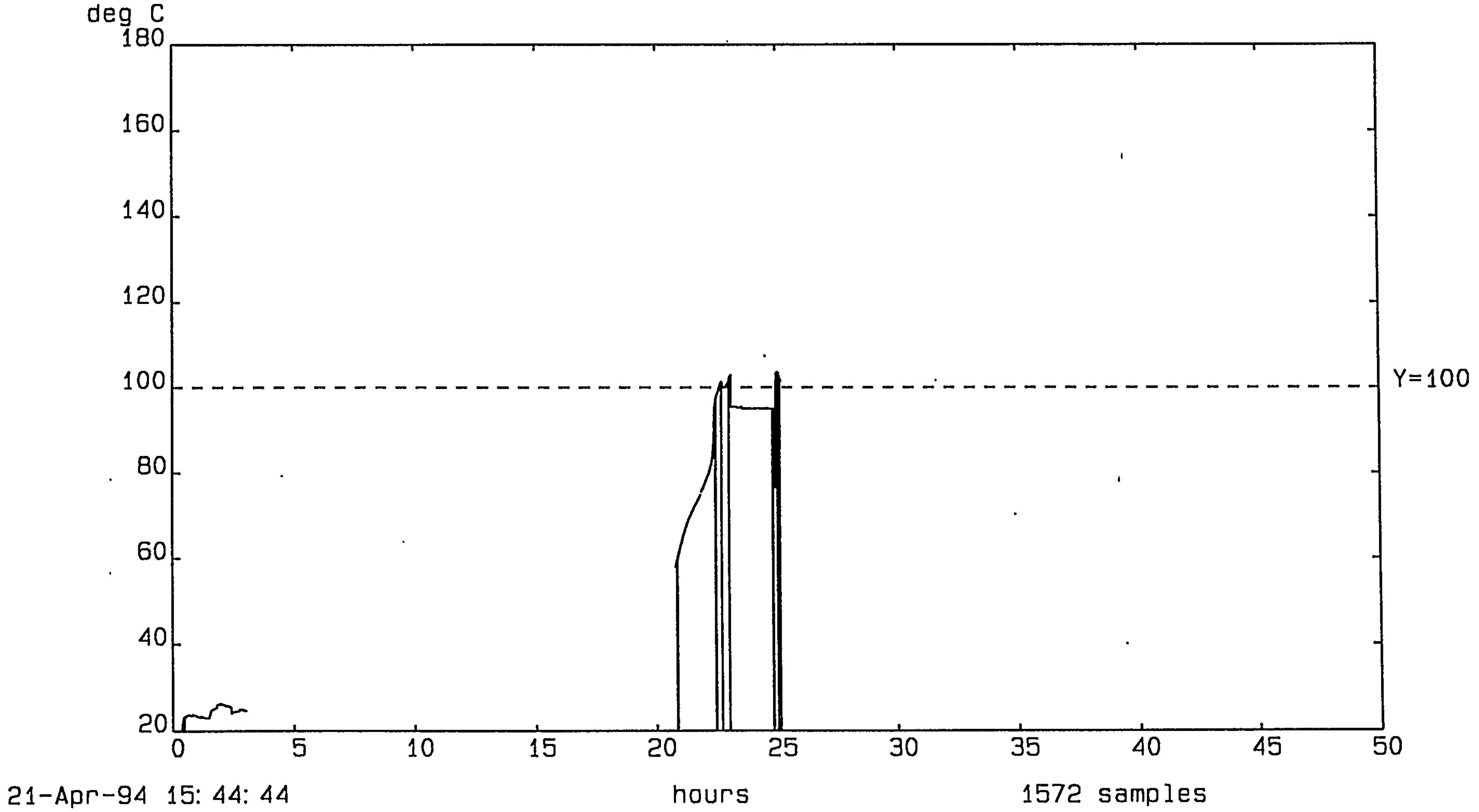
- Channel 21 - outside wall temperature of well liner A2 at a depth of 10.5 ft.
  - 21 April 1994, 15:44, Day 8.65 - 50 hour plot
  - 24 April 1994, 23:19, Day 11.97 - 120 hour plot
  - 01 May 1994, 22:39, Day 18.94 - 120 hour plot
  - 06 May 1994, 23.82, Day 23.82 - 120 hour plot

- Selected plot of channel 21 - applicator #1
  - 19 May 1994, 15:50, Day ____ - 25 hour plot, peak temperature reading for program
  - 20 May 1994, 18:33, Day ____- 96.8 hour plot
  - 24 May 1994, 21:27, Day ____- 96.8 hour plot
- Selected plot of channel 22 - applicator #2
  - 20 May 1994, 18:33, Day_____- 96.8 hour plot
  - 24 May 1994, 21:27, Day_____- 96.8 hour plot
  - 28 May 1994, 23:22, Day_____- 39.9 hour plot

DRAFT NOTE: The above and others to be provided in 120 hour plot format for final report.

END FILE: KELLYD.A

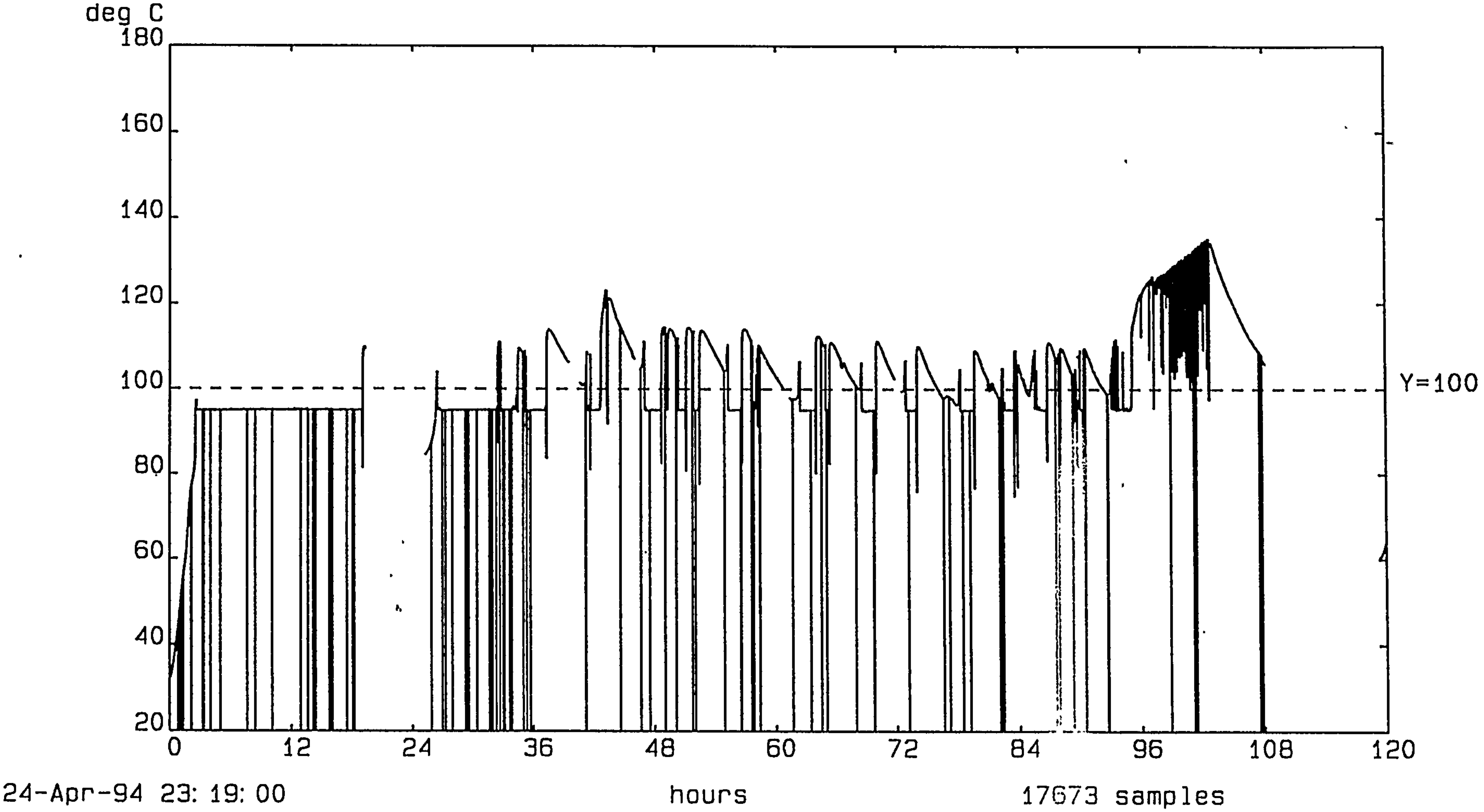
Preheat EMI test period - Start: Day 8.65



Tkel0021.01C Emissions test LUX 1 - APP#1 WALL @ 9.5' 21-Apr-94 15: 44: 44
tkel0021.01c ... tkel0221.06c

3[illegible]-94

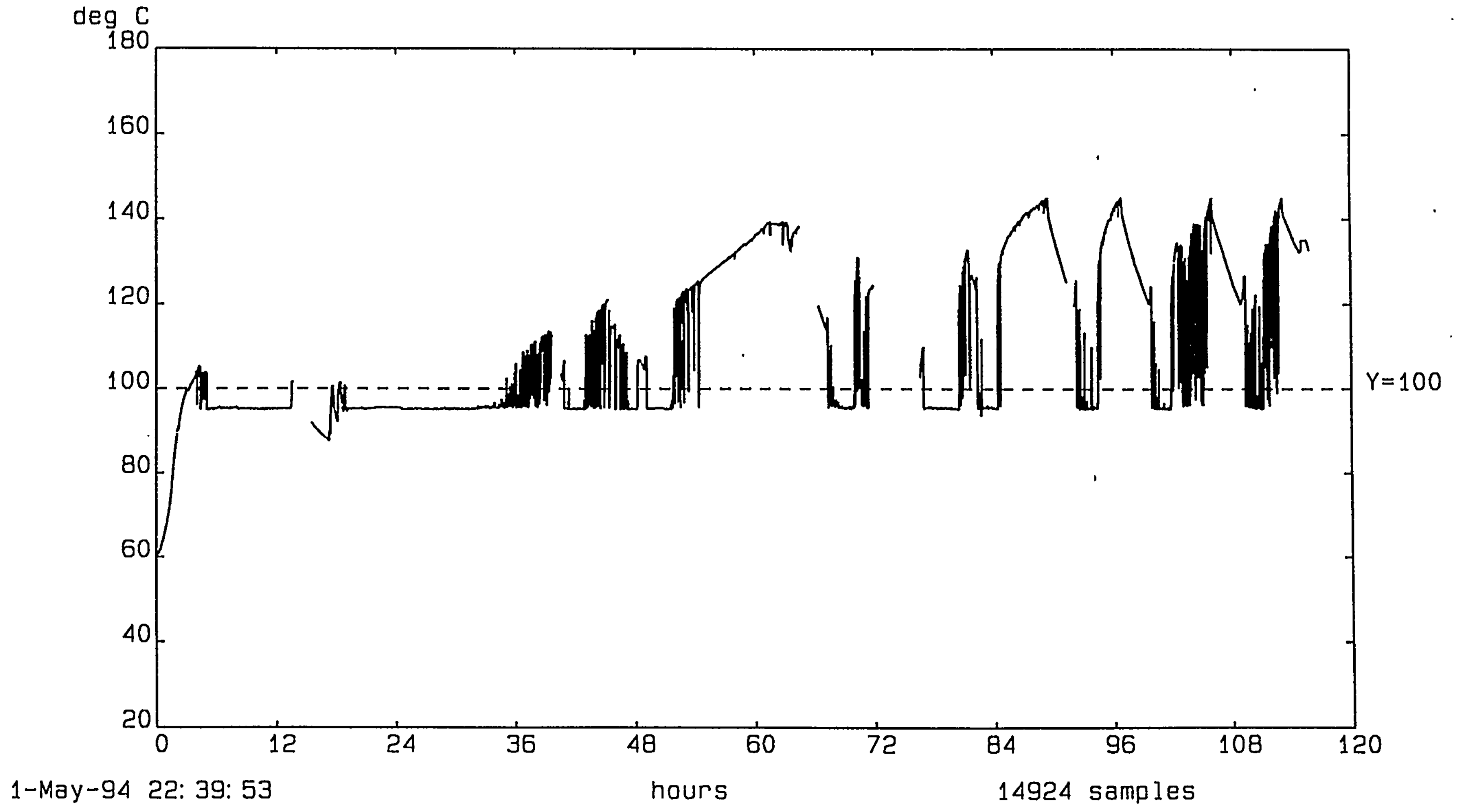
Start of Applicator #1 heating period - Start: Day 11.97



Tkel0321.01C EM test 3 APP#1 WALL @10.5' 24-Apr-94 23: 19: 00
tkel0321.01C ... tkel0421.15c

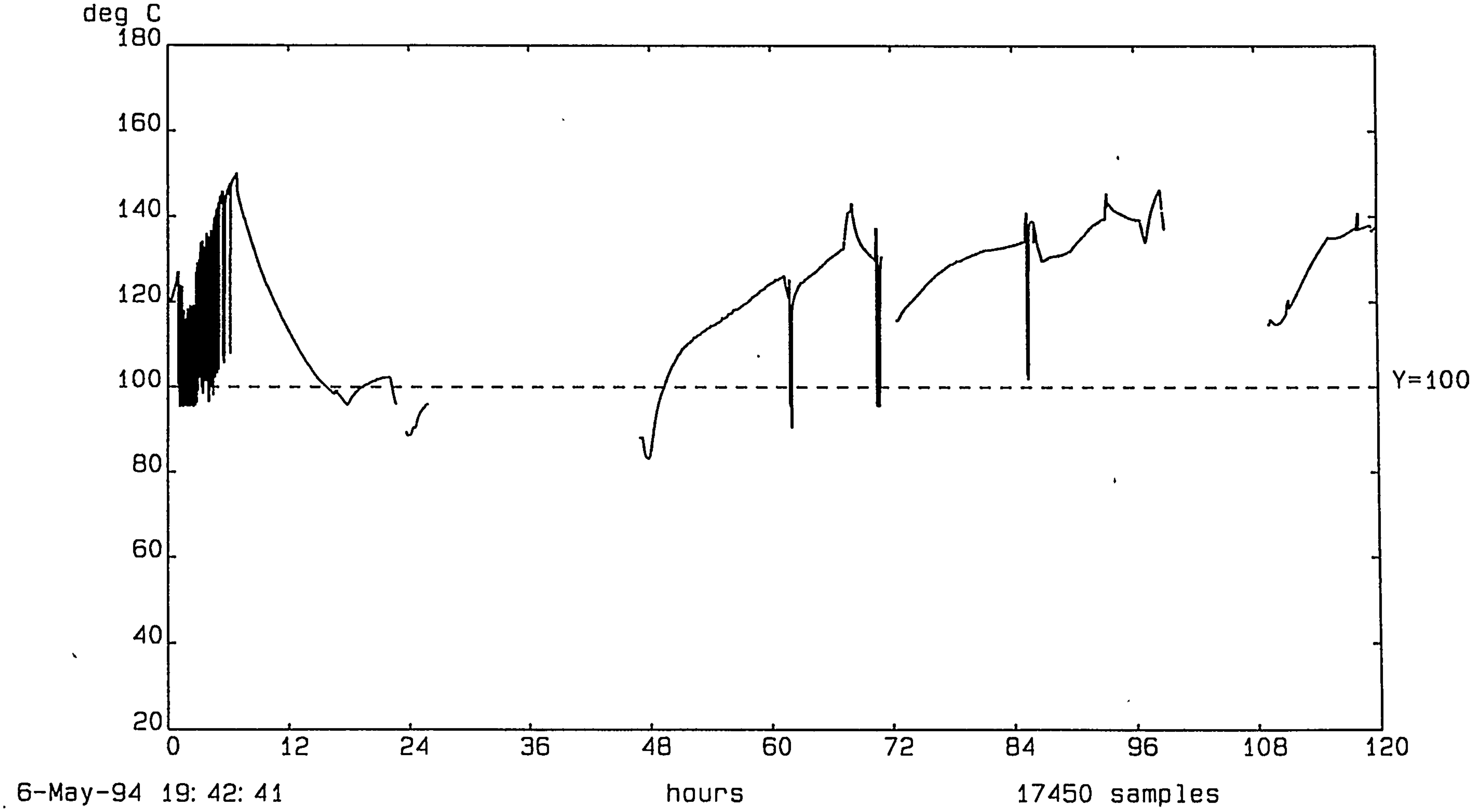
31-Oct-94

Continuation of Applicator #1 heating period - Start: Day 18.94



TKEL0421.01C Test 4 APP#1 WALL @10.5'(s) 1-May-94 22: 39: 53
tkel0421.01c ... tkel0521.38C

Start of Applicator #1 heating period - Start: Day 23.82

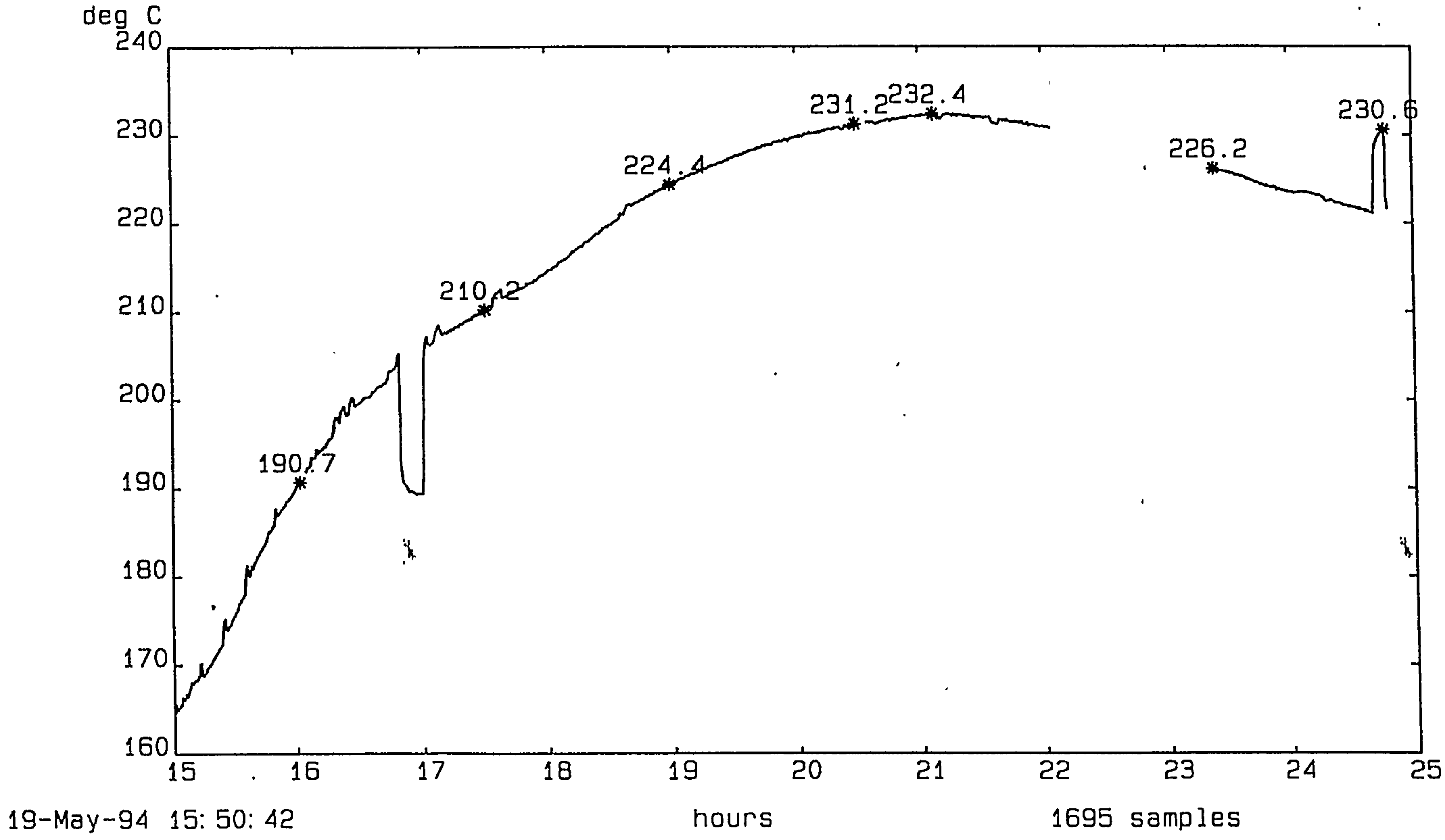


TKEL0621.01C Test 6 APP#1 WALL @10.5'(s) 6-May-94 19: 42: 41
tkel0621.01C ... tkel0721.01C

31-Oct-94

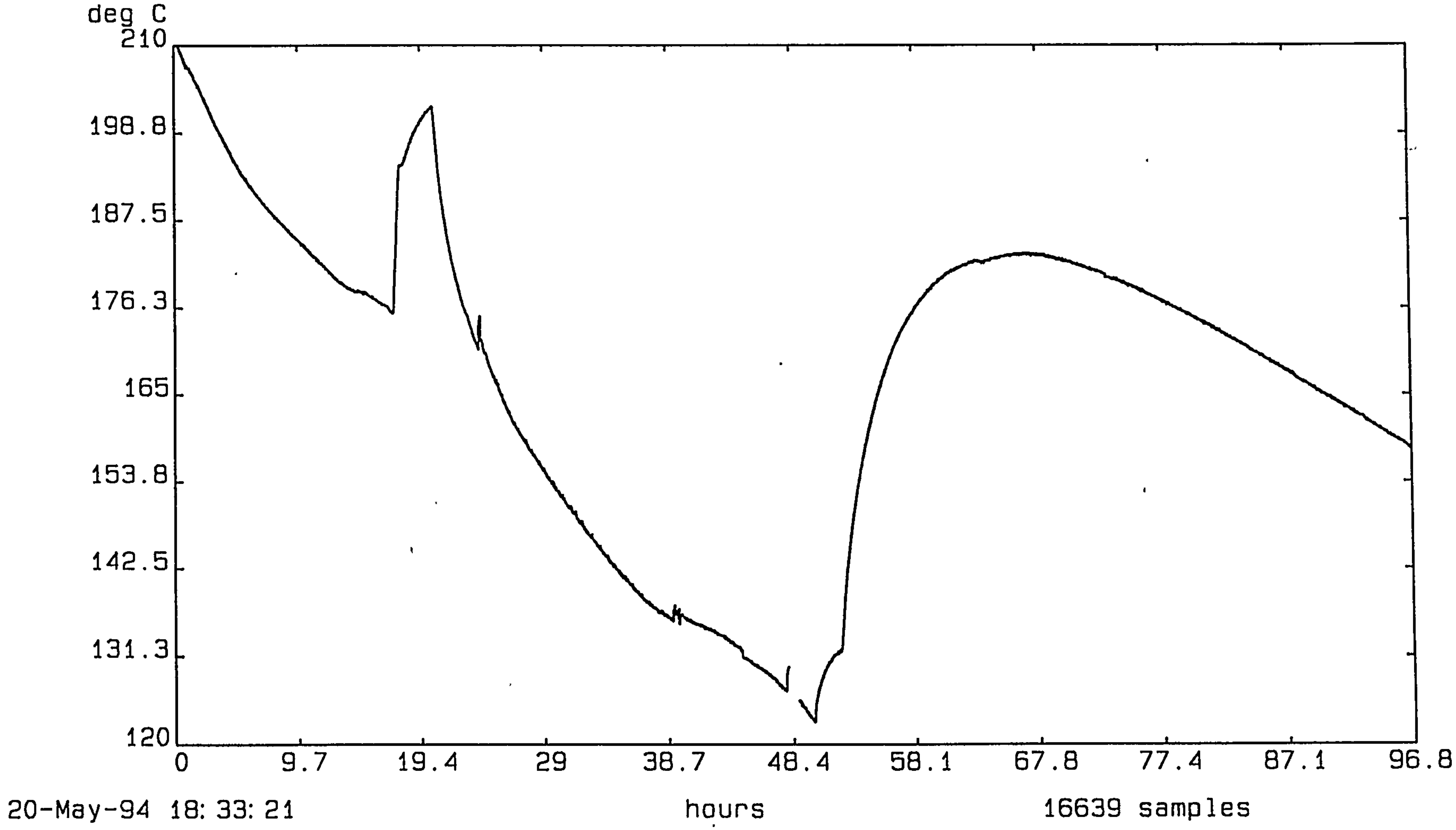
DRAFT Copy

Applicator A1 - outside wall sleeve temperature by fiber optic probe (add 1.5 deg)



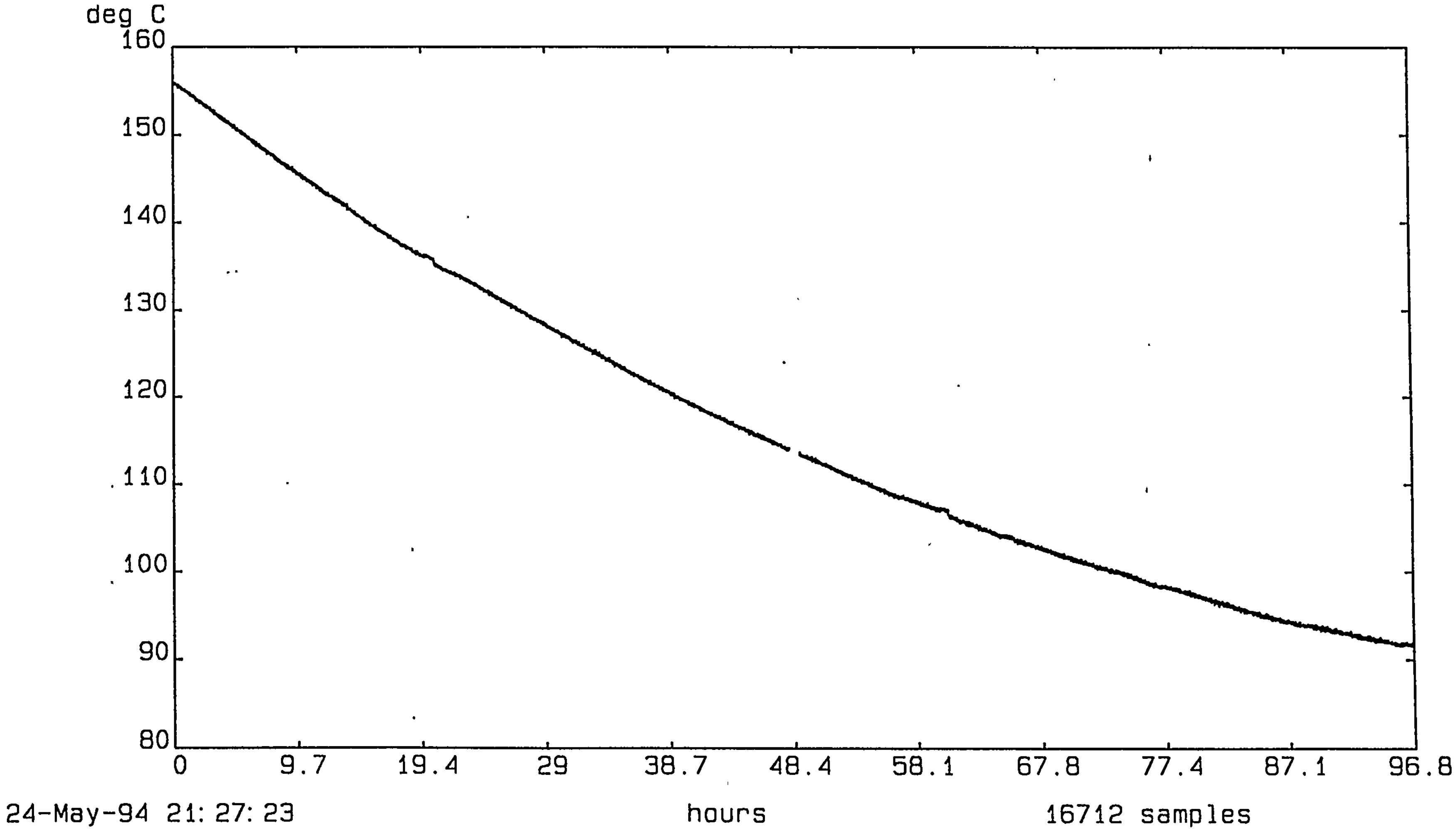
TKEL0821.80C Test 8 APP#1 WALL @10.5'(s) 19-May-94 15: 50: 42
tkel0821.80c ... tkel0921.02c

25-Oct-94

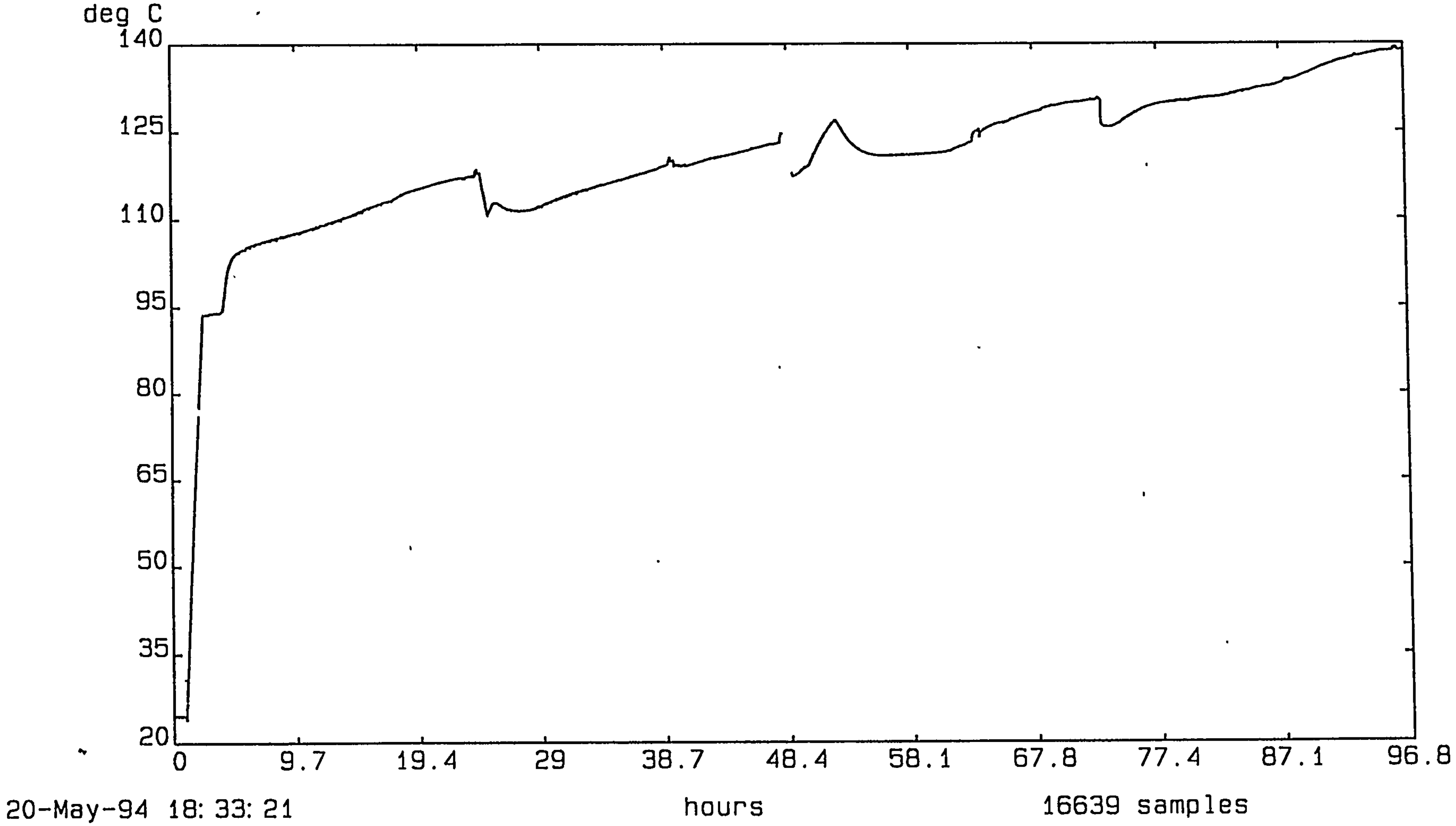


TKEL0921.00C Test 9 APP#1 WALL @10.5'(s) 20-May-94 18:33:21
tkel0921.00C ... tkel0921.93C

25-May-94

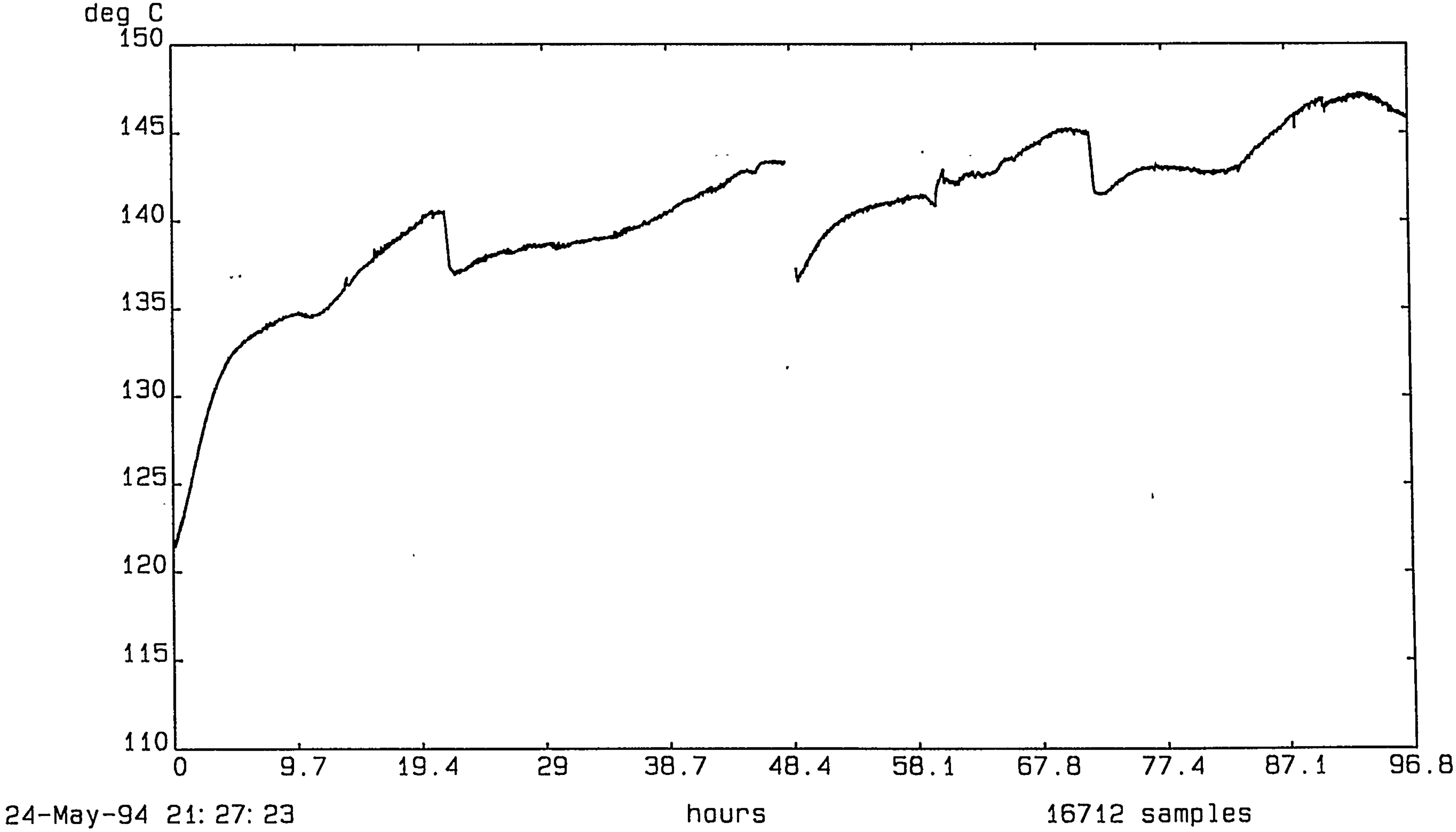


TKEL1021.00C Test 10 APP#1 WALL @10.5'(s) 24-May-94 21:27:23
tkel1021.00C ... tkel1021.92C



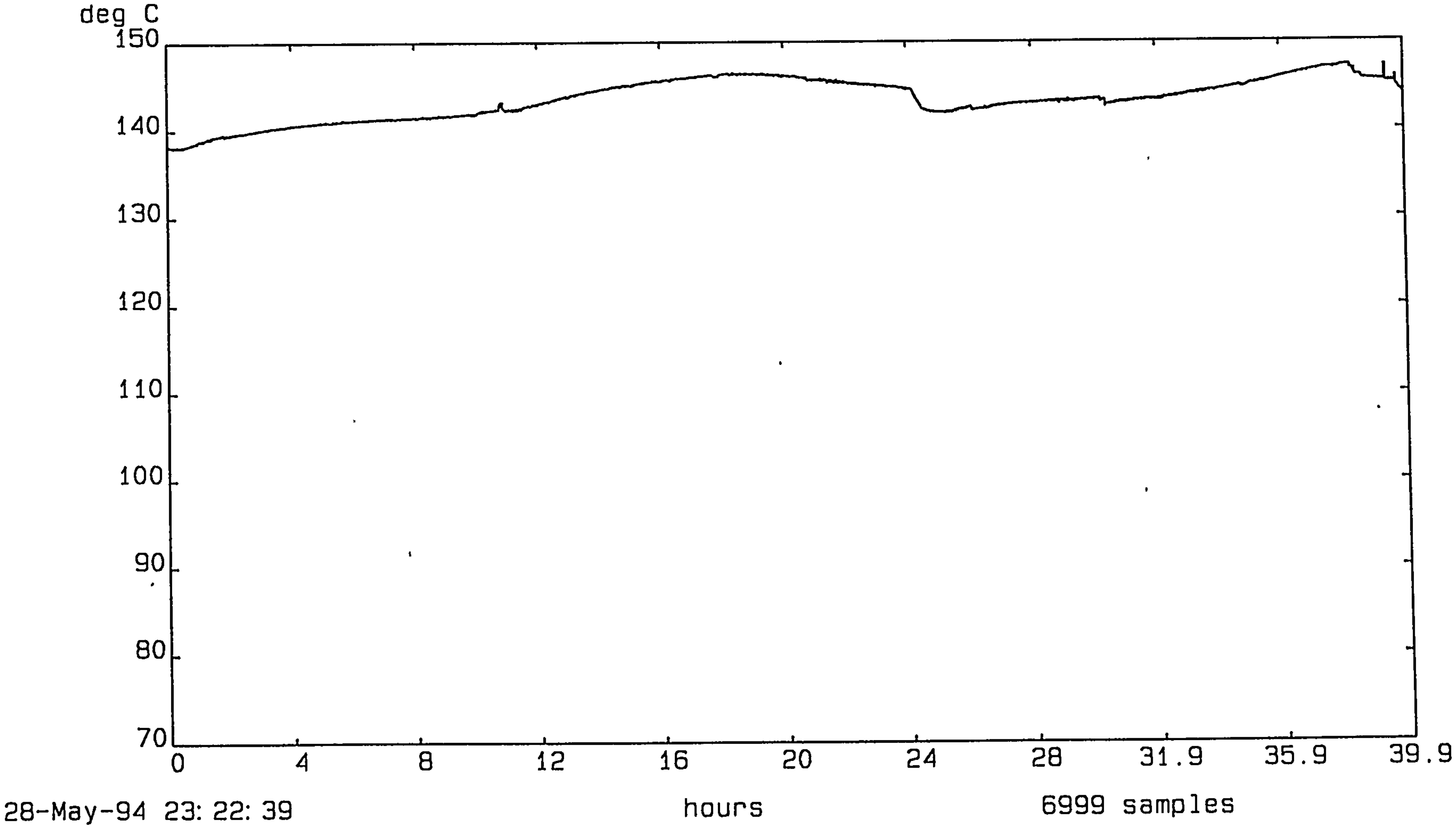
TKEL0922.00C Test 9 APP#2 WALL @10.5' ( ) 20-May-94 18: 33: 21
tkel0922.00C ... tkel0922.93C

25-May-94



TKEL1022.00C Test 10 APP#2 WALL @10.5' ( ) 24-May-94 21:27:23
tkel1022.00C ... tkel1022.92C

30-May-94



TKEL1122.00C Test 11 APP#2 WALL @10.5' ( ) 28-May-94 23: 22: 39
tkel1122.00C ... tkel1122.38C

3-Jun-94

APPENDIX E - Temperature Profiles Using Thermocouples

Thermocouple measurements

Plot TC-1 over a 7 to 77 day span - all depths
Plot TC-2 - all depths
Plot TC-3 - all depths

Plot TC-1 - at 5 depths
Plot TC-2 - at 5 depths
Plot TC-3 - at 5 depths

TC-1 Temperature profiles - 20 May to 24 May
TC-1 Temperature profiles - 24 May to 29 May
TC-1 Temperature profiles - 29 May to 02 June
TC-1 Temperature profiles - 02 June to 13 June
TC-1 Temperature profiles - 07 June to 14 June

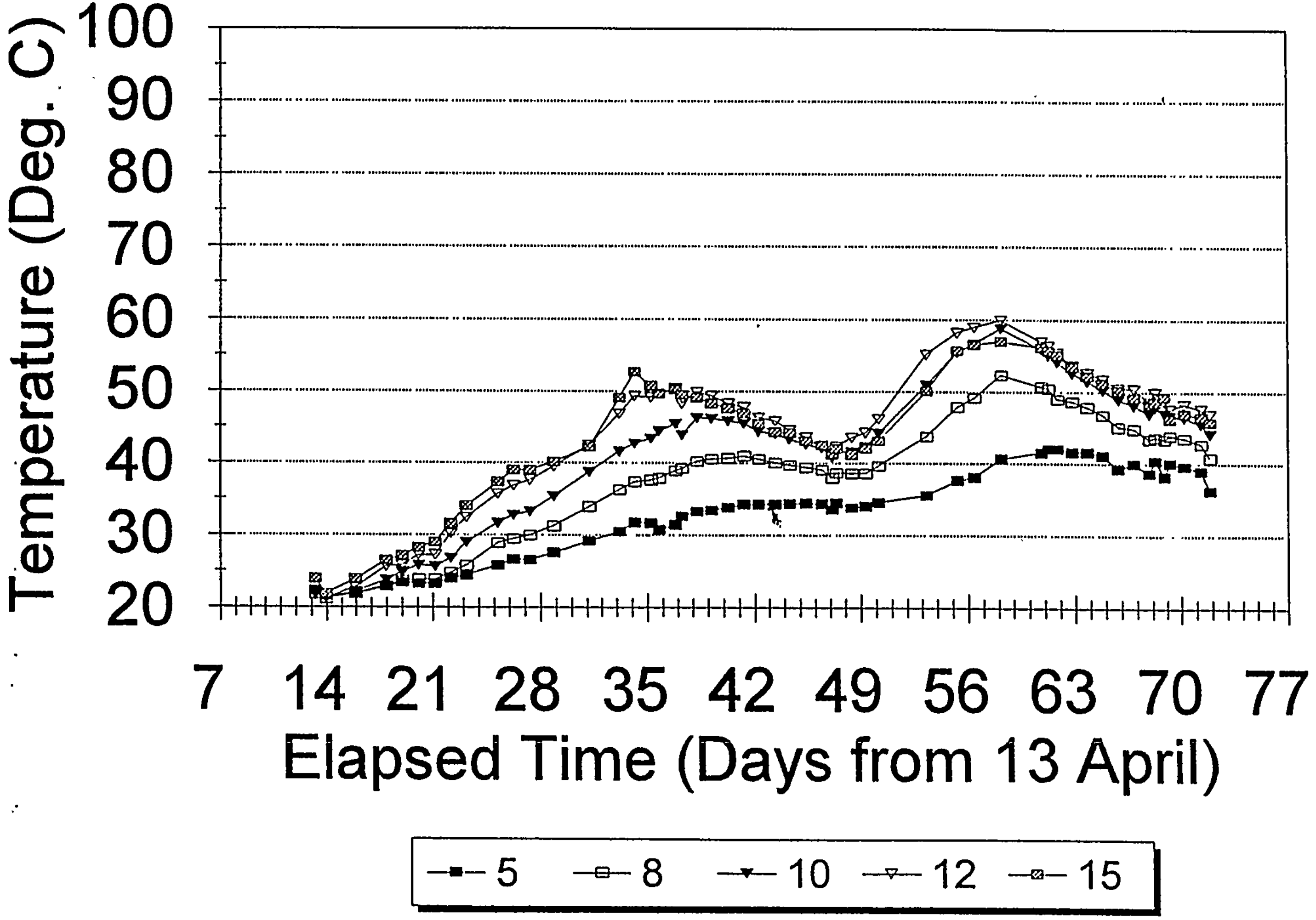
TC-2 Temperature profiles - 20 May to 24 May
TC-2 Temperature profiles - 24 May to 29 May
TC-2 Temperature profiles - 29 May to 02 June
TC-2 Temperature profiles - 02 June to 13 June
TC-2 Temperature profiles - 07 June to 14 June

TC-3 Temperature profiles - 20 May to 24 May
TC-3 Temperature profiles - 24 May to 29 May
TC-3 Temperature profiles - 29 May to 02 June
TC-3 Temperature profiles - 02 June to 13 June
TC-3 Temperature profiles - 07 June to 14 June

END FILE: KELLYE.A

Thermocouple Measurements at TC-2
Five selected Depths

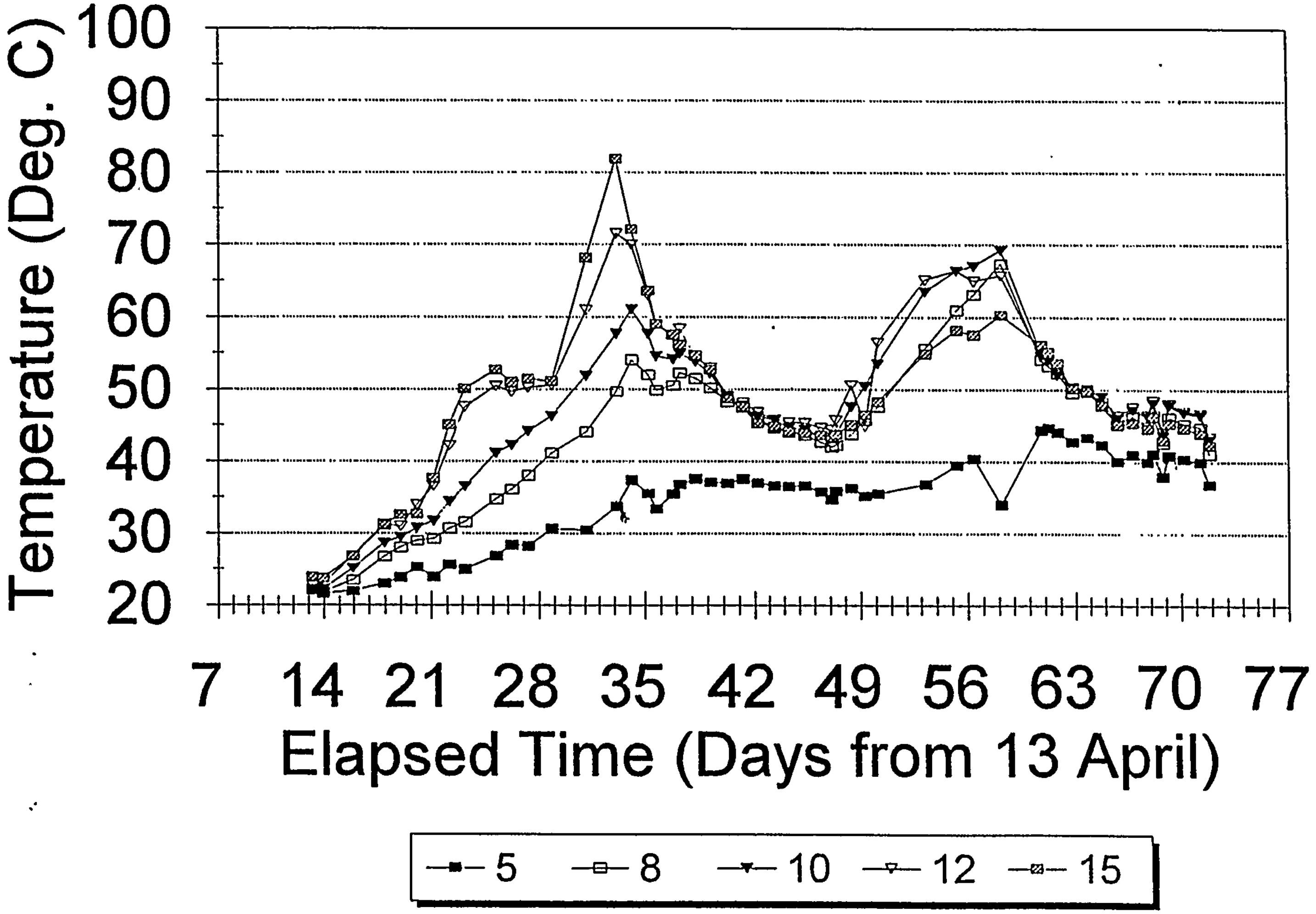
DRAFT Copy



Thermocouple Measurements at TC-1

Five selected Depths

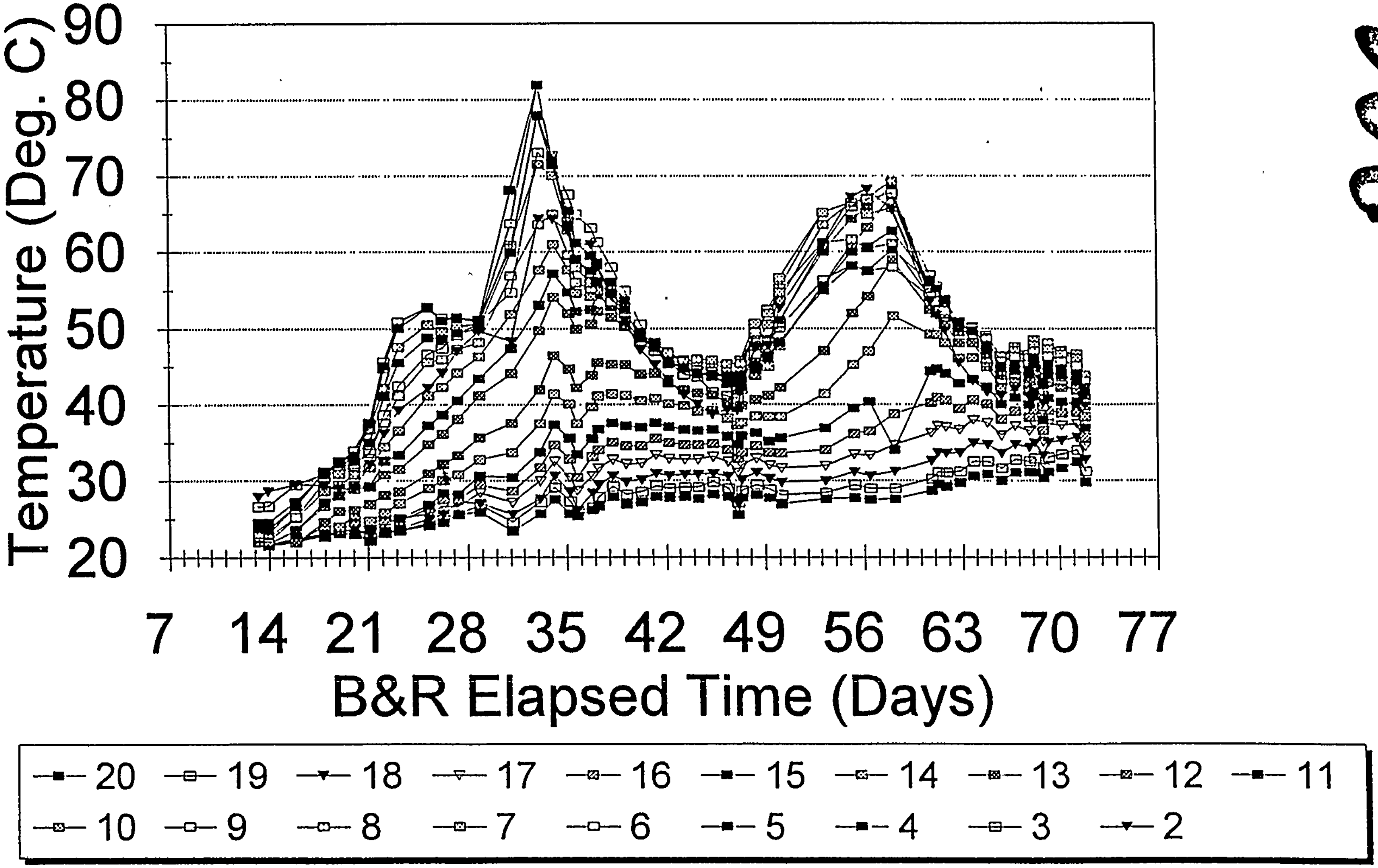
DRAFT
Copy



DRAFT Copy

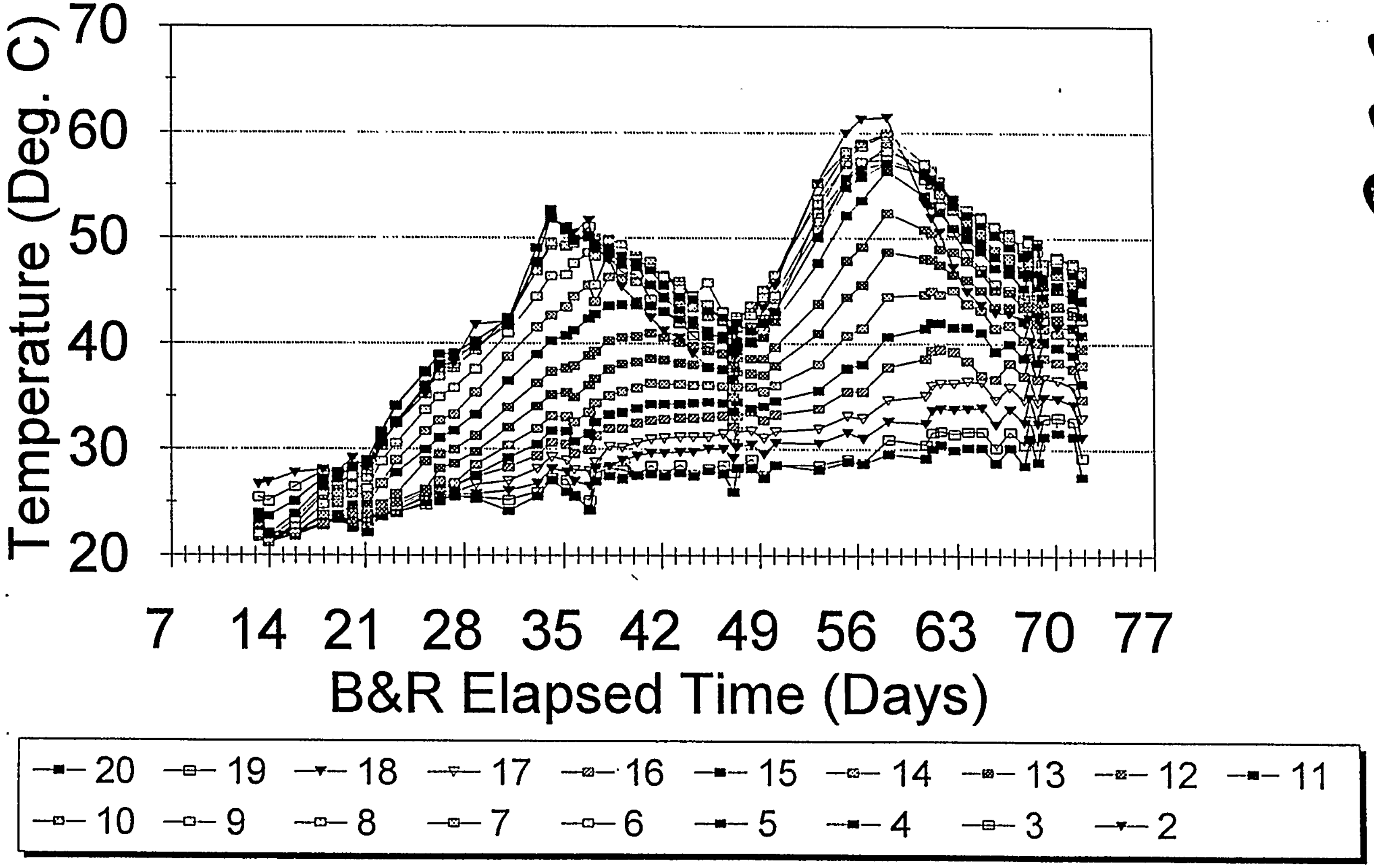
Thermocouple Measurements at TC-1

All Depths

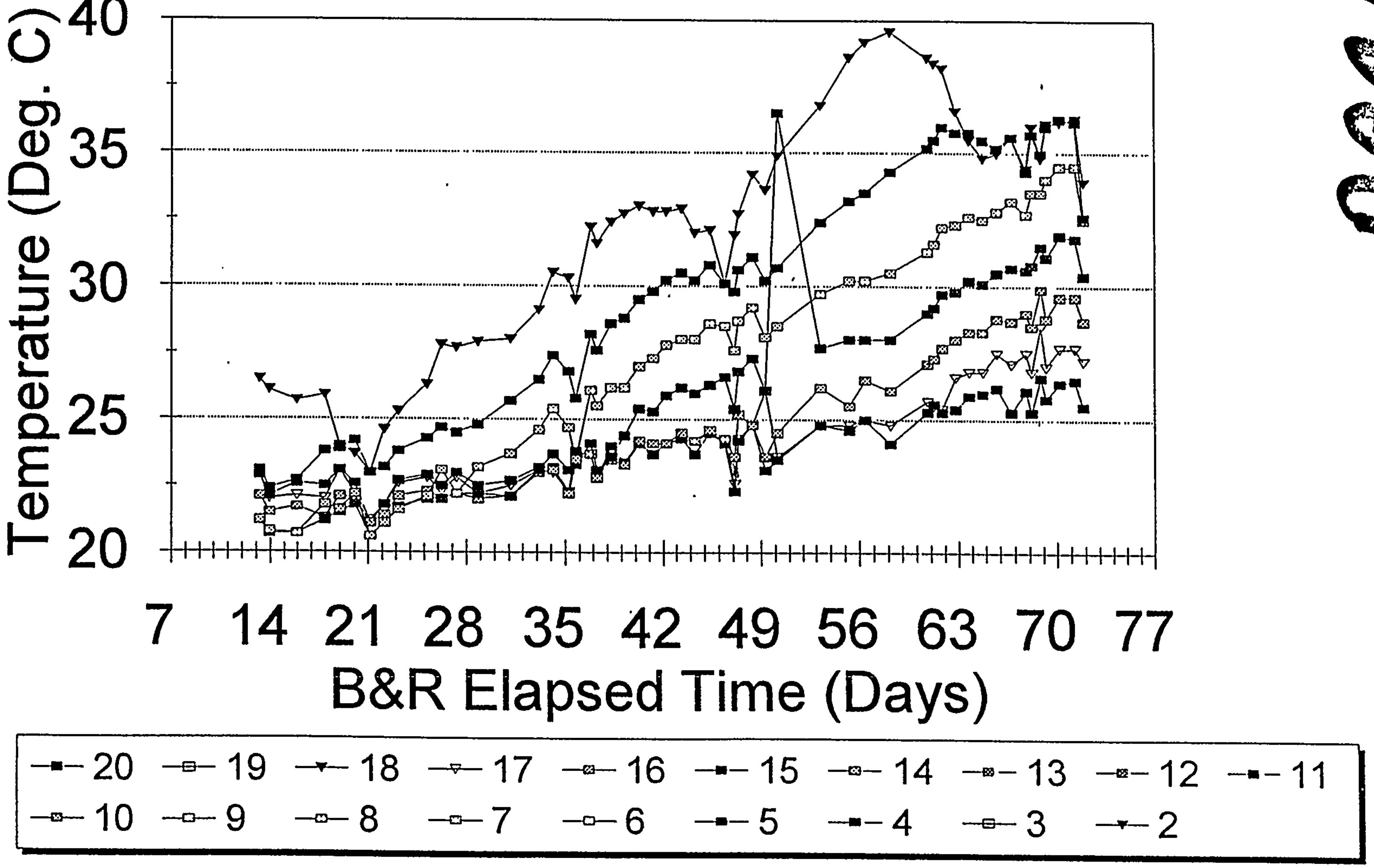


DRAFT
copy

Thermocouple Measurements at TC-2
All Depths



Thermocouple Measurements at TC-3
All Depths



DRAFT
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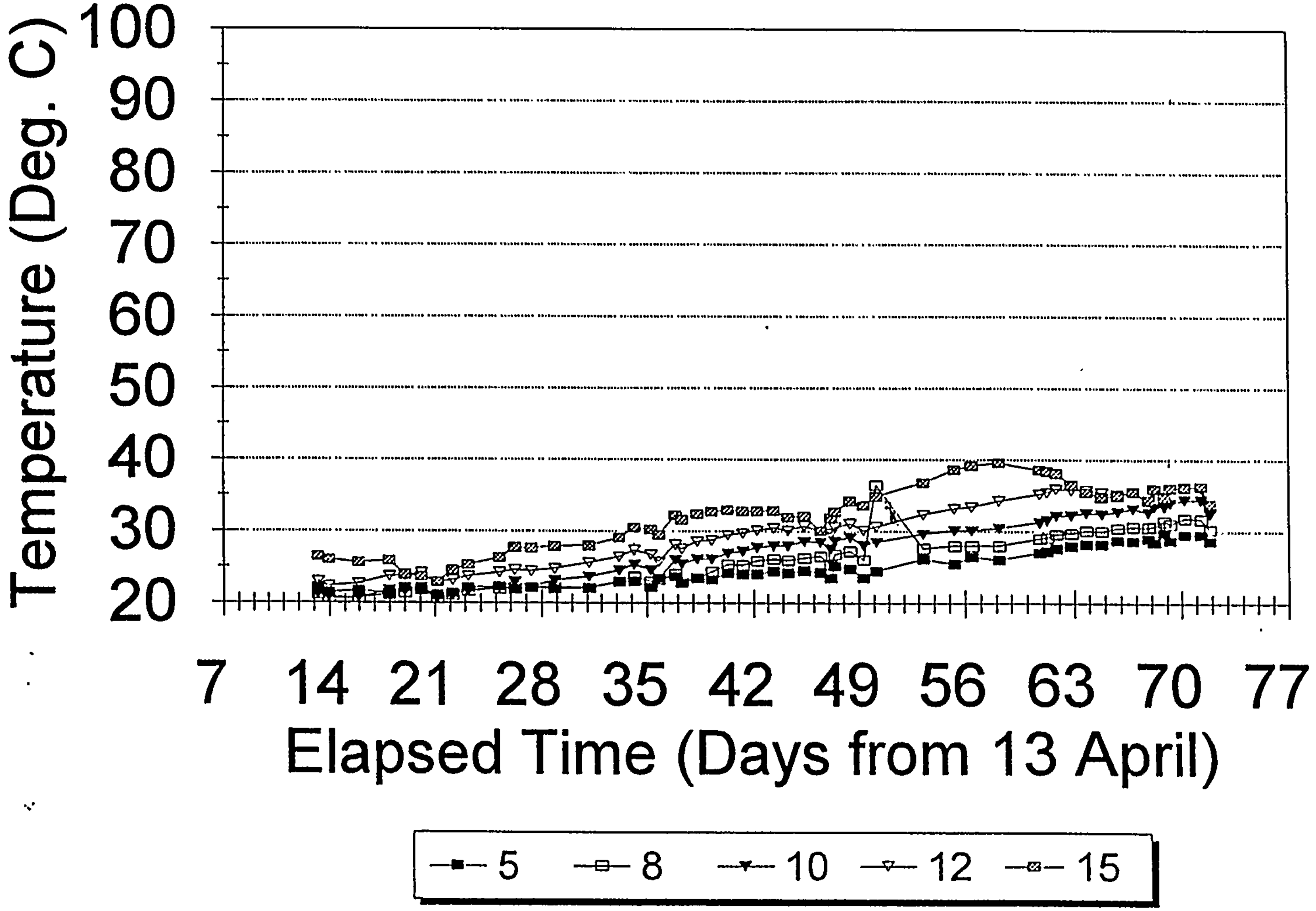
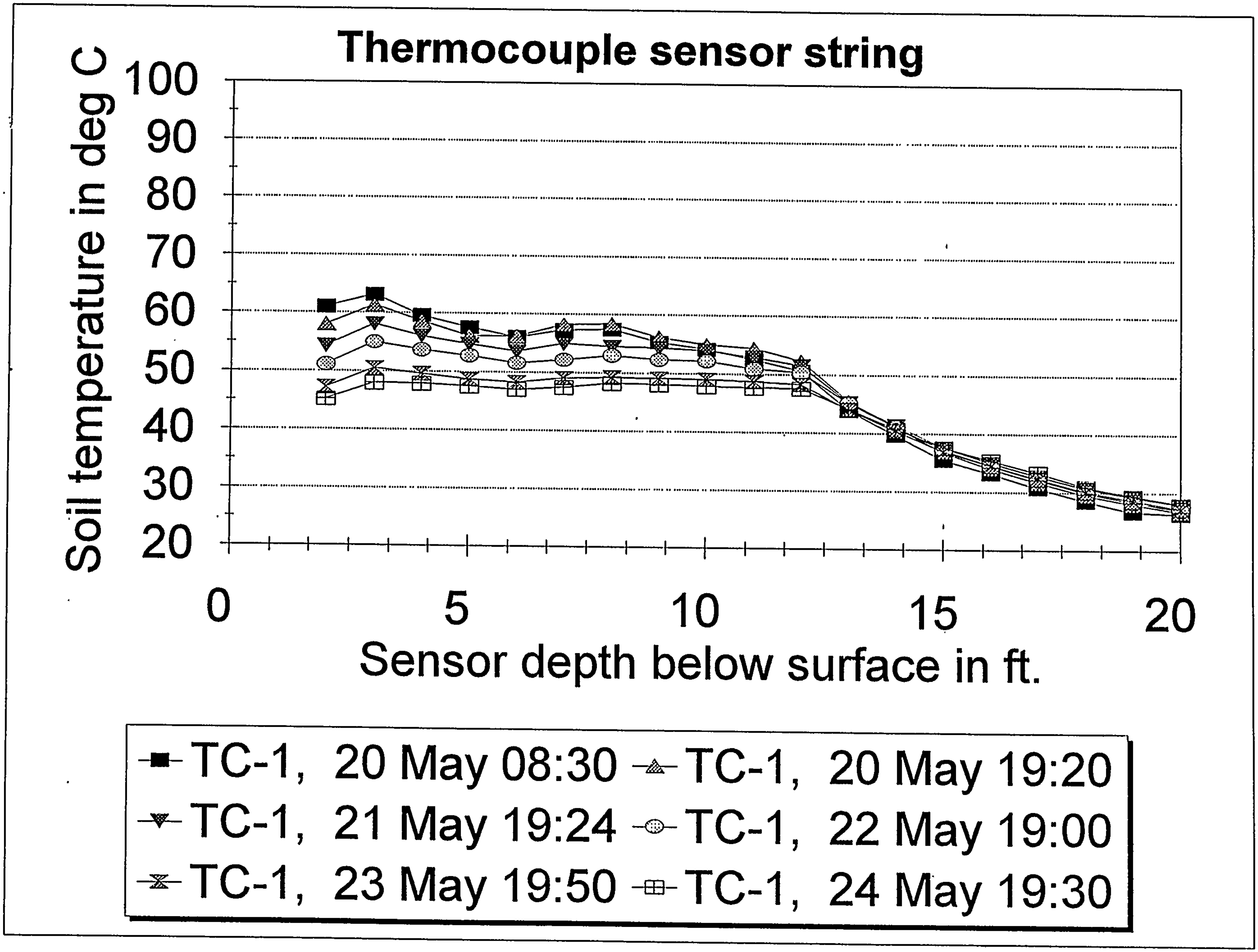
Point @
10 ft con

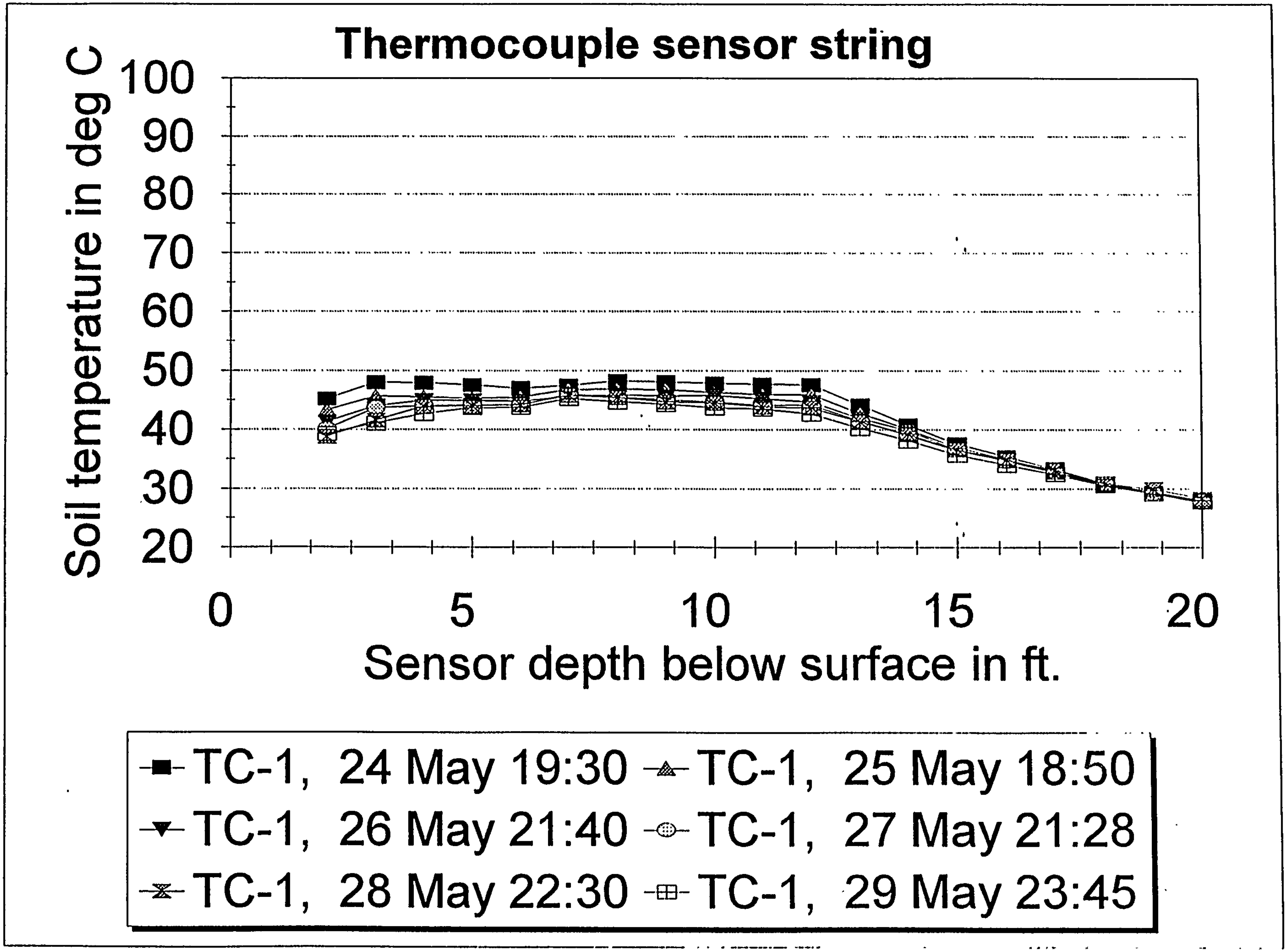
Thermocouple Measurements at TC-3

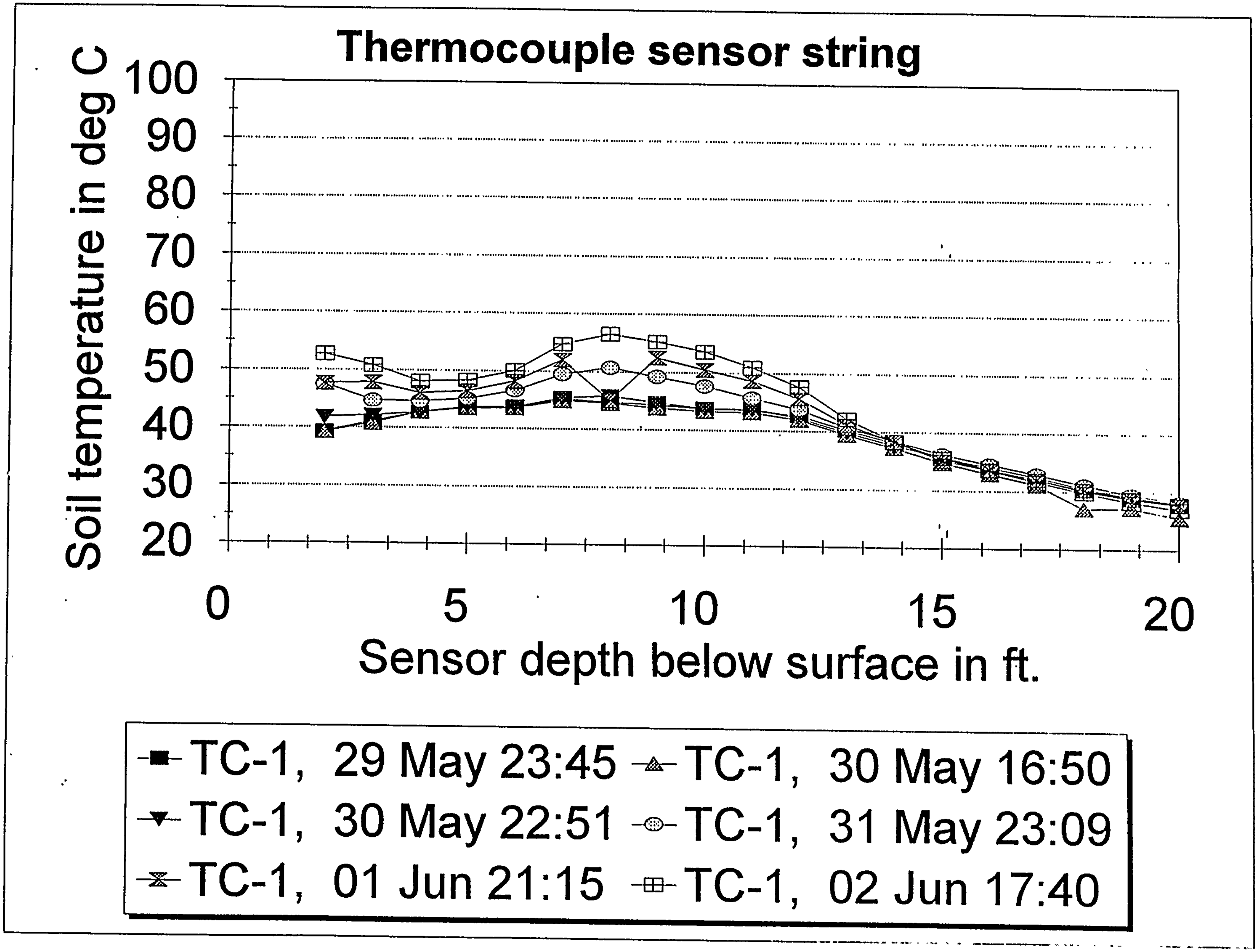
Five selected Depths

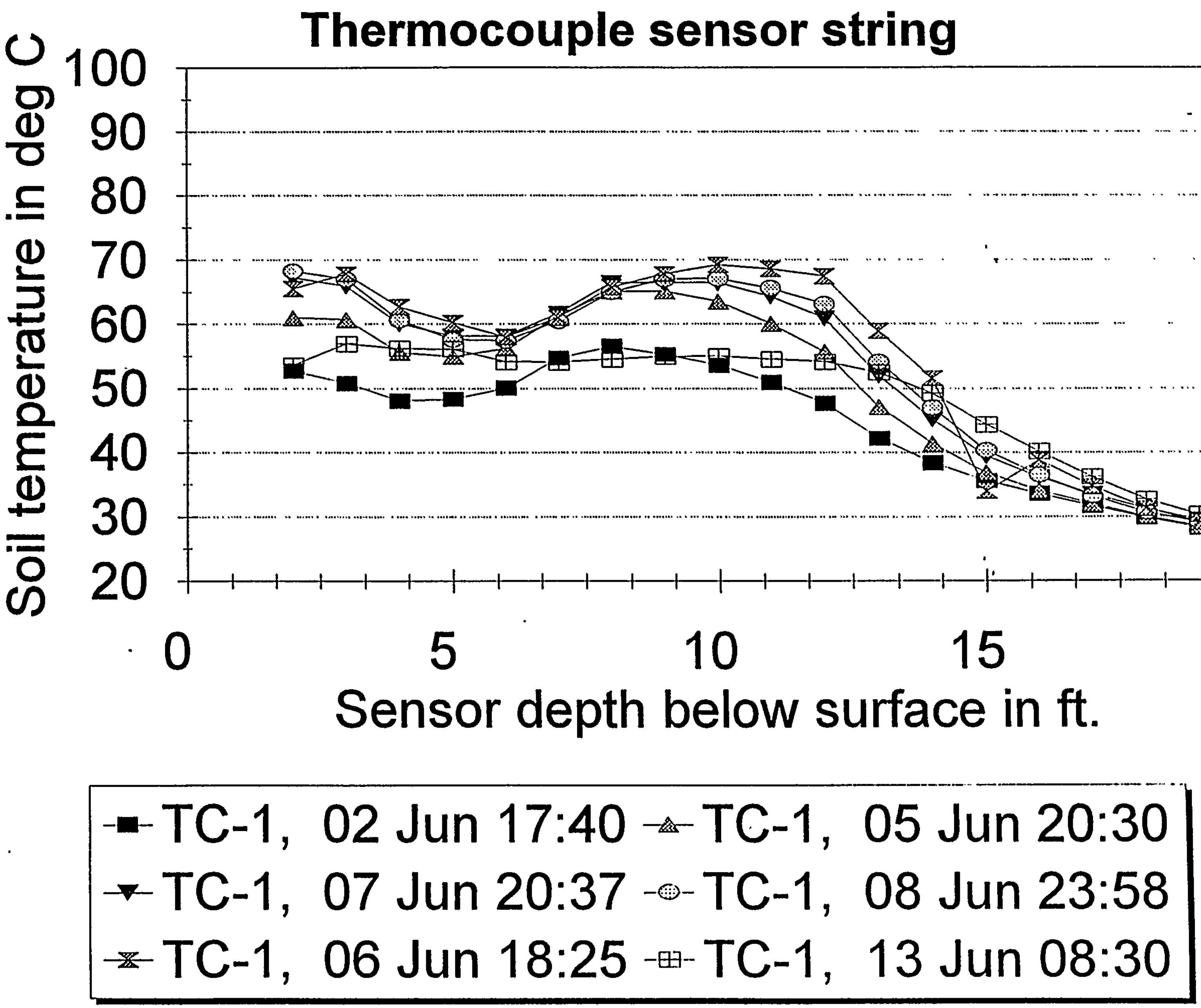
DRAFT Copy

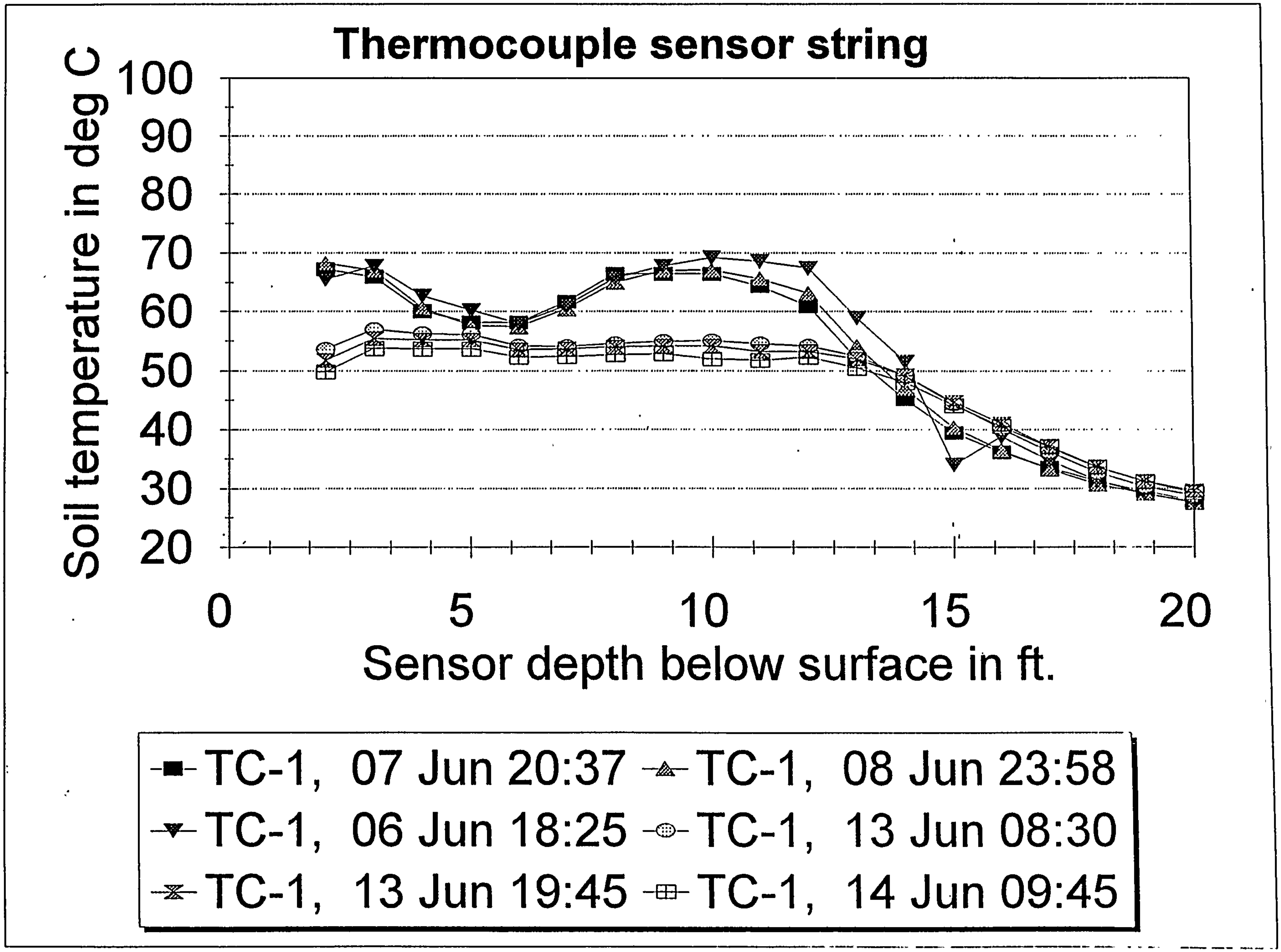


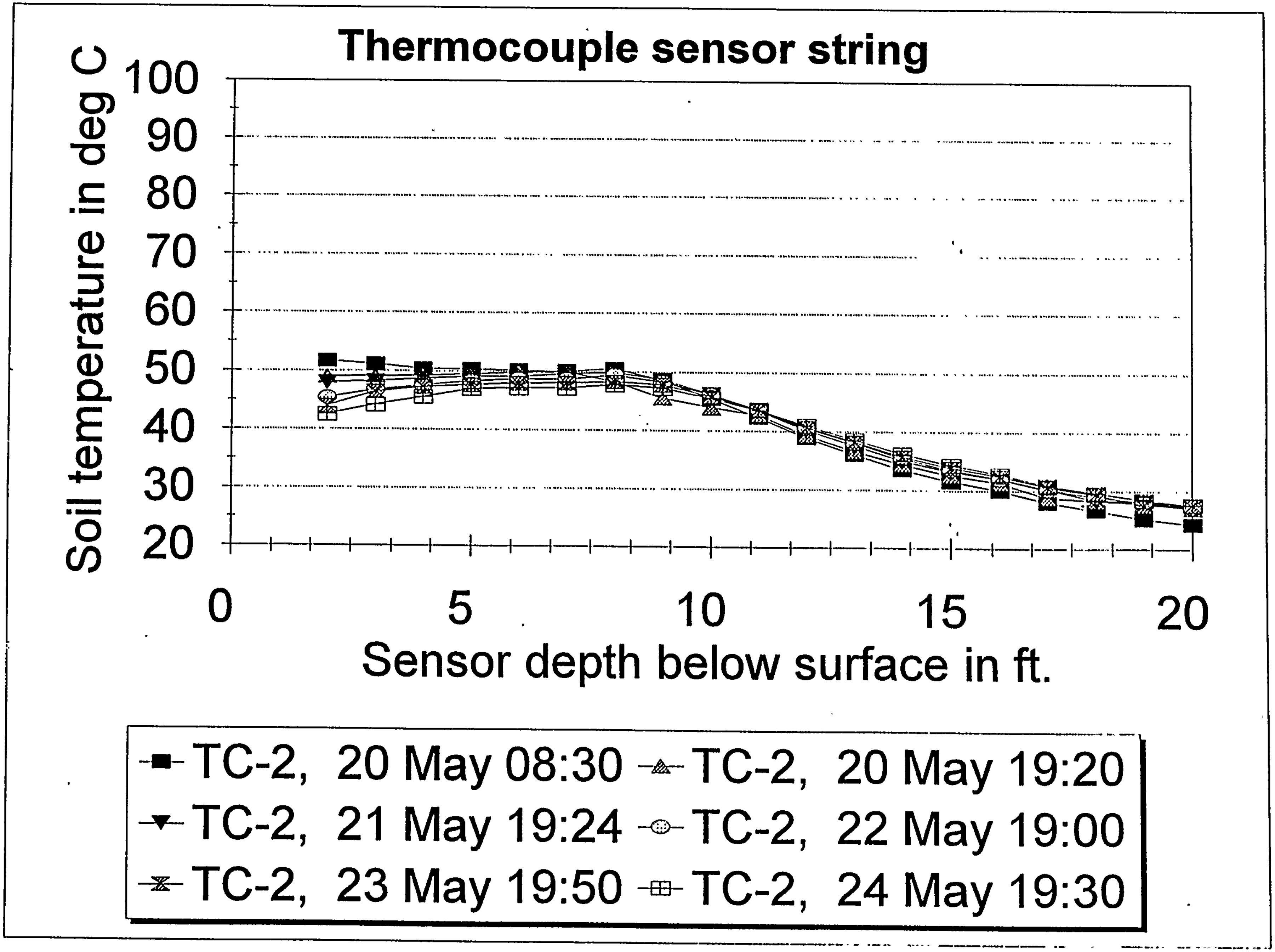

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-1, 20 May 08:30
TC-1, 20 May 19:20
TC-1, 21 May 19:24
TC-1, 22 May 19:00
TC-1, 23 May 19:50
TC-1, 24 May 19:30

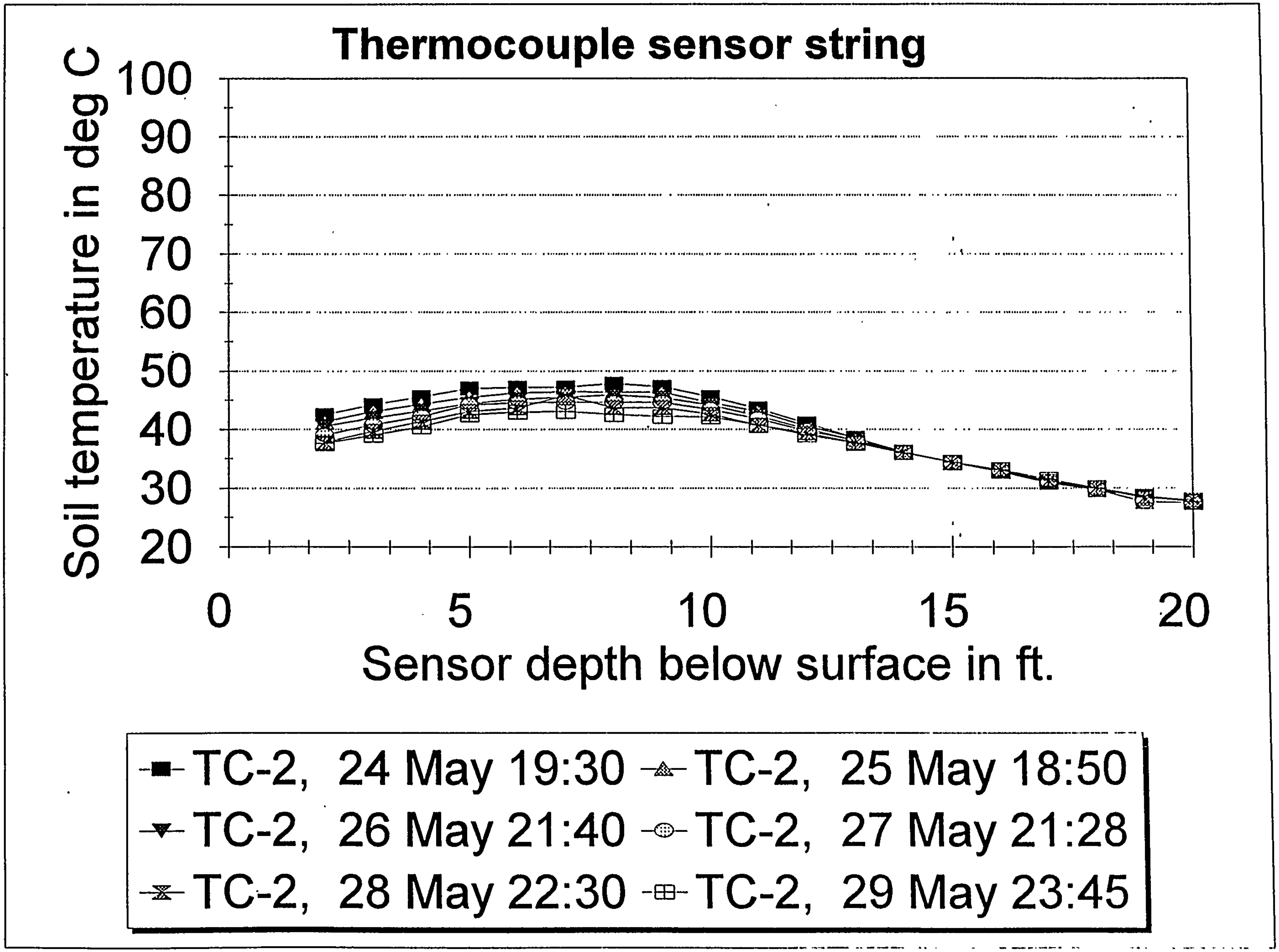

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-1, 24 May 19:30
TC-1, 25 May 18:50
TC-1, 26 May 21:40
TC-1, 27 May 21:28
TC-1, 28 May 22:30
TC-1, 29 May 23:45

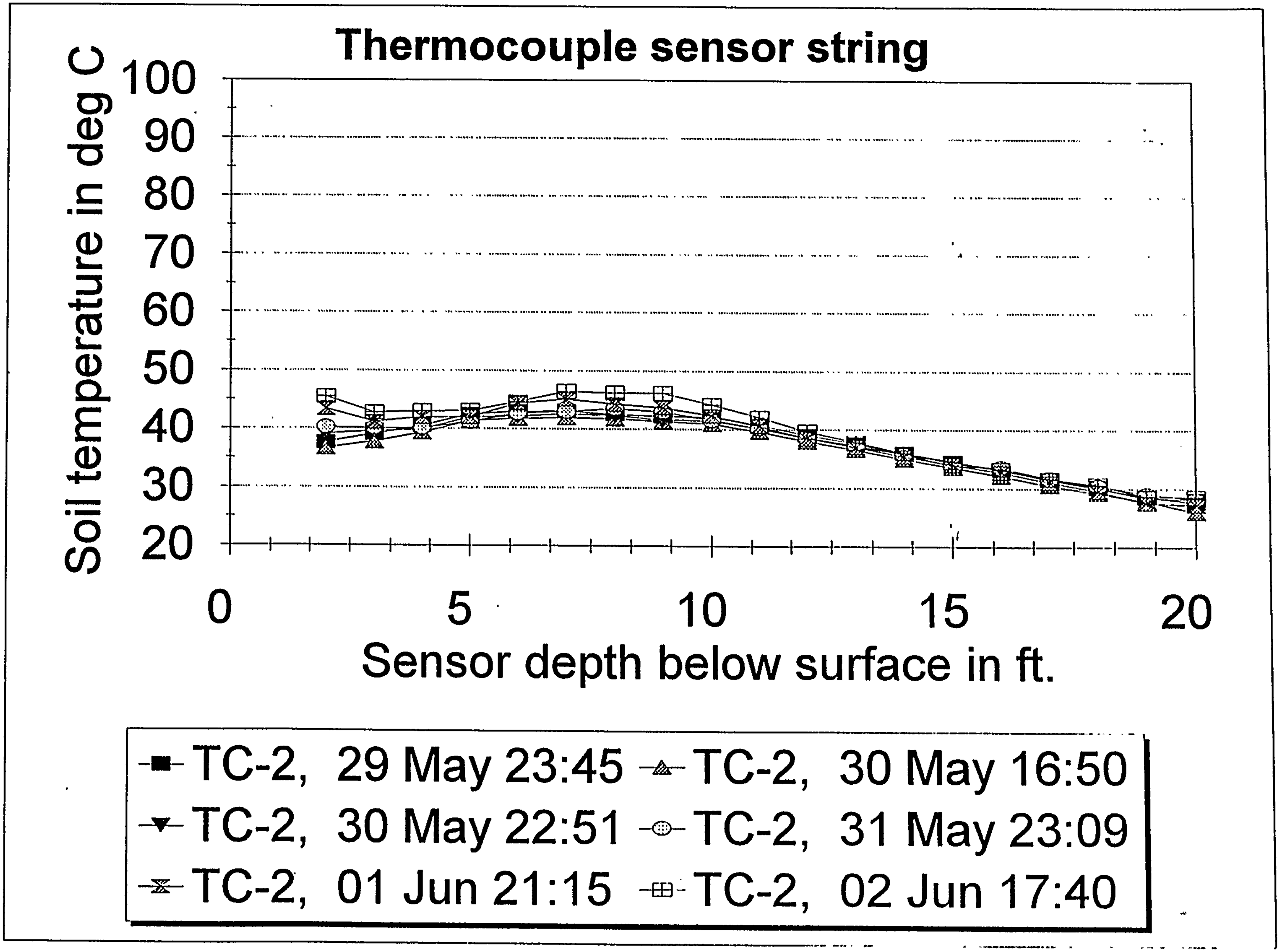

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-1, 29 May 23:45
TC-1, 30 May 16:50
TC-1, 30 May 22:51
TC-1, 31 May 23:09
TC-1, 01 Jun 21:15
TC-1, 02 Jun 17:40

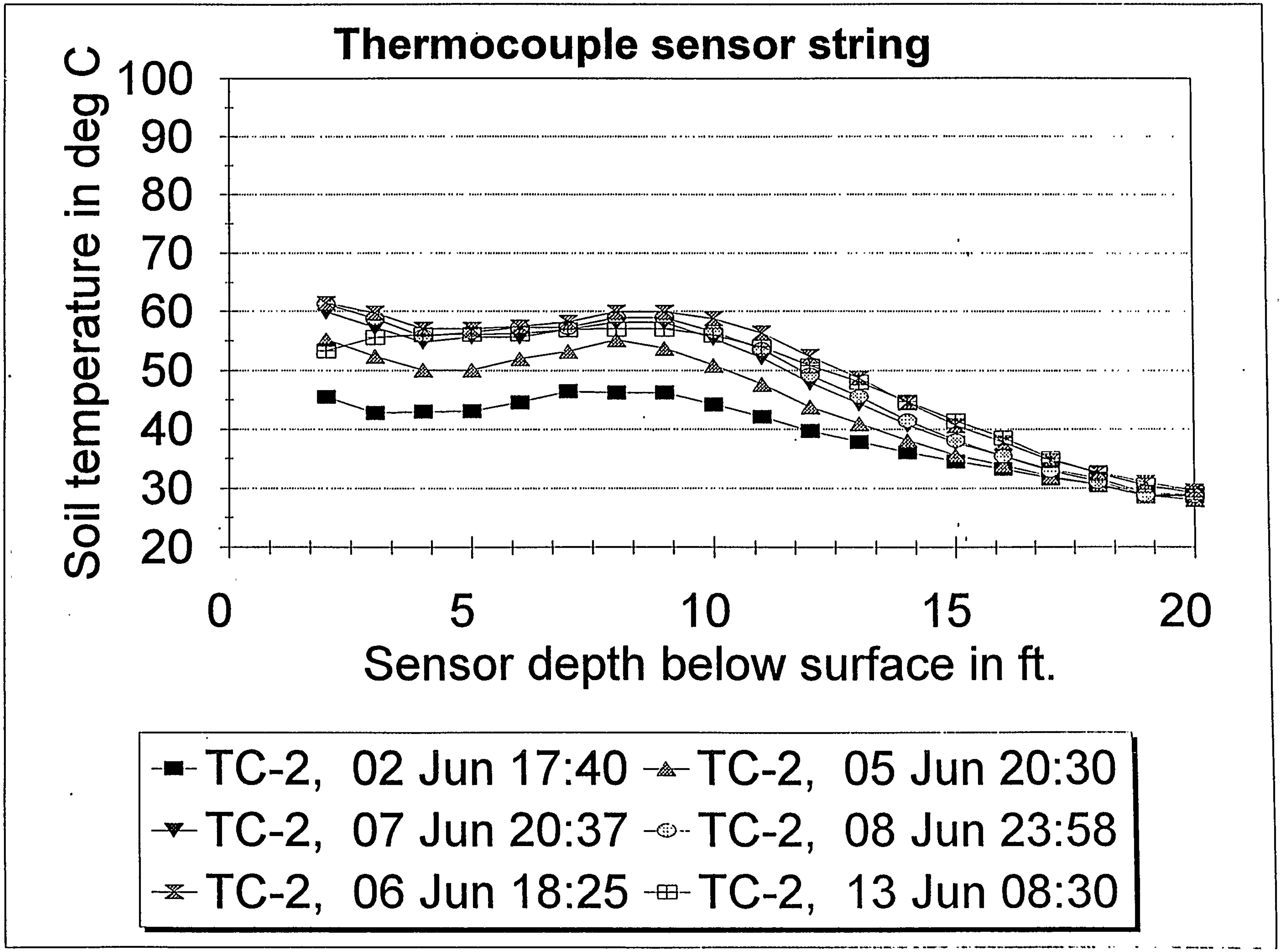

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-1, 02 Jun 17:40
TC-1, 05 Jun 20:30
TC-1, 07 Jun 20:37
TC-1, 08 Jun 23:58
TC-1, 06 Jun 18:25
TC-1, 13 Jun 08:30

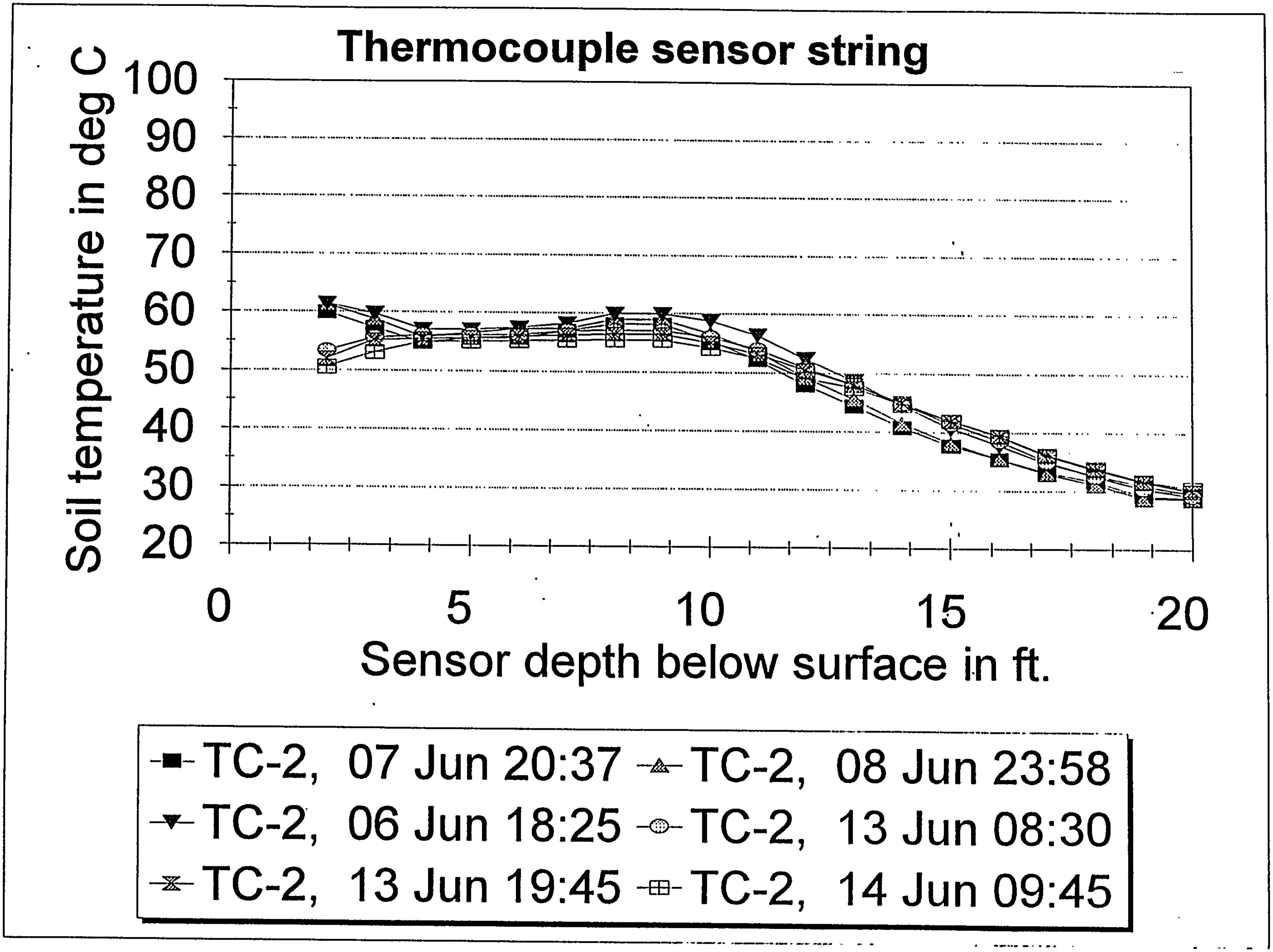

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-1, 07 Jun 20:37
TC-1, 08 Jun 23:58
TC-1, 06 Jun 18:25
TC-1, 13 Jun 08:30
TC-1, 13 Jun 19:45
TC-1, 14 Jun 09:45

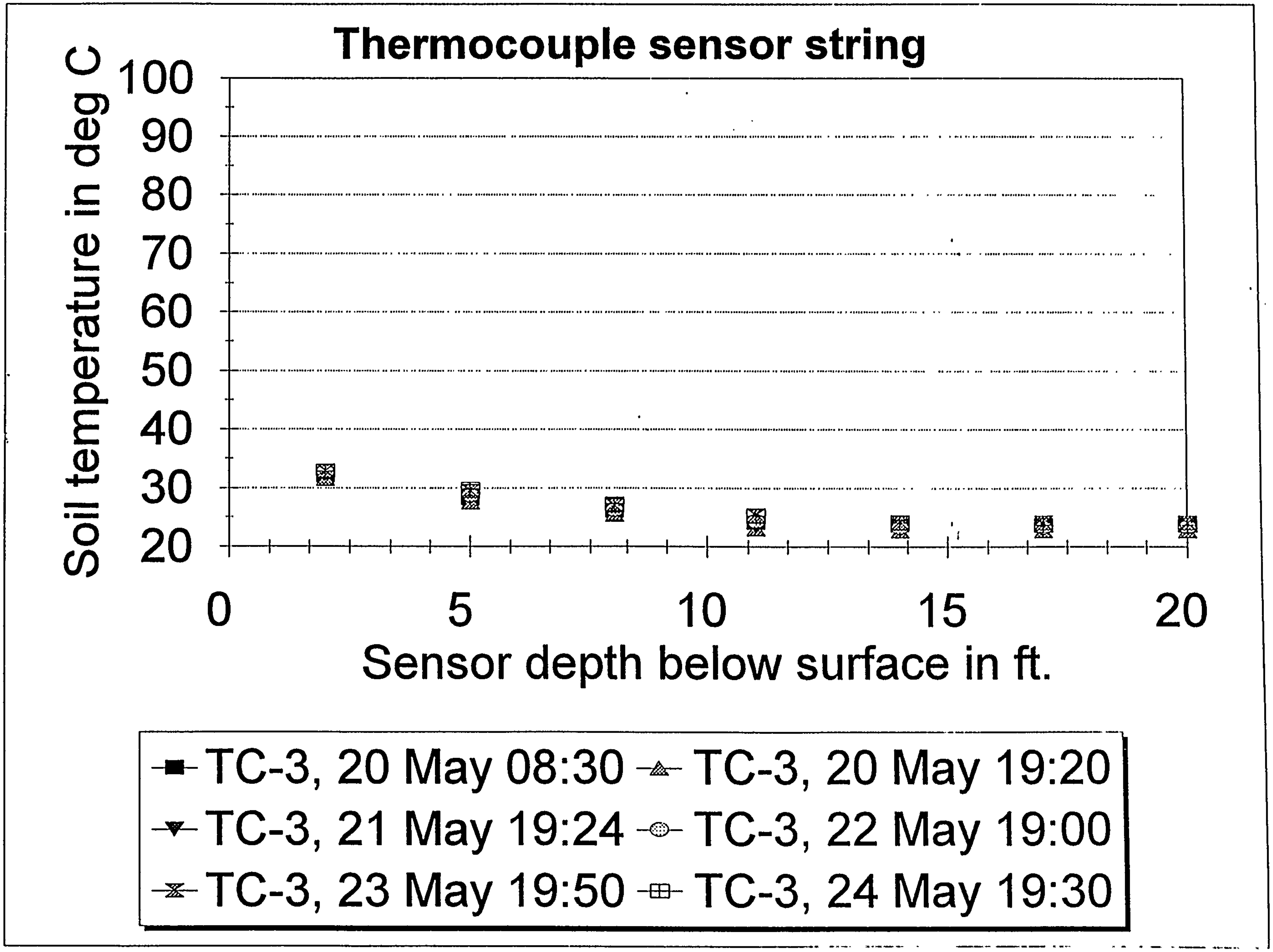

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-2, 20 May 08:30
TC-2, 20 May 19:20
TC-2, 21 May 19:24
TC-2, 22 May 19:00
TC-2, 23 May 19:50
TC-2, 24 May 19:30

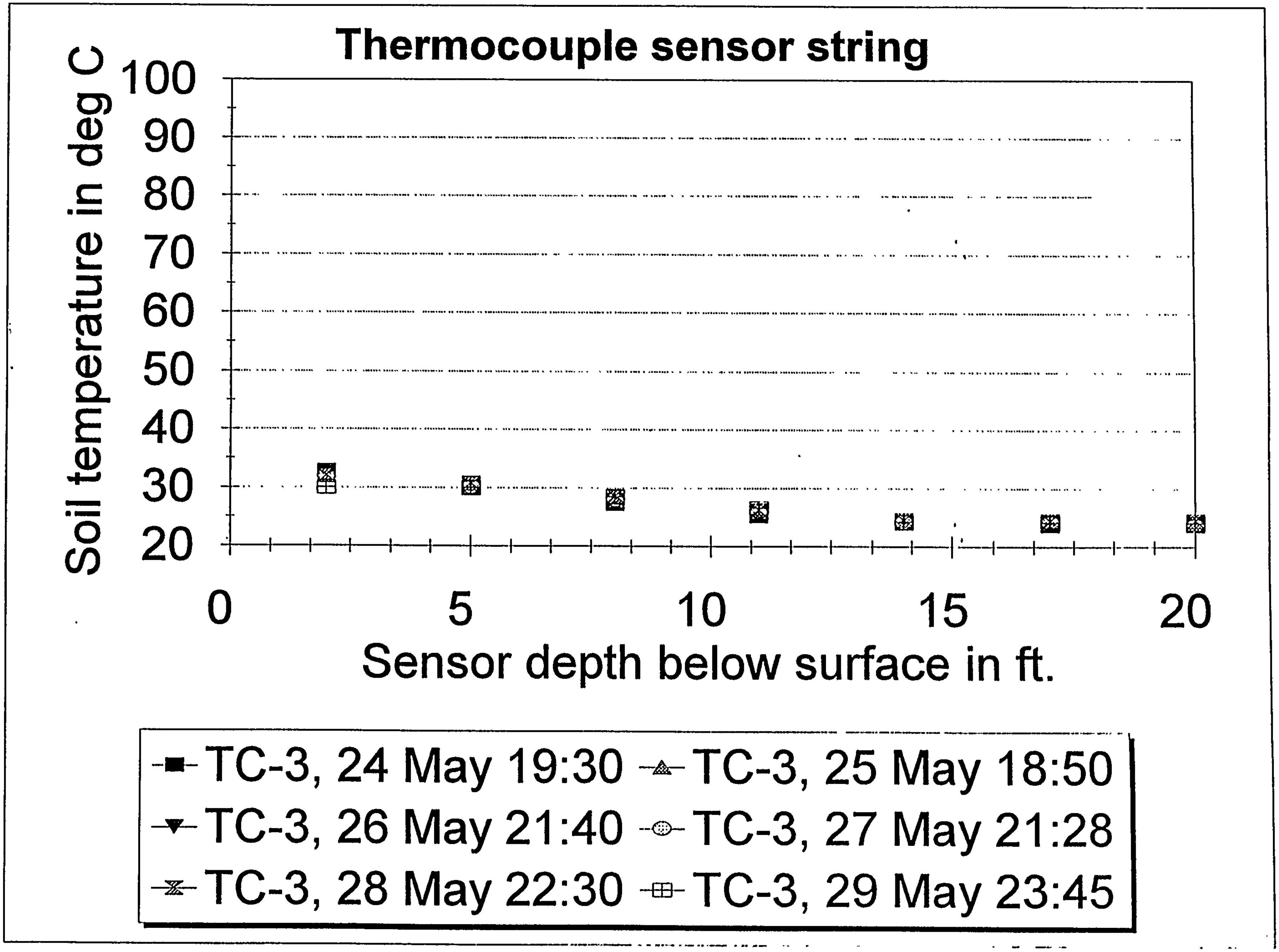

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-2, 24 May 19:30
TC-2, 25 May 18:50
TC-2, 26 May 21:40
TC-2, 27 May 21:28
TC-2, 28 May 22:30
TC-2, 29 May 23:45

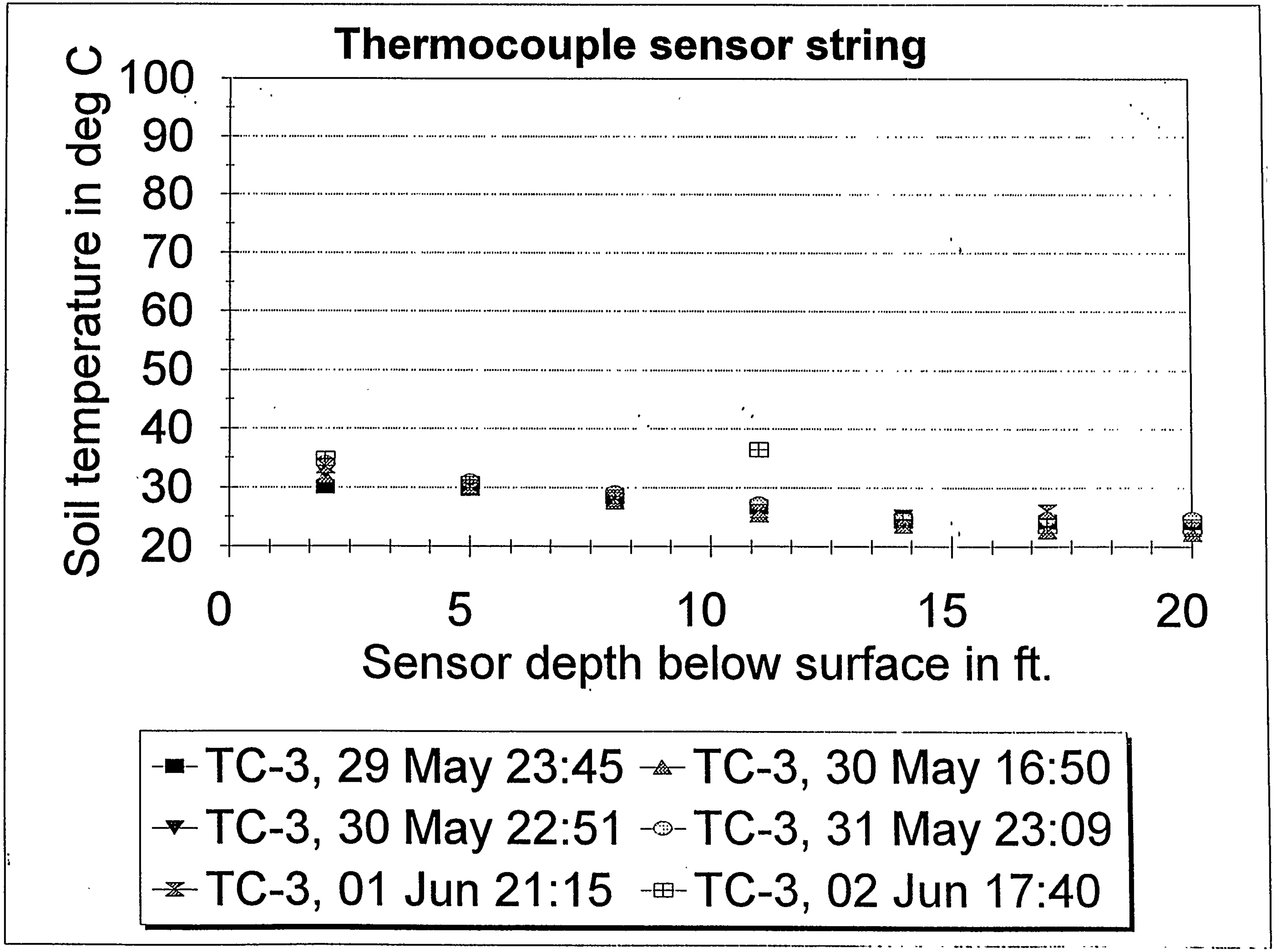

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-2, 29 May 23:45
TC-2, 30 May 16:50
TC-2, 30 May 22:51
TC-2, 31 May 23:09
TC-2, 01 Jun 21:15
TC-2, 02 Jun 17:40


Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-2, 02 Jun 17:40
TC-2, 05 Jun 20:30
TC-2, 07 Jun 20:37
TC-2, 08 Jun 23:58
TC-2, 06 Jun 18:25
TC-2, 13 Jun 08:30

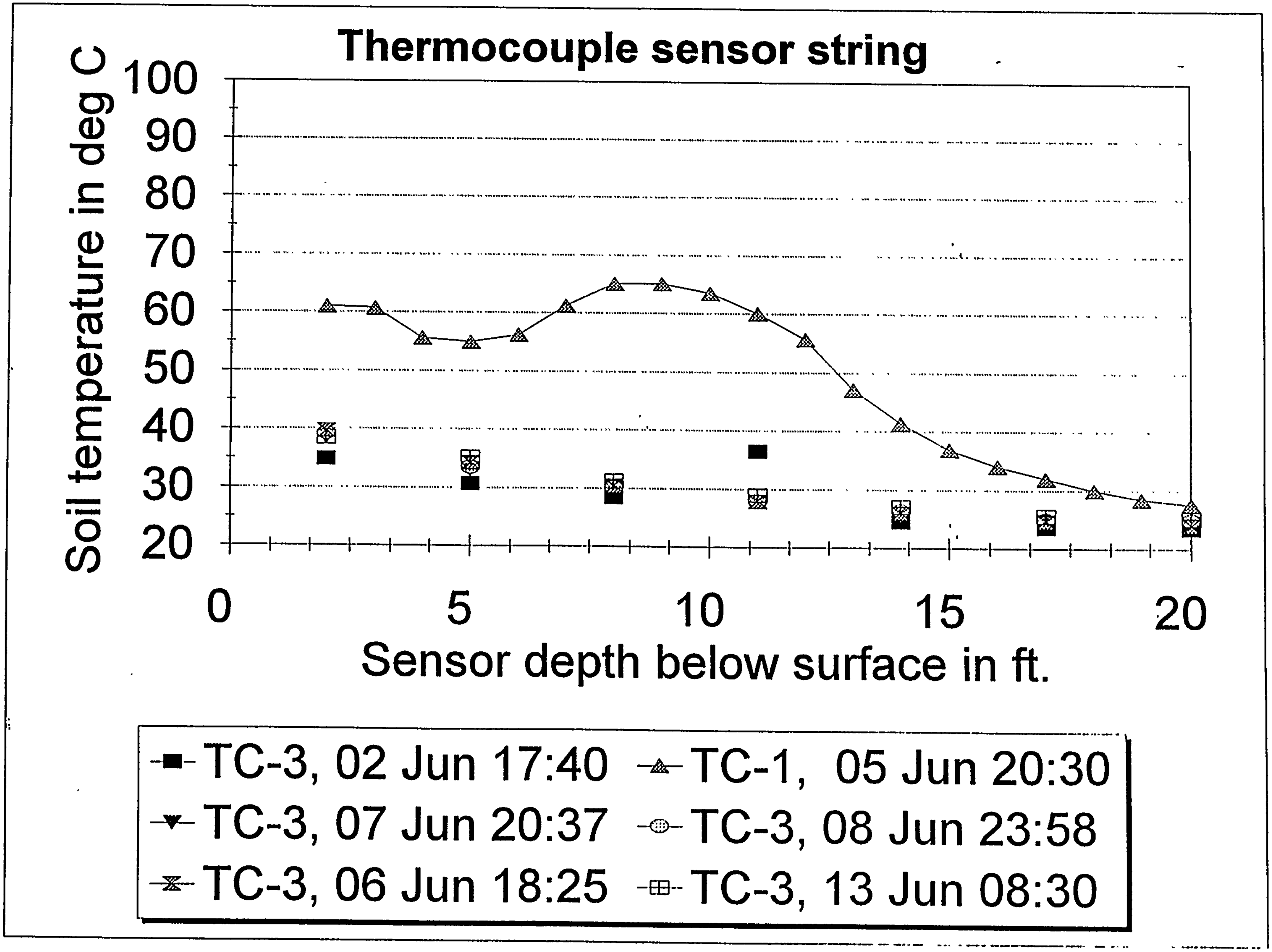

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-2, 07 Jun 20:37
TC-2, 08 Jun 23:58
TC-2, 06 Jun 18:25
TC-2, 13 Jun 08:30
TC-2, 13 Jun 19:45
TC-2, 14 Jun 09:45

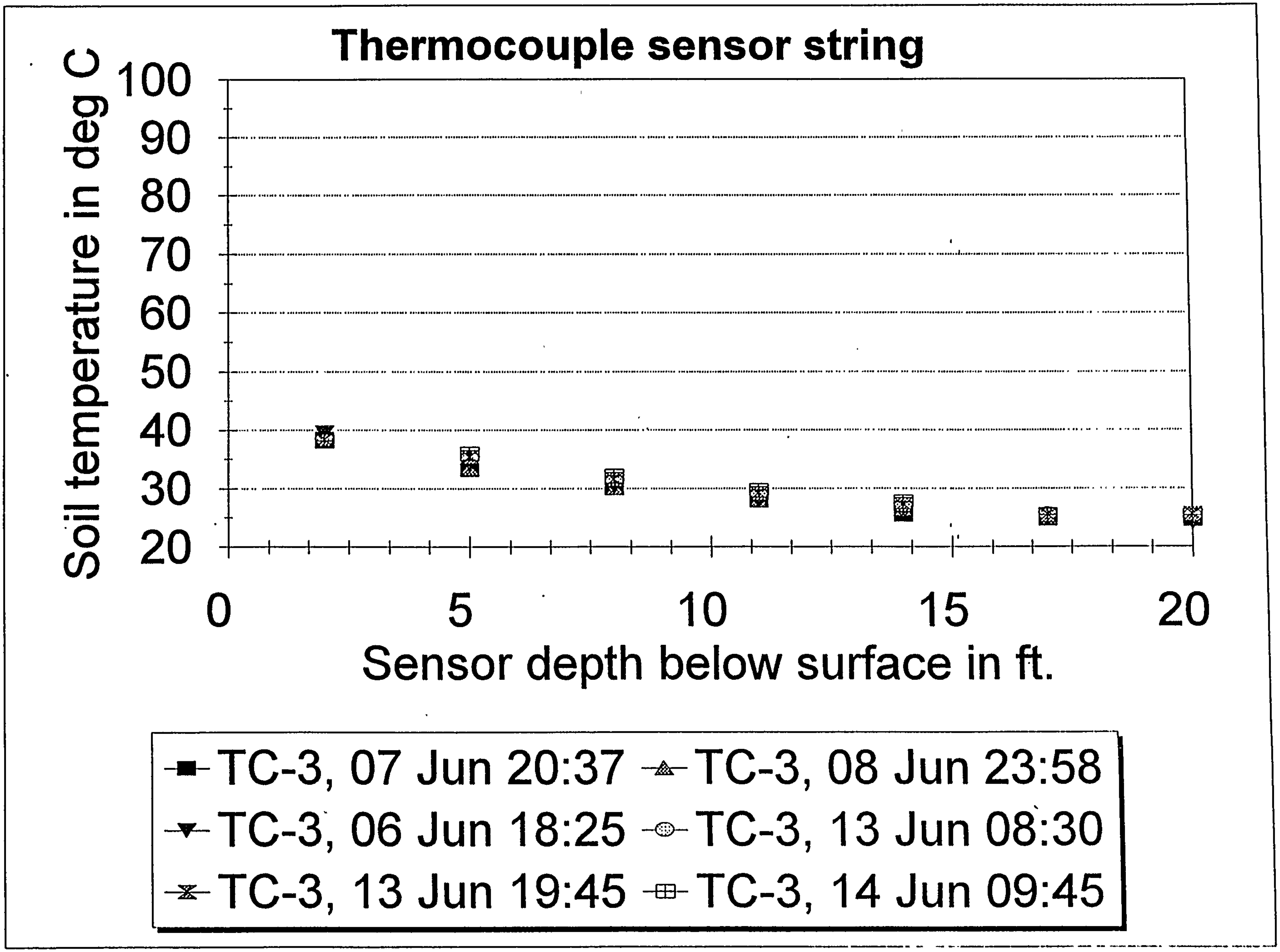

Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-3, 20 May 08:30
TC-3, 20 May 19:20
TC-3, 21 May 19:24
TC-3, 22 May 19:00
TC-3, 23 May 19:50
TC-3, 24 May 19:30


Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-3, 24 May 19:30
TC-3, 25 May 18:50
TC-3, 26 May 21:40
TC-3, 27 May 21:28
TC-3, 28 May 22:30
TC-3, 29 May 23:45



Thermocouple sensor string


Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-3, 02 Jun 17:40
TC-1, 05 Jun 20:30
TC-3, 07 Jun 20:37
TC-3, 08 Jun 23:58
TC-3, 06 Jun 18:25
TC-3, 13 Jun 08:30


Thermocouple sensor string
Soil temperature in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Sensor depth below surface in ft.
TC-3, 07 Jun 20:37
TC-3, 08 Jun 23:58
TC-3, 06 Jun 18:25
TC-3, 13 Jun 08:30
TC-3, 13 Jun 19:45
TC-3, 14 Jun 09:45

APPENDIX F - Temperature Profiles Using An IR Probe
Infrared probe measurements

NOTE: All IR temperature plots are labeled "UNCORRECTED" to alert the reviewer to both the fact that the probe is not a liner, absolute calibration device and because these measurements must be considered within the context of air flow around the wall of the borehole being measured.

- Measurement plots of F2 and F5 were clustered about heating borehole liner A2. This liner, A2 was the first heating location. The borehole was loaded with Applicator #1 on heating channel #1.

  Plot F2 over a 7 to 77 day span - All depths
  Plot F5 over a 7 to 77 day span - All depths

  Plot F2 over a 7 to 77 day span at 5 depths
  Plot F5 over a 7 to 77 day span at 5 depths (100 deg C scale)
  Plot F5 over a 7 to 77 day span at 5 depths (130 deg C scale)

  F2 Temperature profiles - 24 May to 29 May
  F2 Temperature profiles - 29 May to 02 June
  F2 Temperature profiles - 02 June to 13 June
  F2 Temperature profiles - 05 June to 24 June

  F5 Temperature profiles - 24 May to 29 May
  F5 Temperature profiles - 29 May to 02 June
  F5 Temperature profiles - 02 June to 13 June
  F5 Temperature profiles - 05 June to 24 June

- Measurement plots of F1 and F4 were clustered about heating borehole liner A1. This liner, A1 was the second heating location. The borehole was loaded with Applicator #2 on heating channel #2.

  Plot F1 over a 7 to 77 day span - All depths
  Plot F4 over a 7 to 77 day span - All depths

  Plot F1 over a 7 to 77 day span at 5 depths
  Plot F4 over a 7 to 77 day span at 5 depths

  F1 Temperature profiles - 24 May to 29 May
  F1 Temperature profiles - 29 May to 02 June
  F1 Temperature profiles - 02 June to 13 June
  F1 Temperature profiles - 05 June to 24 June

  F4 Temperature profiles - 24 May to 29 May
  F4 Temperature profiles - 29 May to 02 June
  F4 Temperature profiles - 02 June to 13 June
  F4 Temperature profiles - 05 June to 24 June

- Measurement plots of F3 were associated with the heating from liner locations A2 and A1.

  Plot F3 over a 7 to 77 day span - All depths
  Plot F3 over a 7 to 77 day span - at 5 depths

  F3 Temperature profiles - 24 May to 29 May

F3 Temperature profiles - 29 May to 02 June
F3 Temperature profiles - 02 June to 13 June
F3 Temperature profiles - 05 June to 24 June

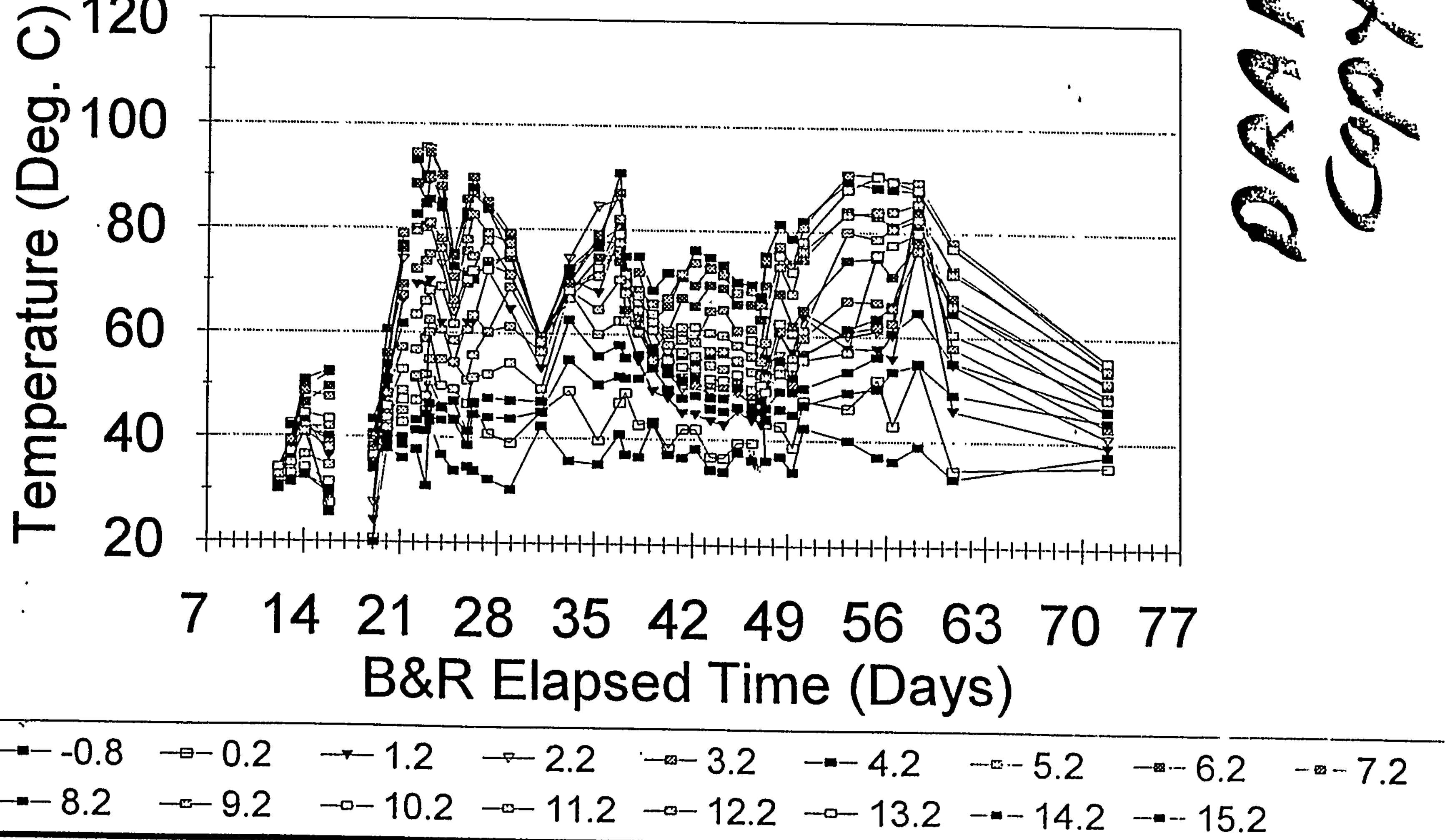
- Applicator well liner temperature profiles (Applicators are removed from well for periods of 15 minutes to several weeks after the RF energy is turned off). See Appendix B to determine delay from heating time for individual plots.

A2 Temperature profiles - 19 April to 10 June (Applicator #1)
A2 Temperature profiles - 23 April to 24 June (Applicator #1)

A1 Temperature profiles - 15 April to 24 June (Applicator #2)

END FILE: KELLYF.A

Infrared Measurements at F2
All Depths



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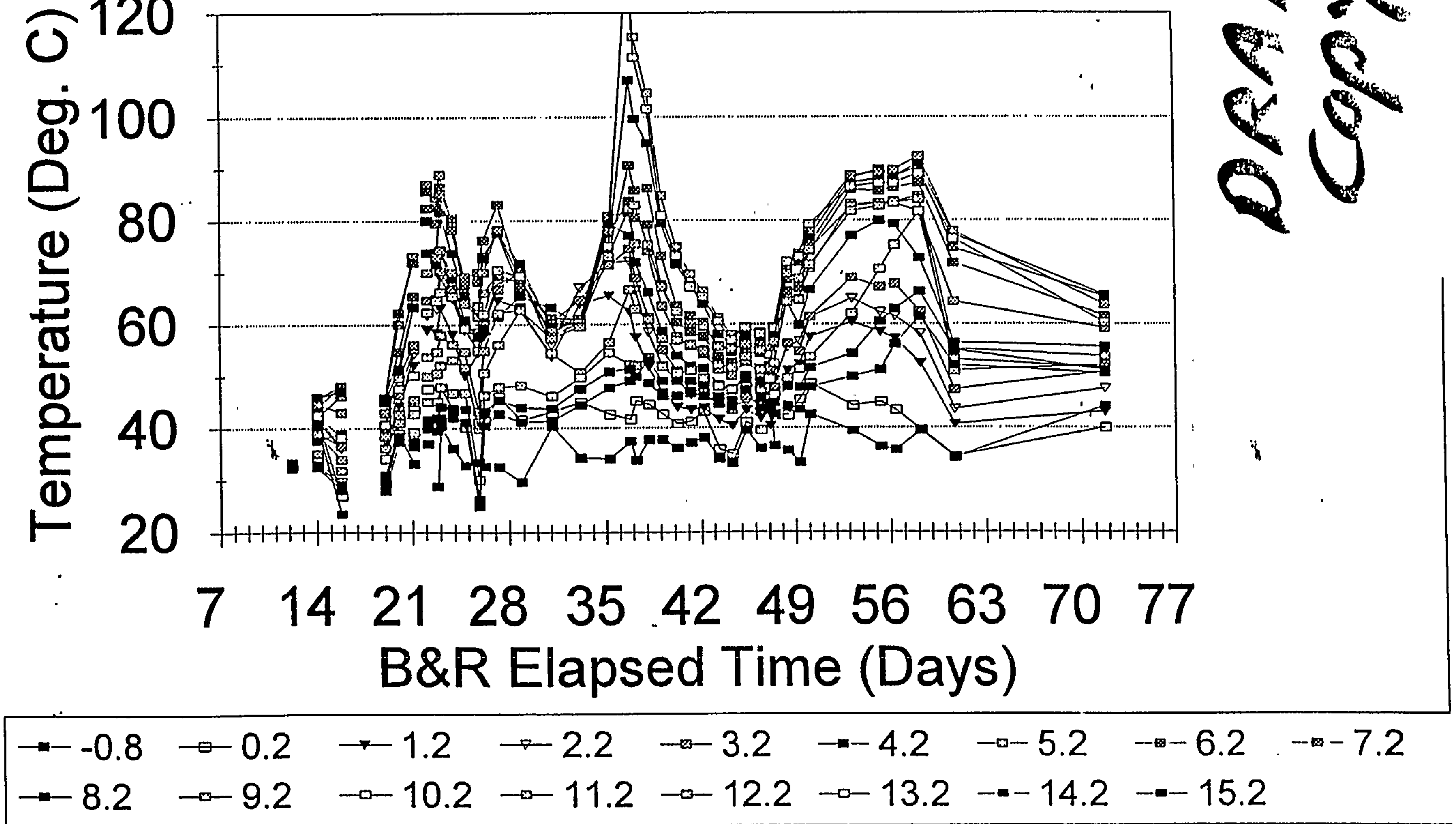
Infrared Measurements at F5
All Depths

DRAFT Copy



IR Sensor Profiles at F2

Five selected Depths

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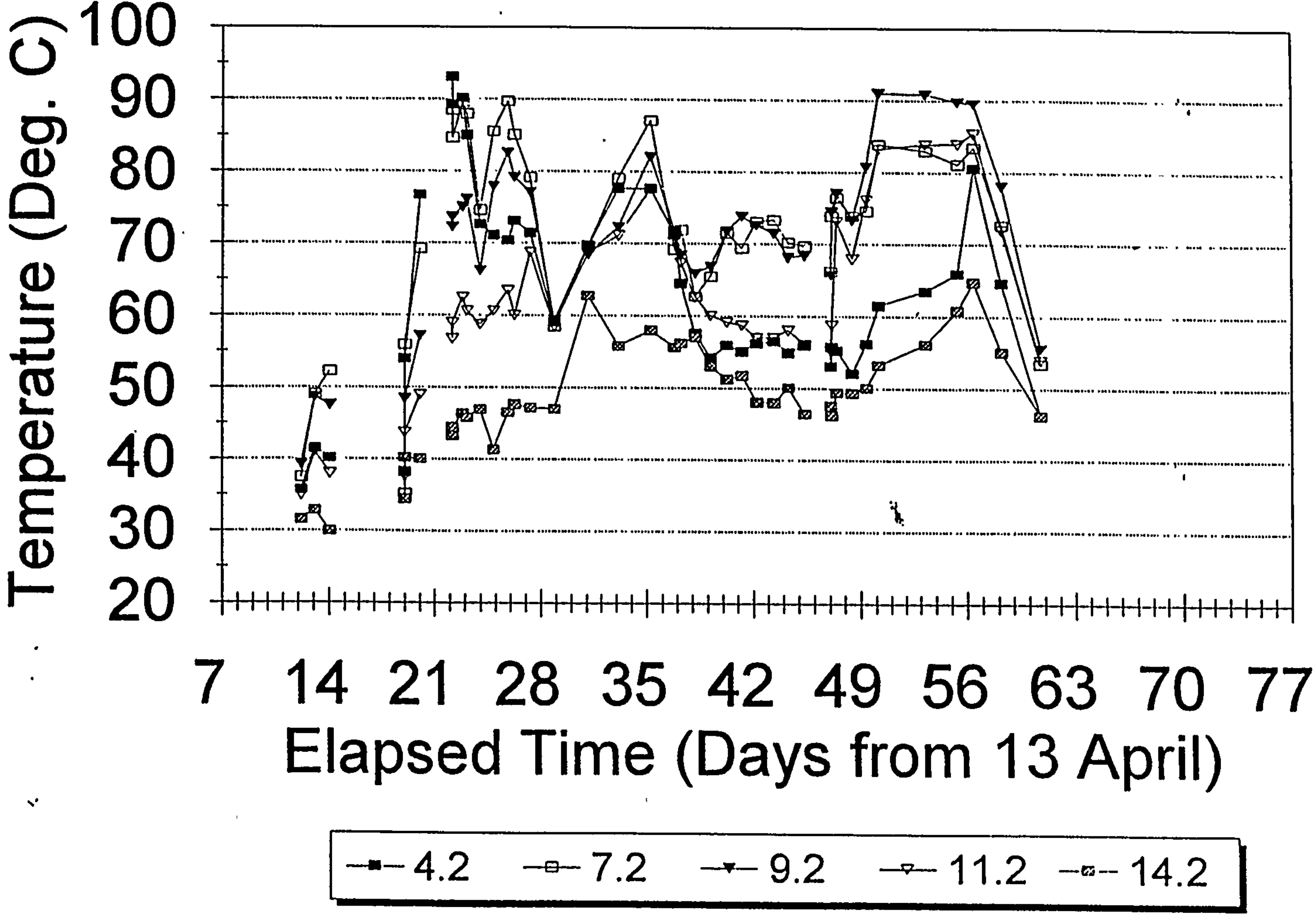
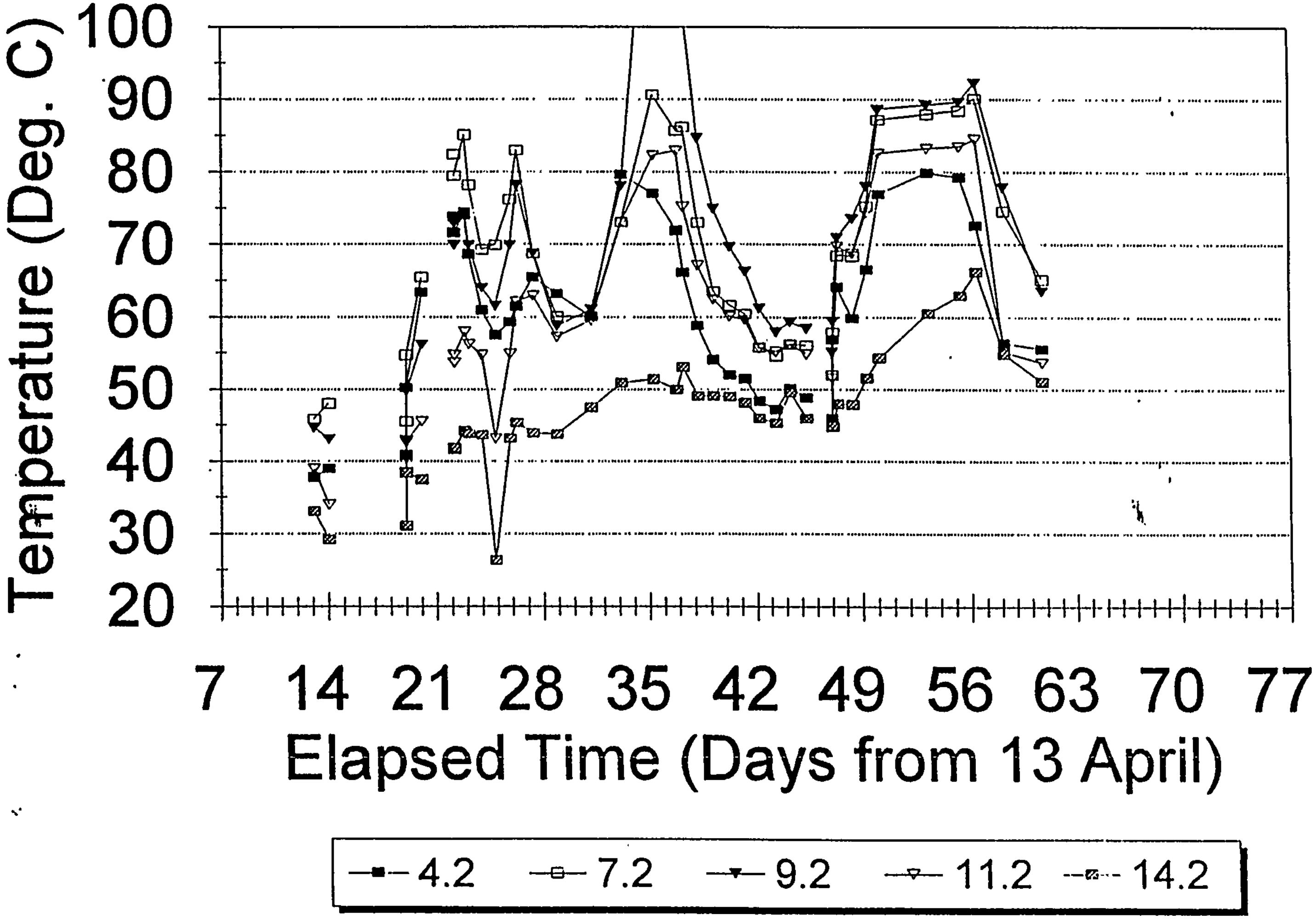


IR Sensor Profiles at F5
Five selected Depths



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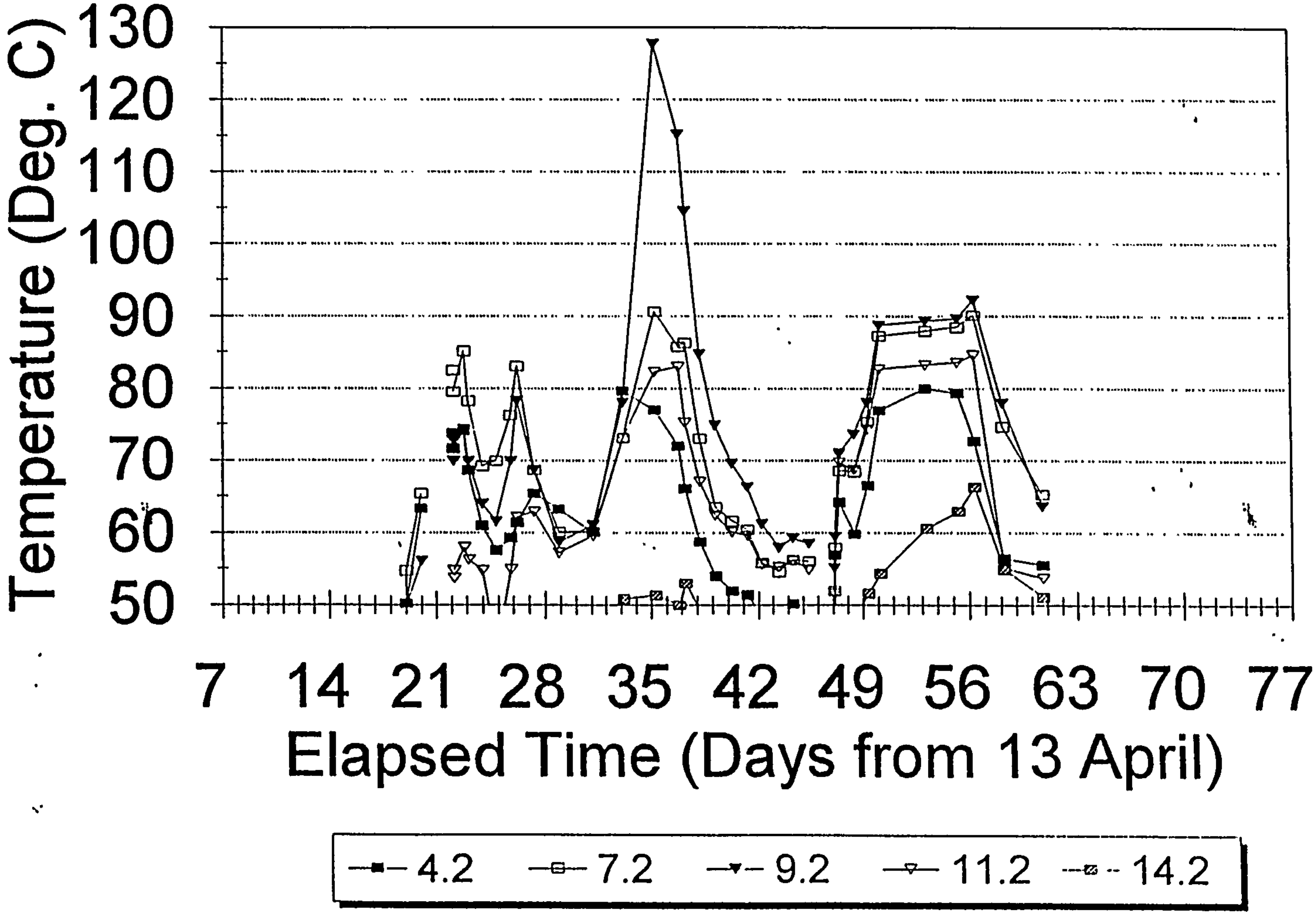
IR Sensor Profiles at F5

Five selected Depths



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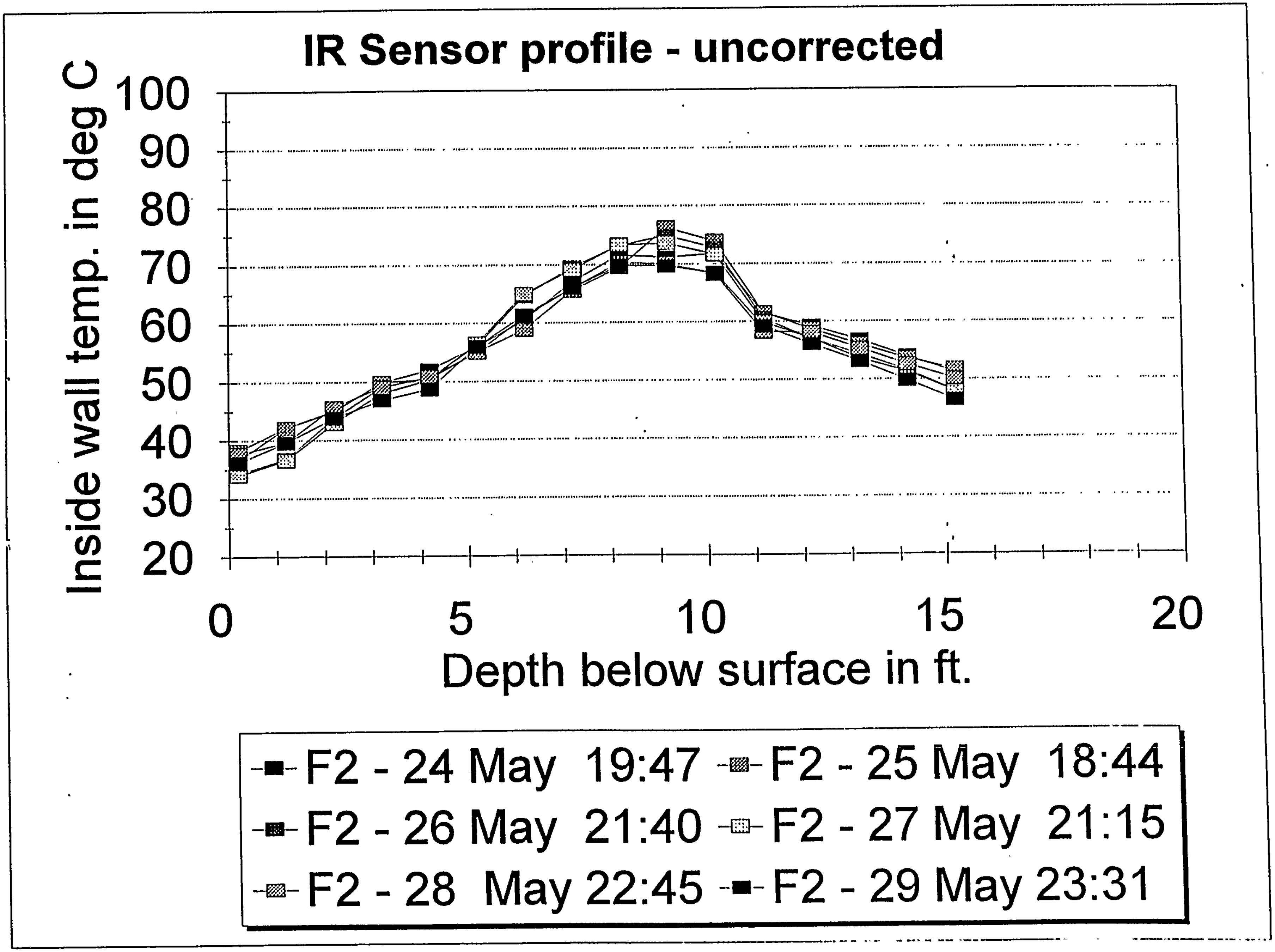
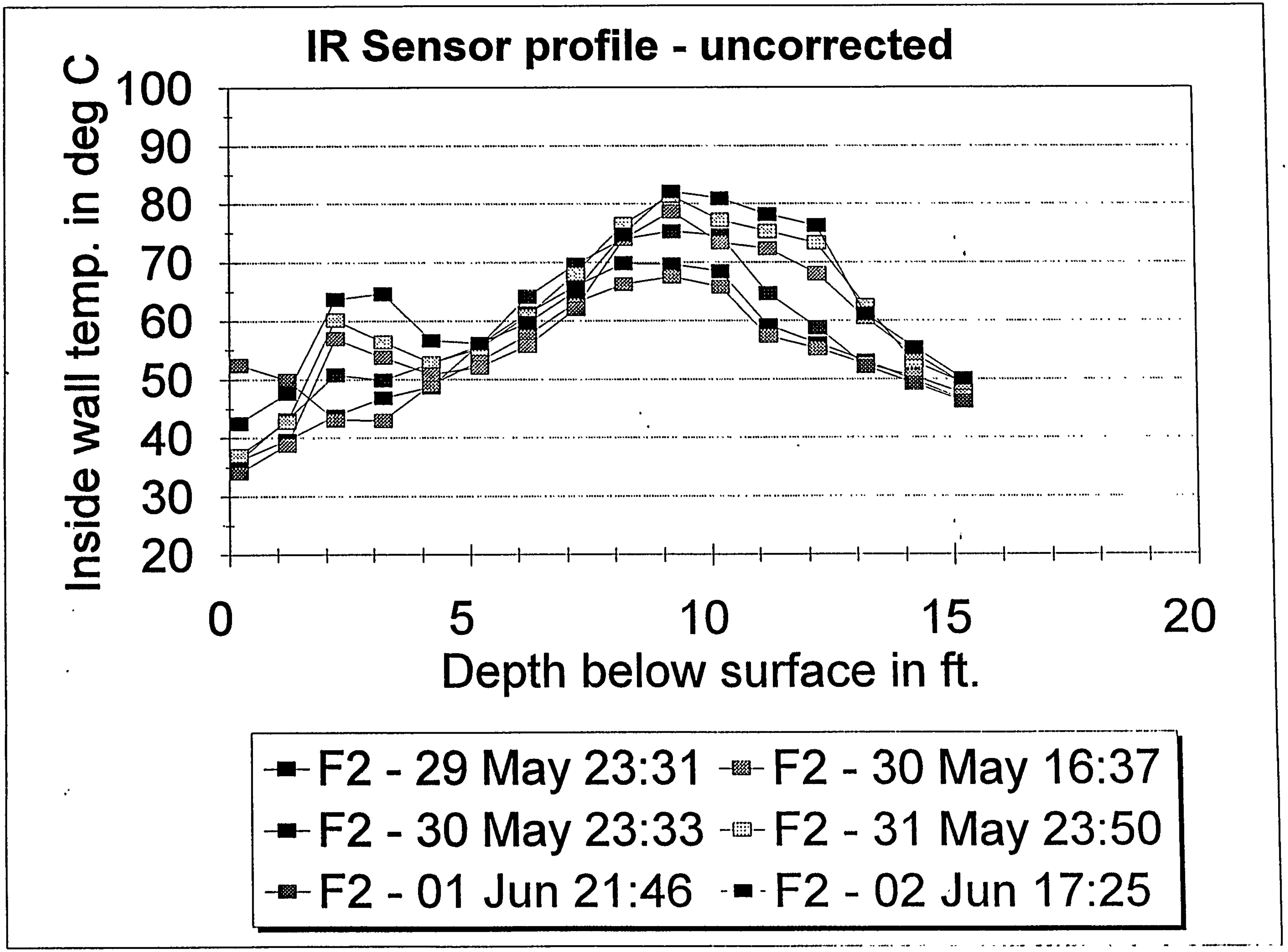
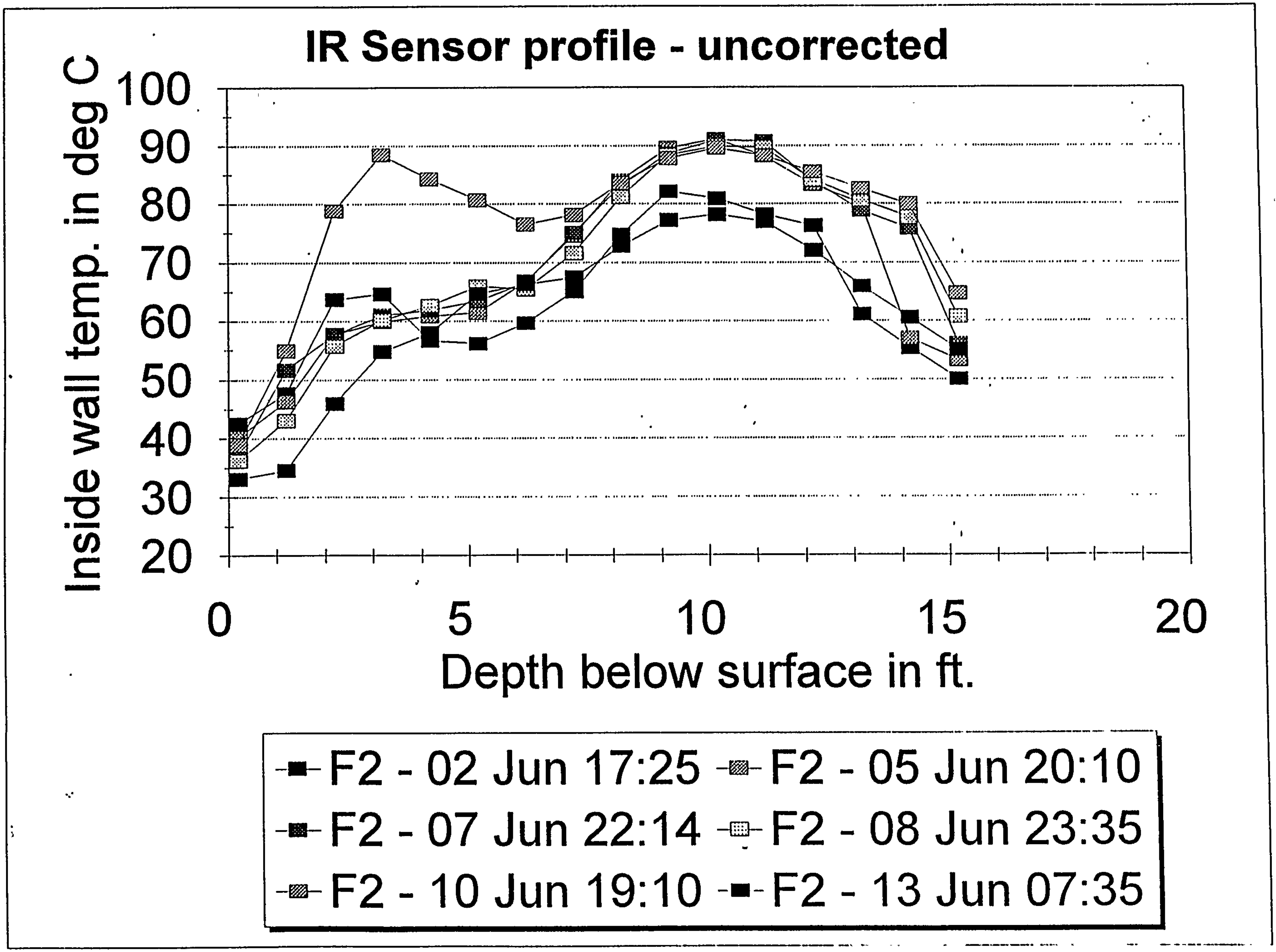
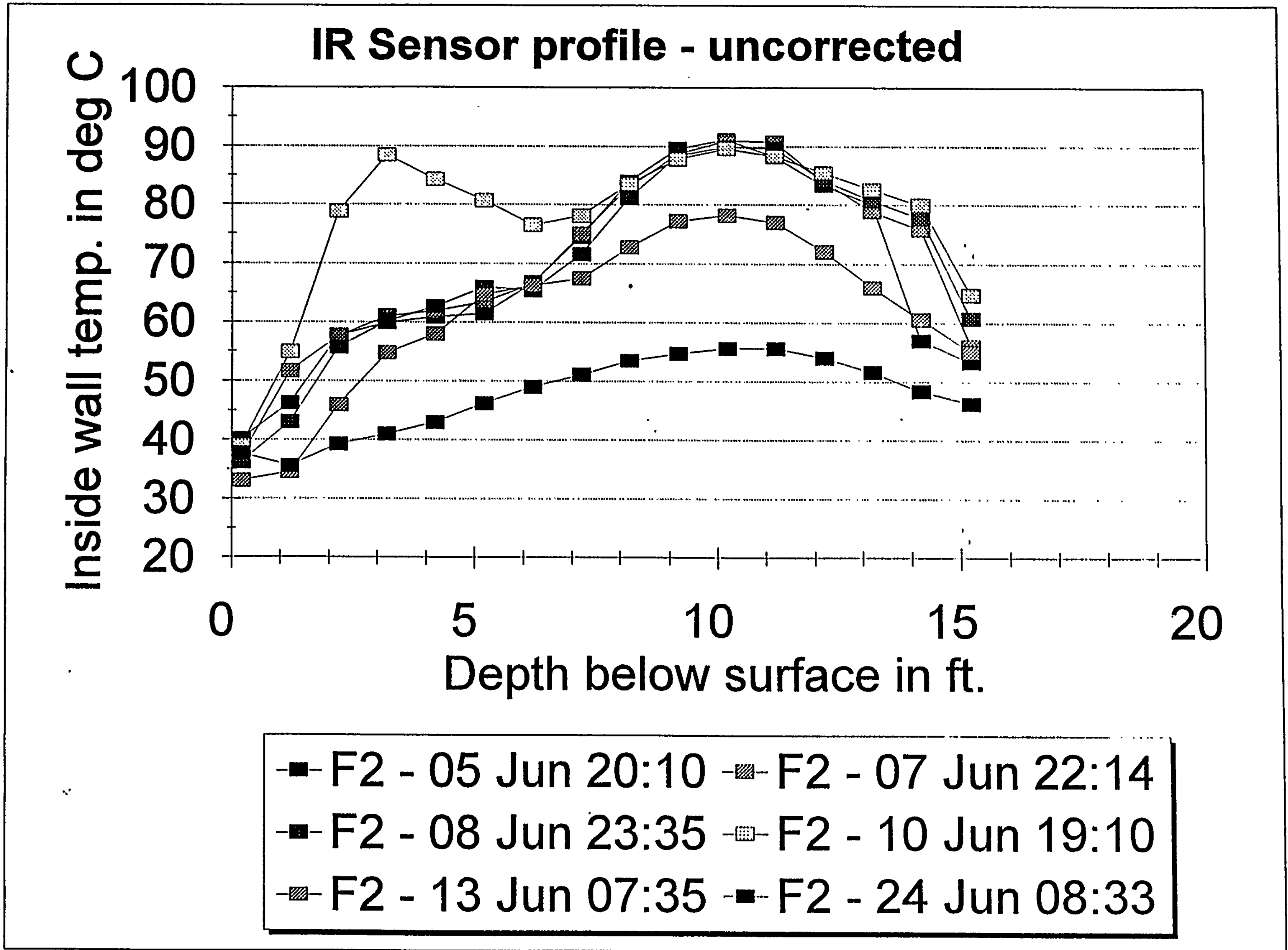
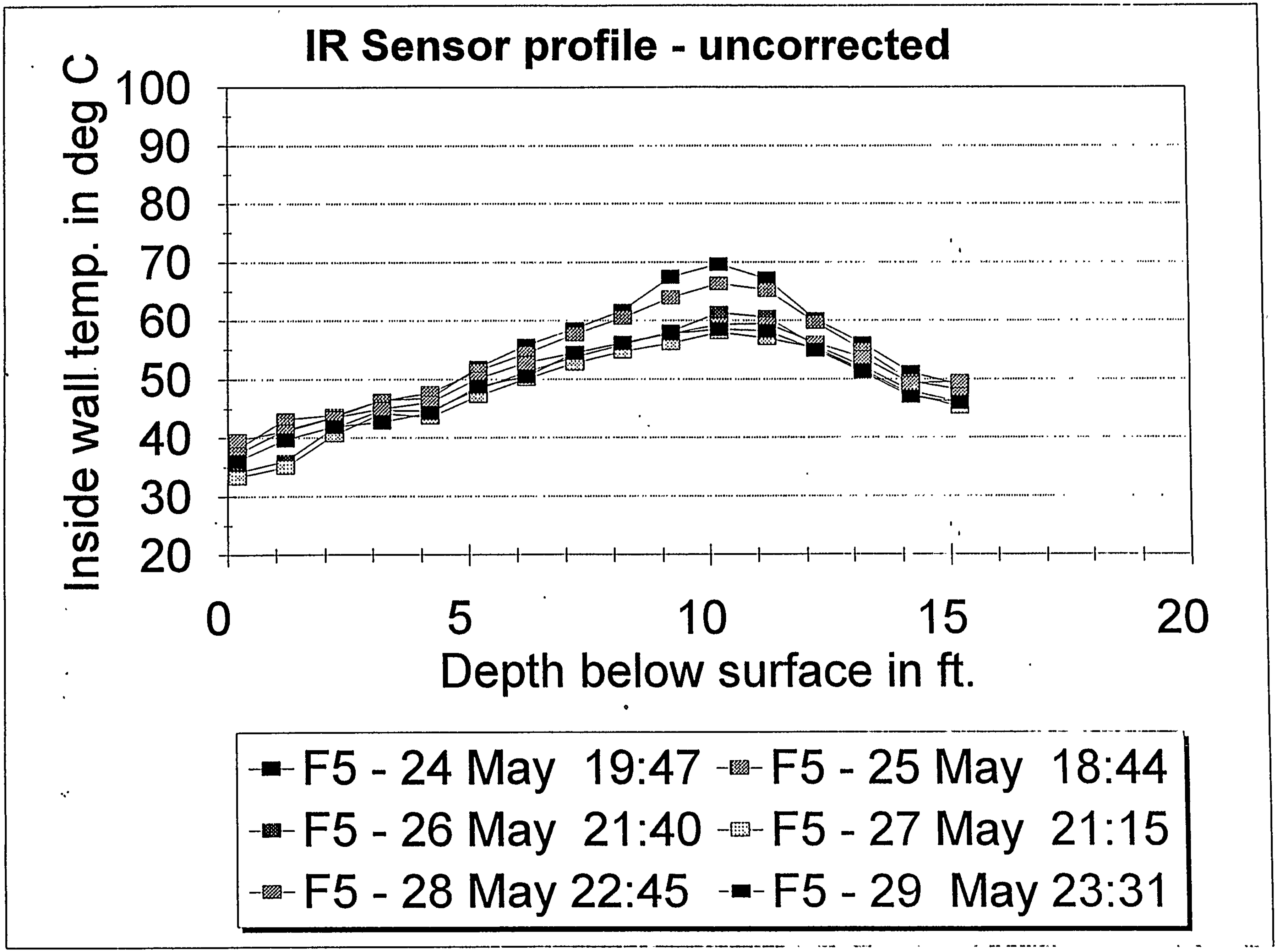
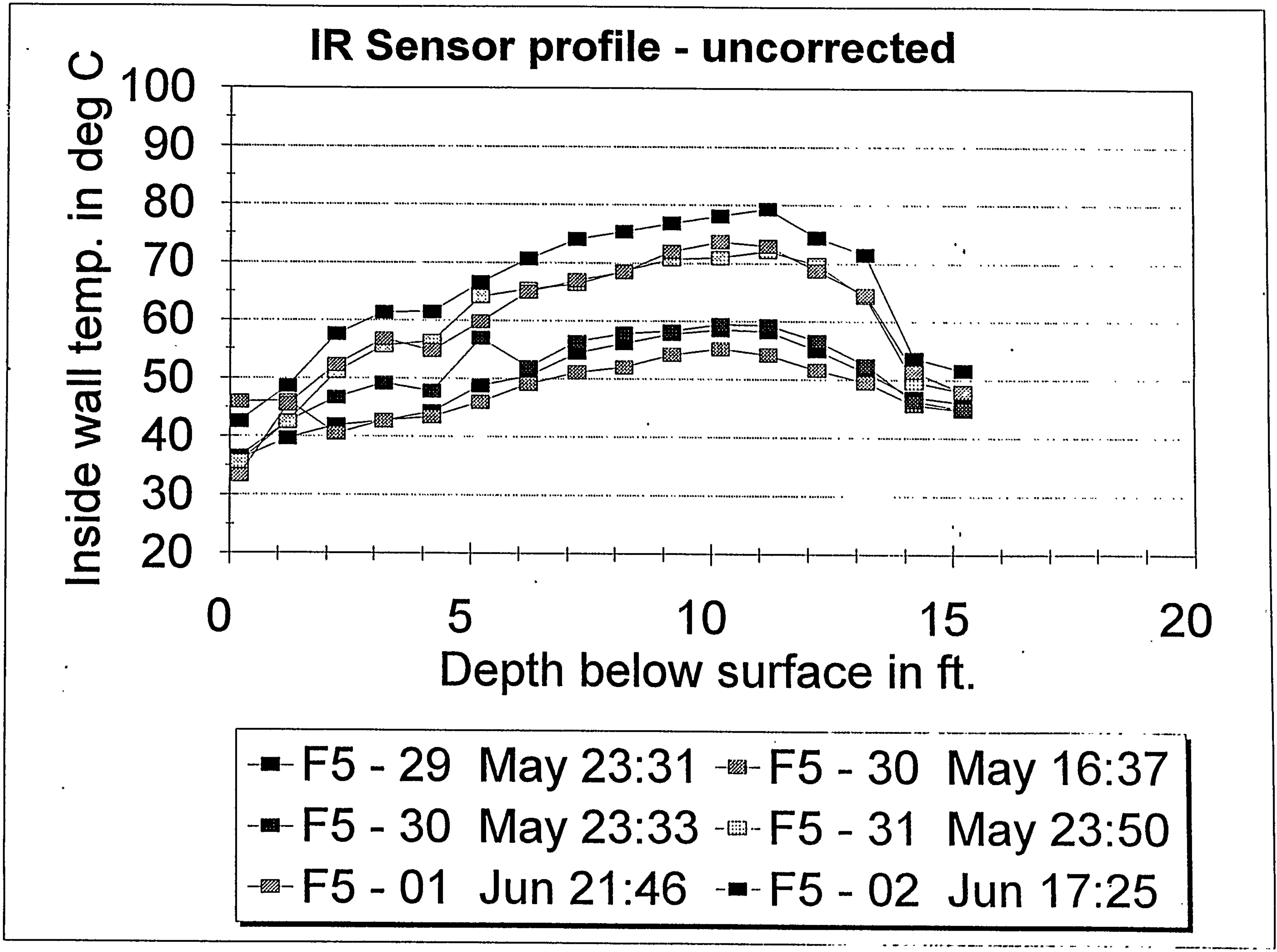
IR Sensor profile - uncorrected
Inside wall temp. in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Depth below surface in ft.
F2 - 24 May 19:47
F2 - 25 May 18:44
F2 - 26 May 21:40
F2 - 27 May 21:15
F2 - 28 May 22:45
F2 - 29 May 23:31

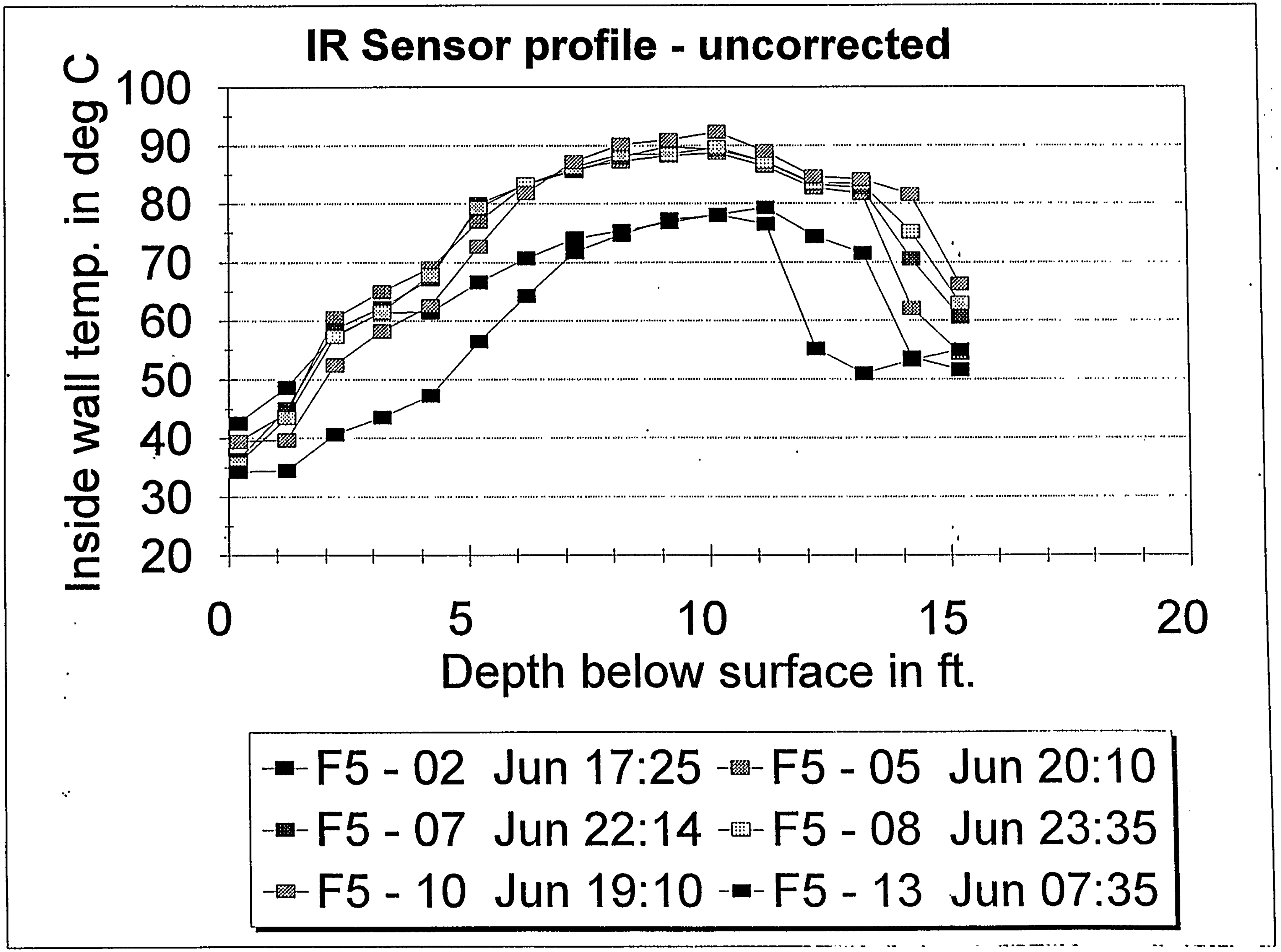

IR Sensor profile - uncorrected
Inside wall temp. in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Depth below surface in ft.
F2 - 29 May 23:31
F2 - 30 May 16:37
F2 - 30 May 23:33
F2 - 31 May 23:50
F2 - 01 Jun 21:46
F2 - 02 Jun 17:25

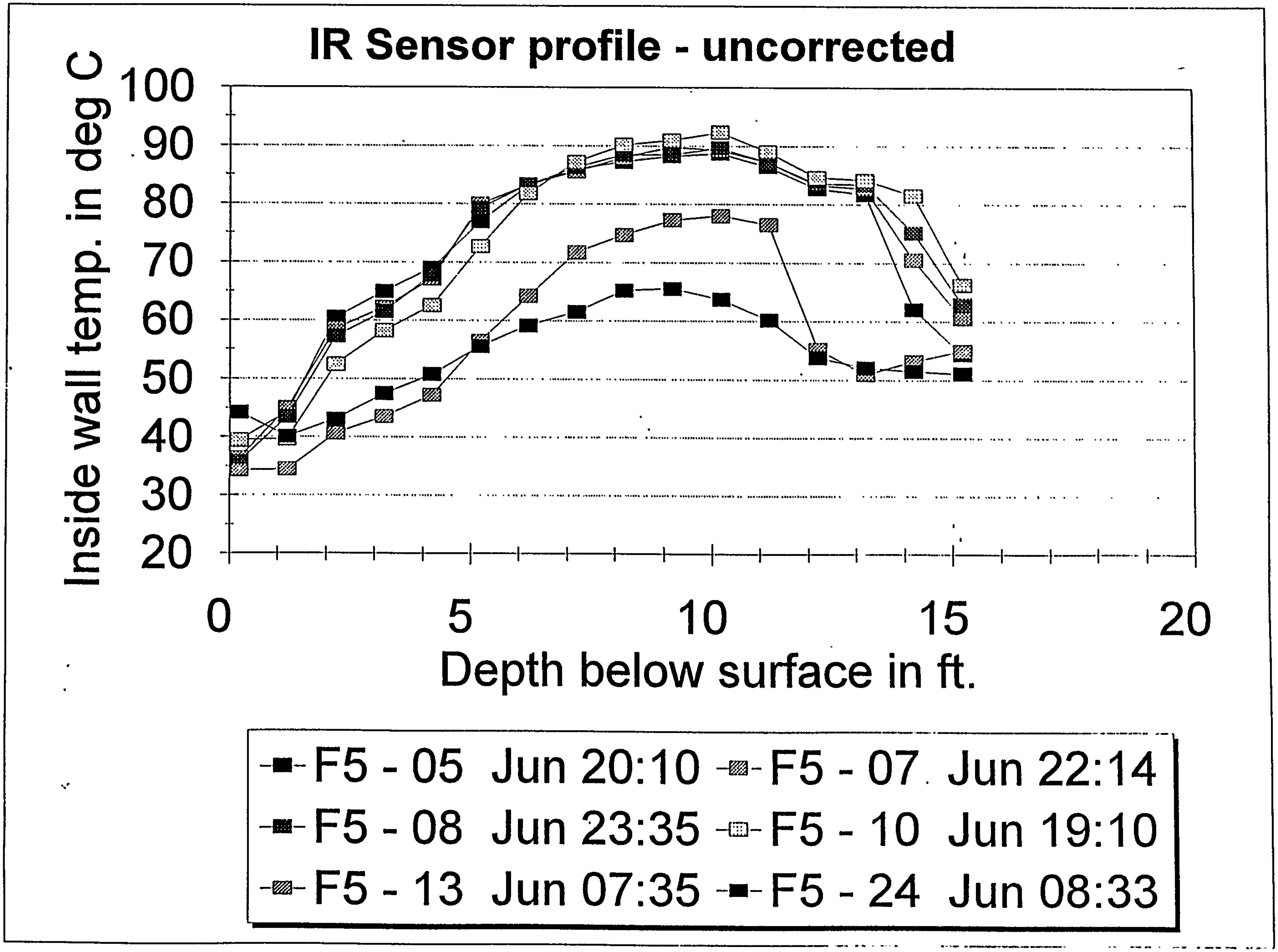

IR Sensor profile - uncorrected
Inside wall temp. in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Depth below surface in ft.
F2 - 02 Jun 17:25
F2 - 05 Jun 20:10
F2 - 07 Jun 22:14
F2 - 08 Jun 23:35
F2 - 10 Jun 19:10
F2 - 13 Jun 07:35


IR Sensor profile - uncorrected
Inside wall temp. in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Depth below surface in ft.
F2 - 05 Jun 20:10
F2 - 07 Jun 22:14
F2 - 08 Jun 23:35
F2 - 10 Jun 19:10
F2 - 13 Jun 07:35
F2 - 24 Jun 08:33


IR Sensor profile - uncorrected
Inside wall temp. in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Depth below surface in ft.
F5 - 24 May 19:47
F5 - 25 May 18:44
F5 - 26 May 21:40
F5 - 27 May 21:15
F5 - 28 May 22:45
F5 - 29 May 23:31


IR Sensor profile - uncorrected
Inside wall temp. in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Depth below surface in ft.
F5 - 29 May 23:31
F5 - 30 May 16:37
F5 - 30 May 23:33
F5 - 31 May 23:50
F5 - 01 Jun 21:46
F5 - 02 Jun 17:25


IR Sensor profile - uncorrected



IR Sensor profile - uncorrected

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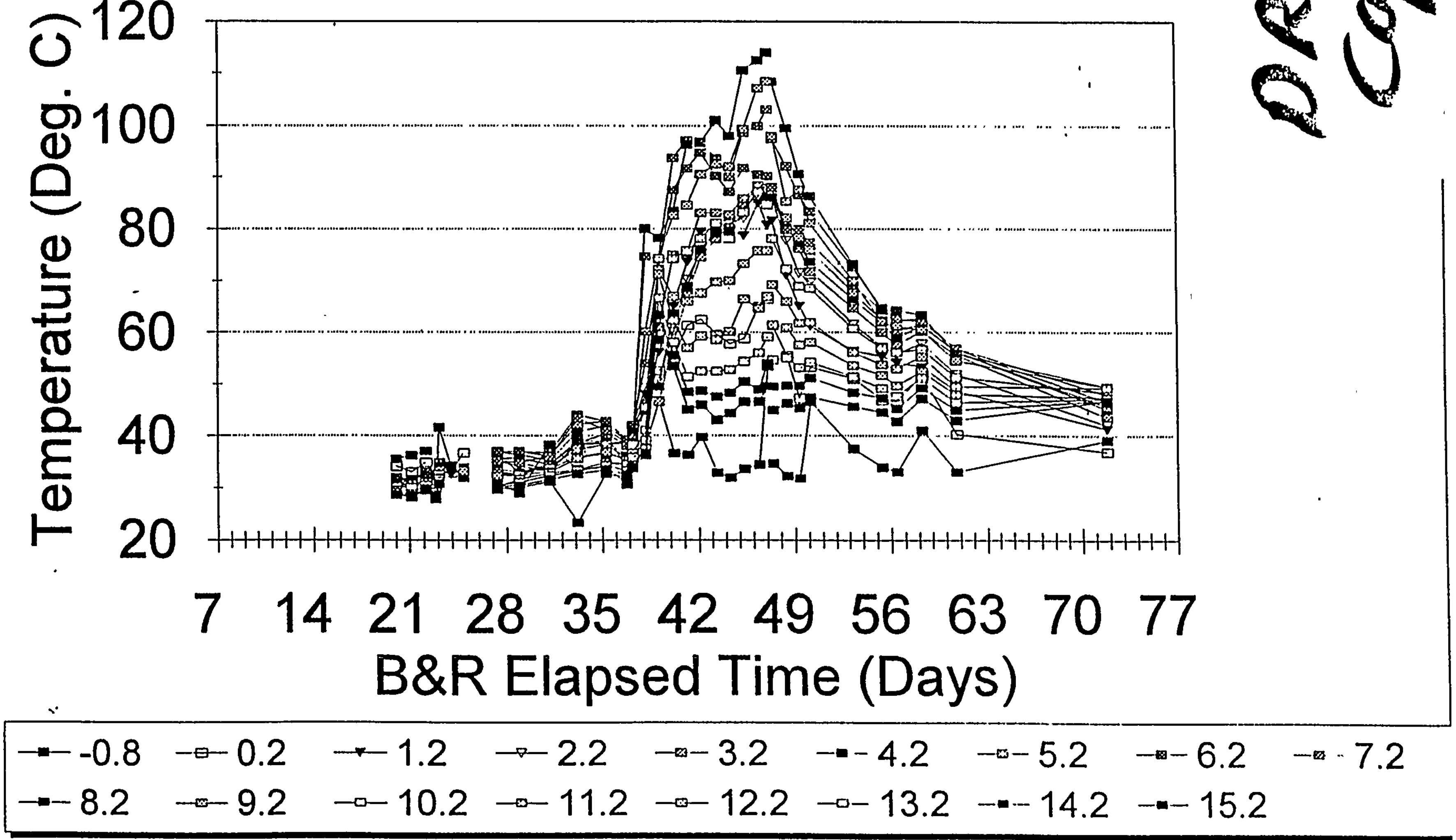
Infrared Measurements at F1
All Depths



Infrared Measurements at F4

All Depths

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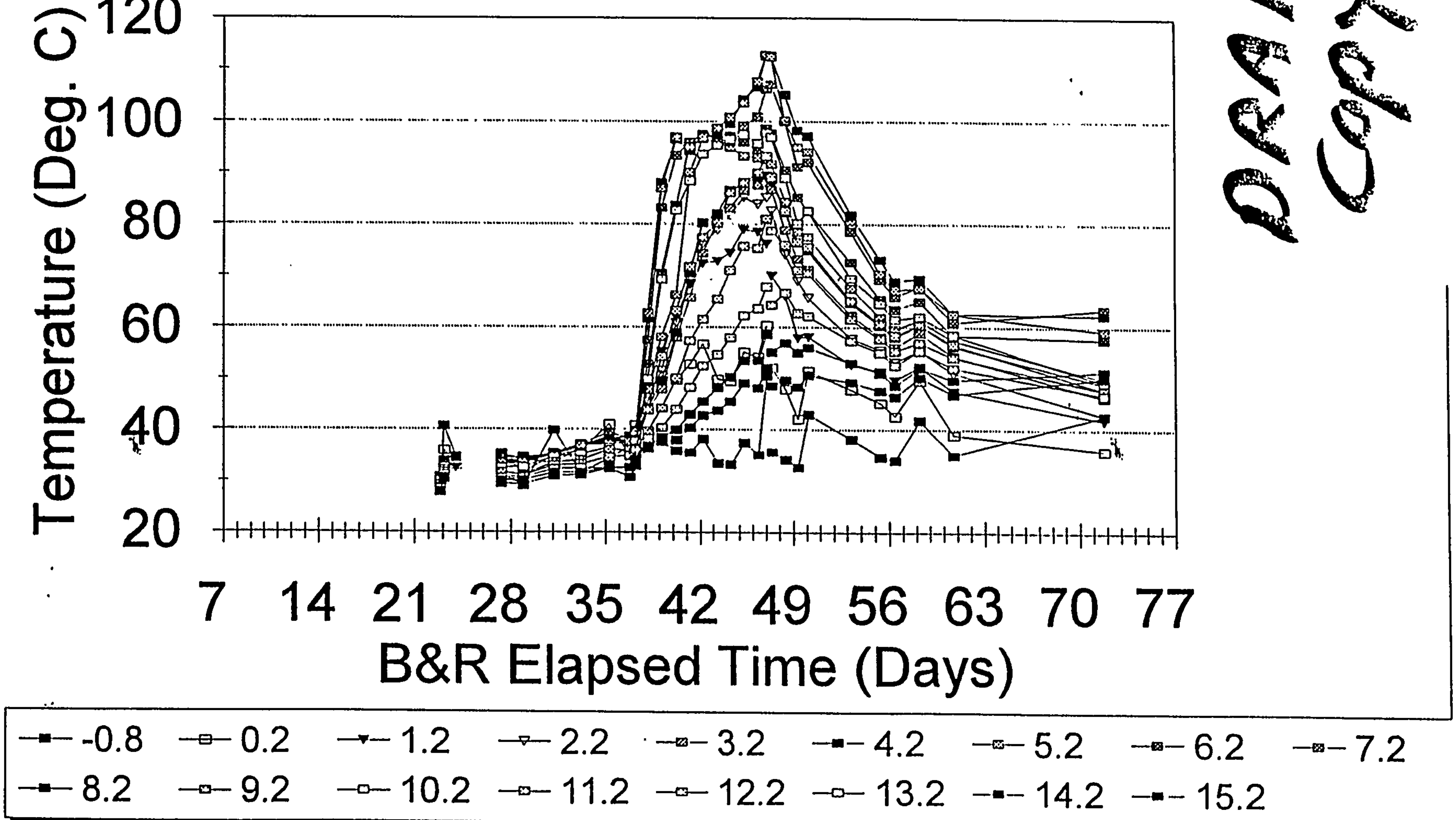

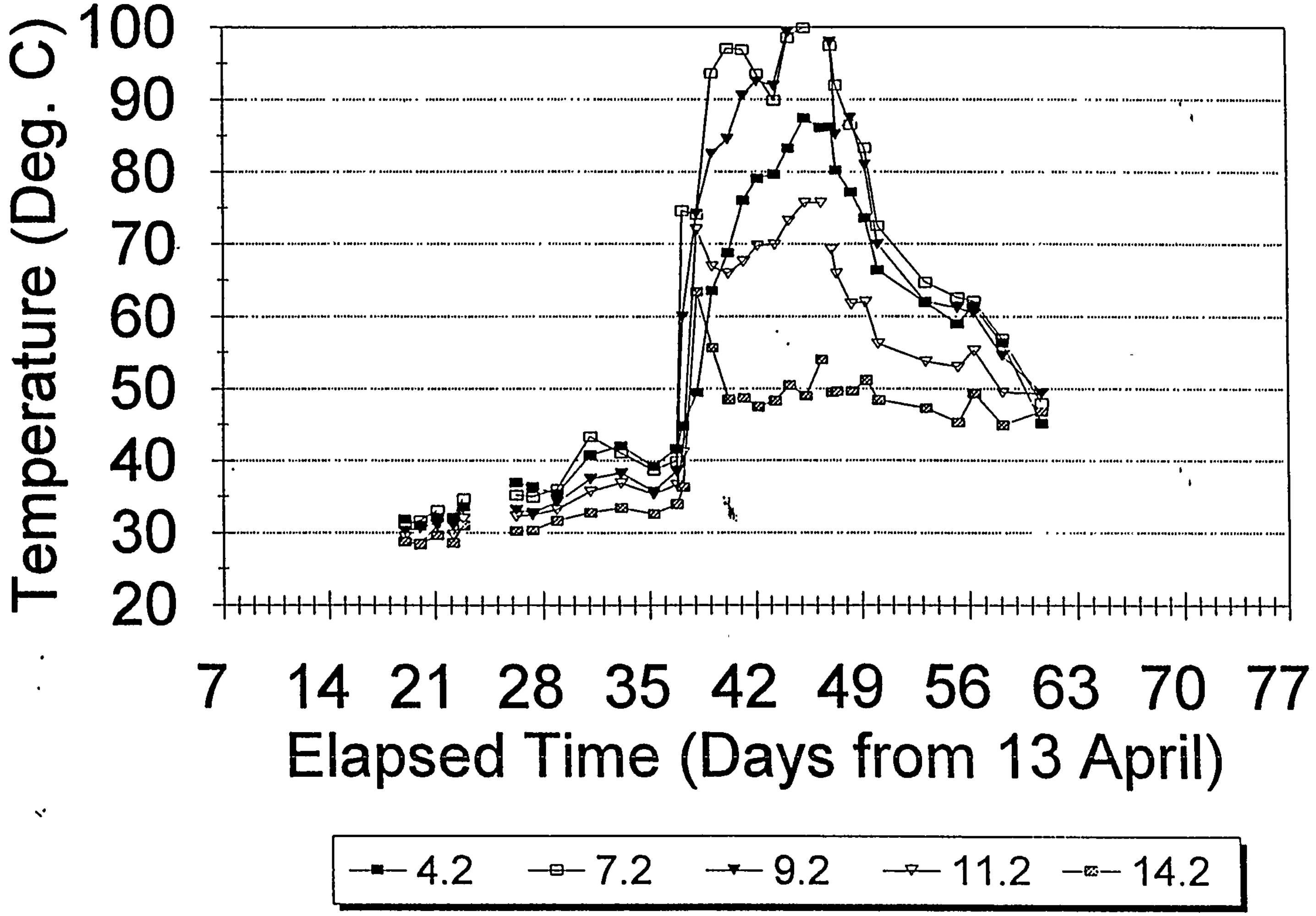
IR Sensor Profiles at F1
Five selected Depths

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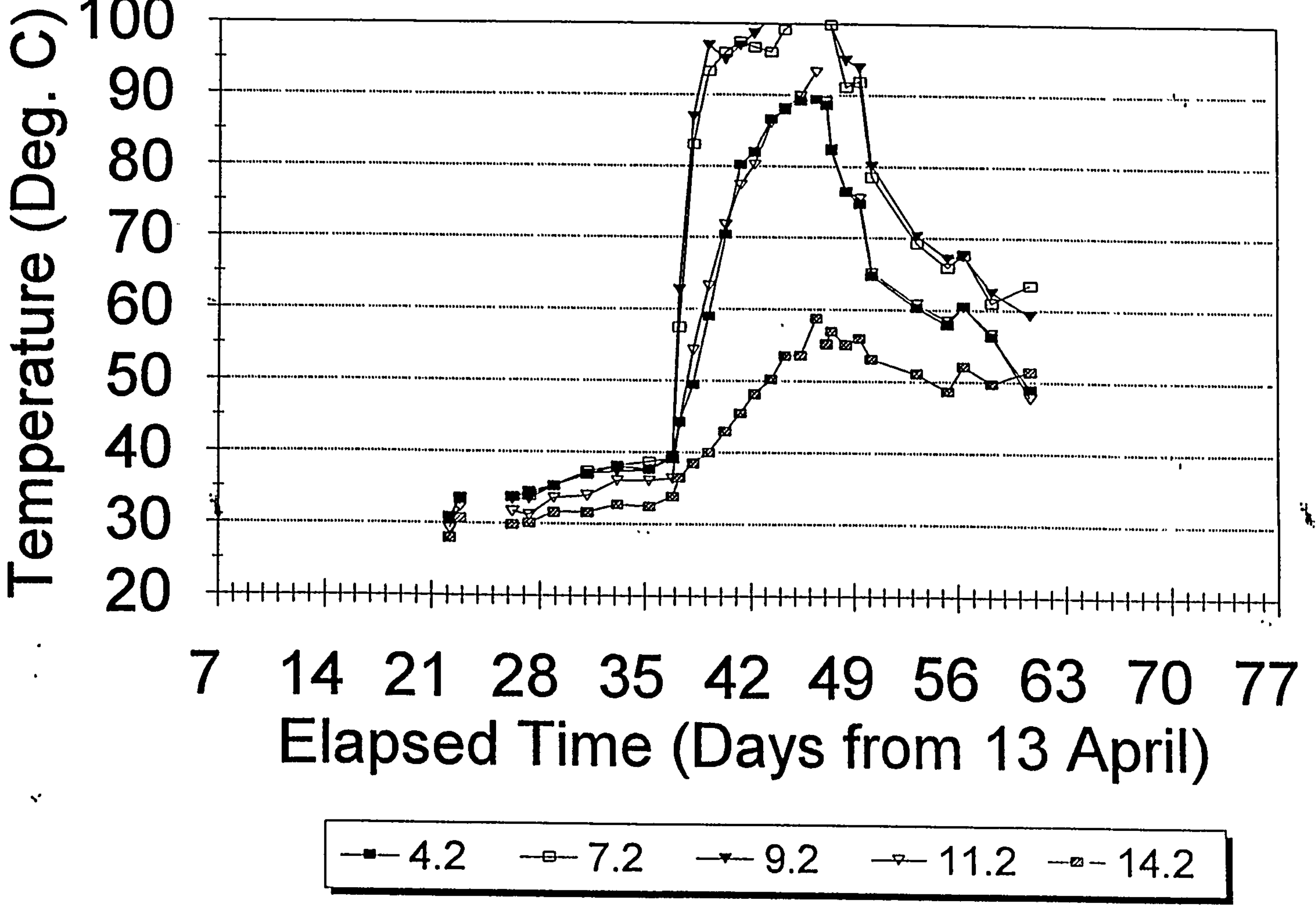
IR Sensor Profiles at F4

Five selected Depths



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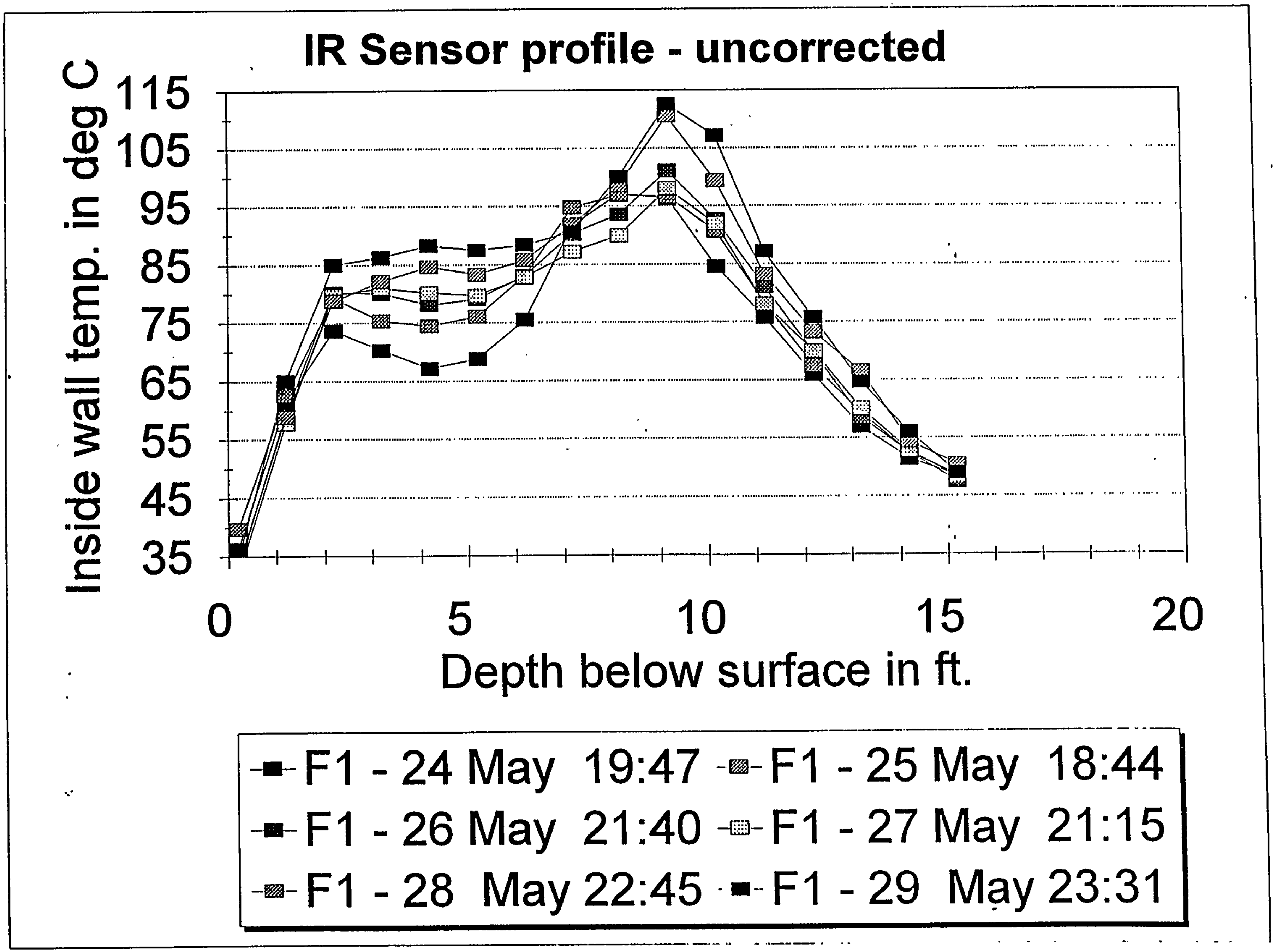
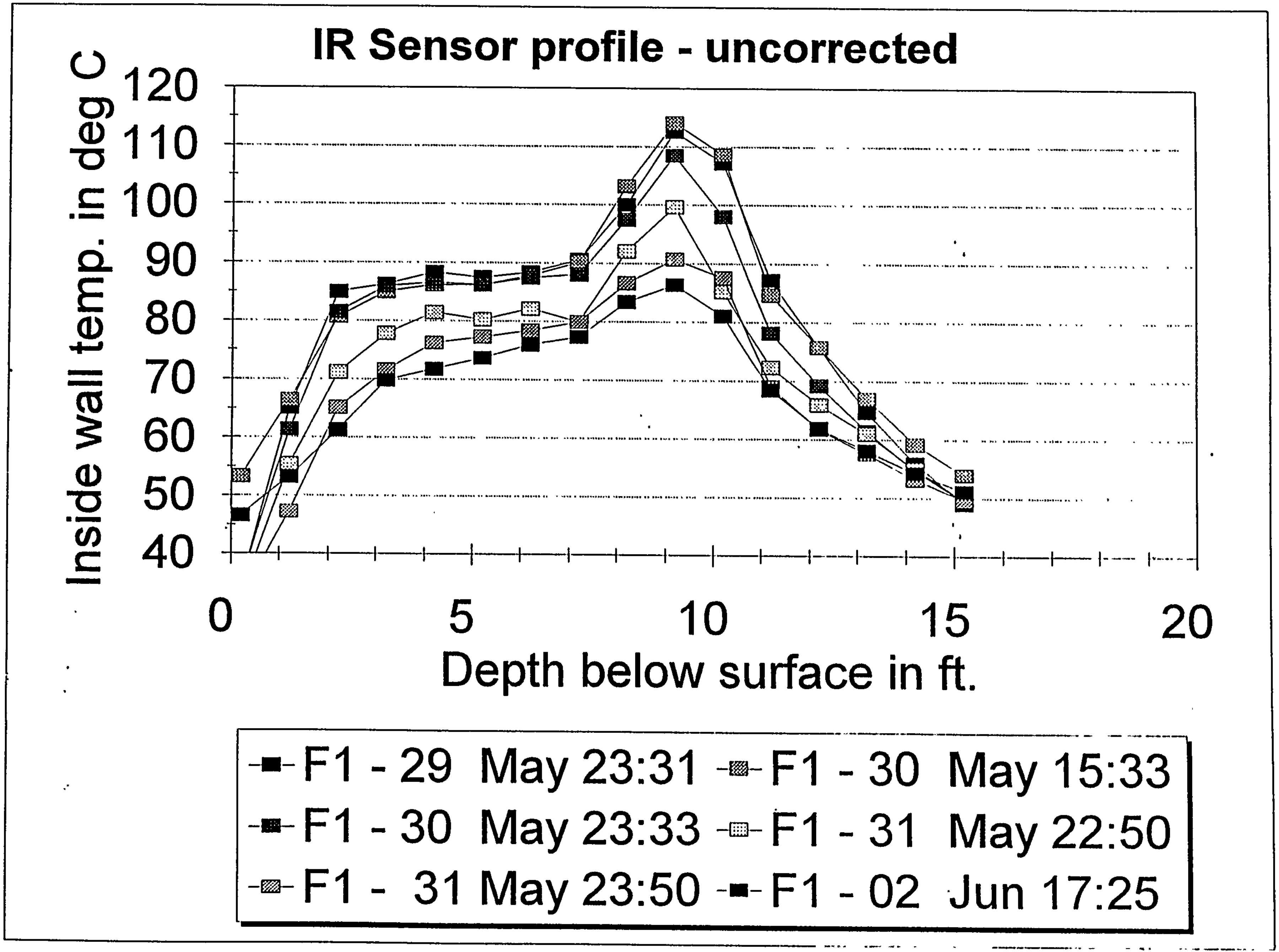
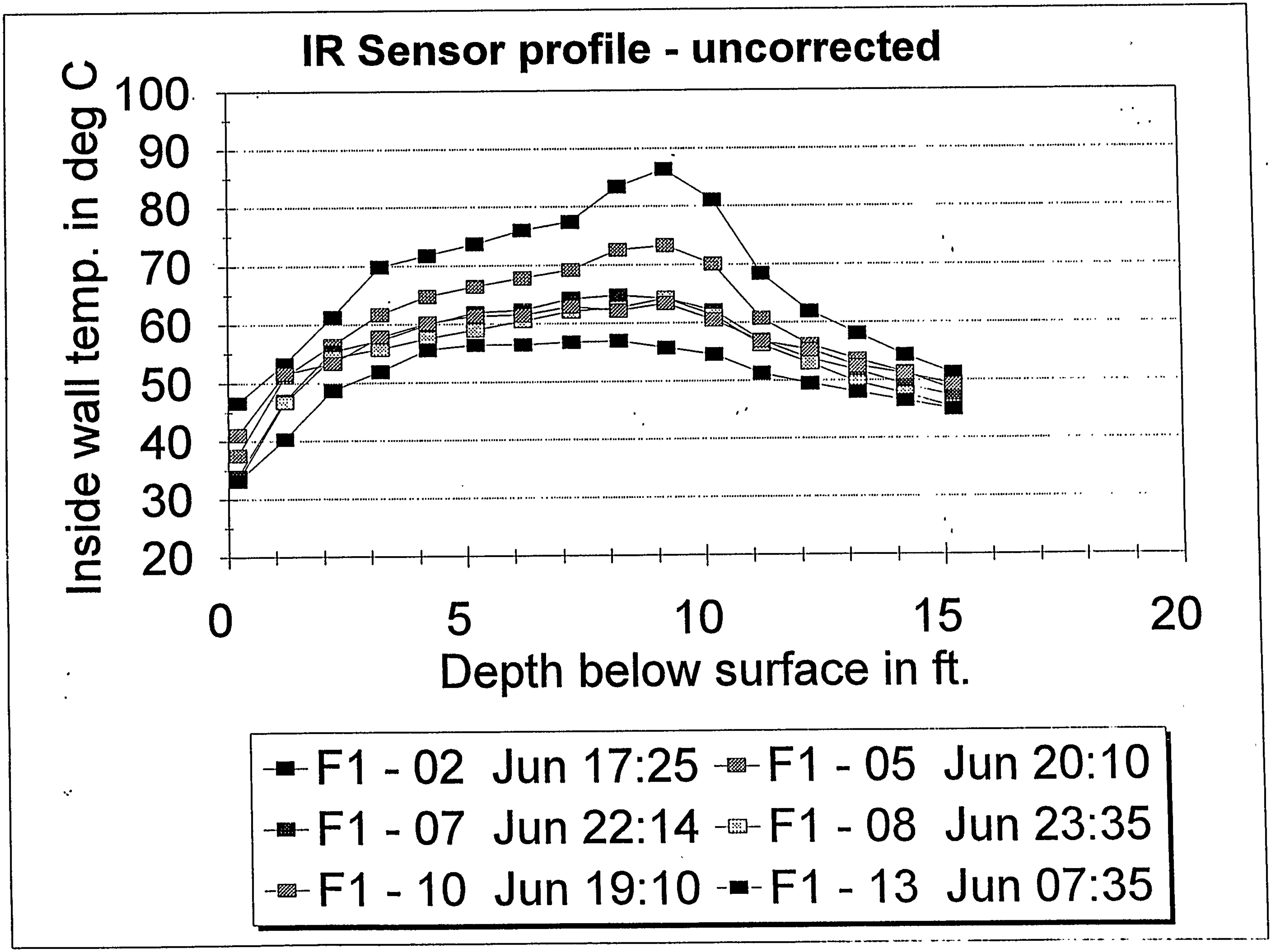
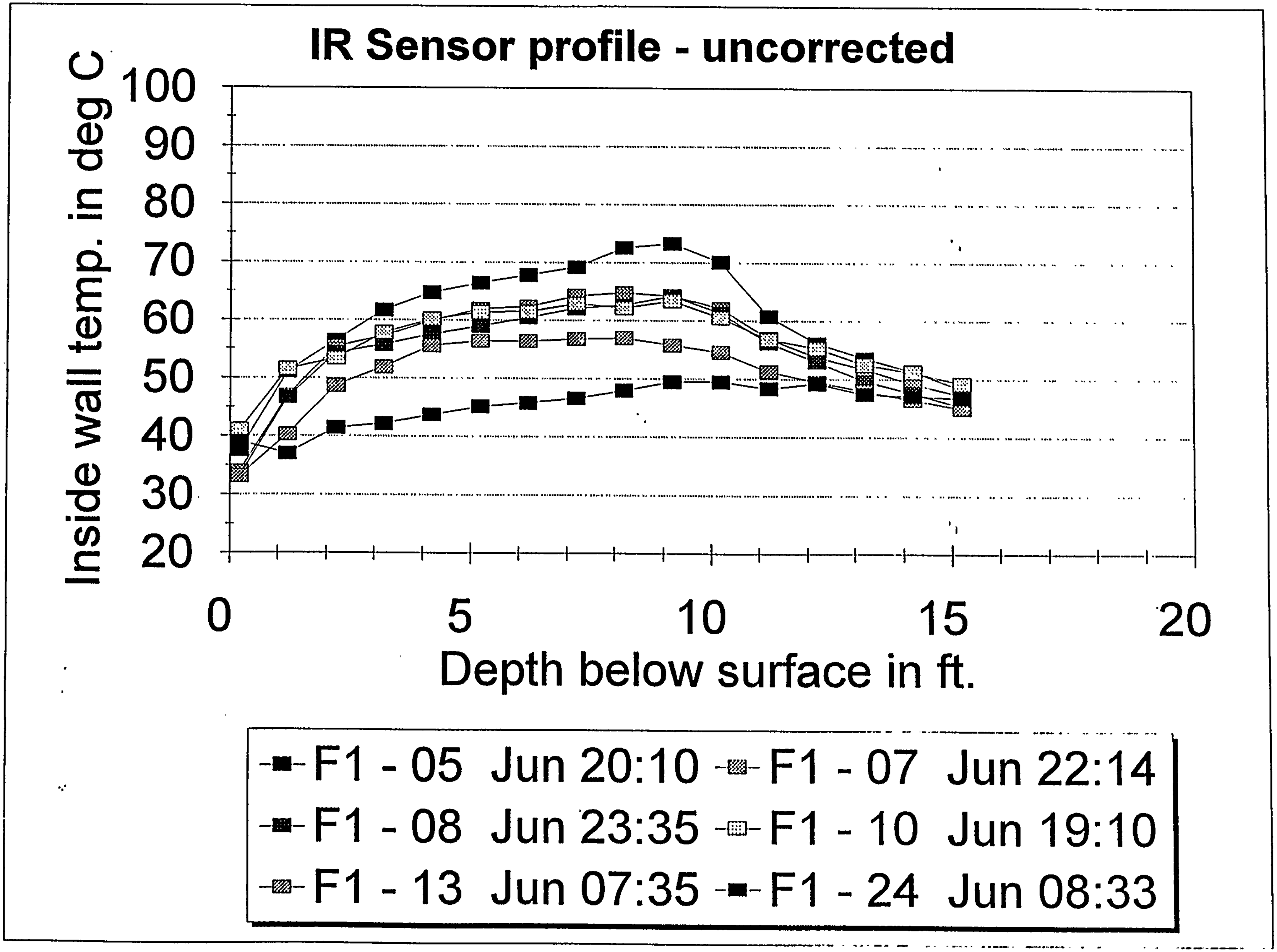
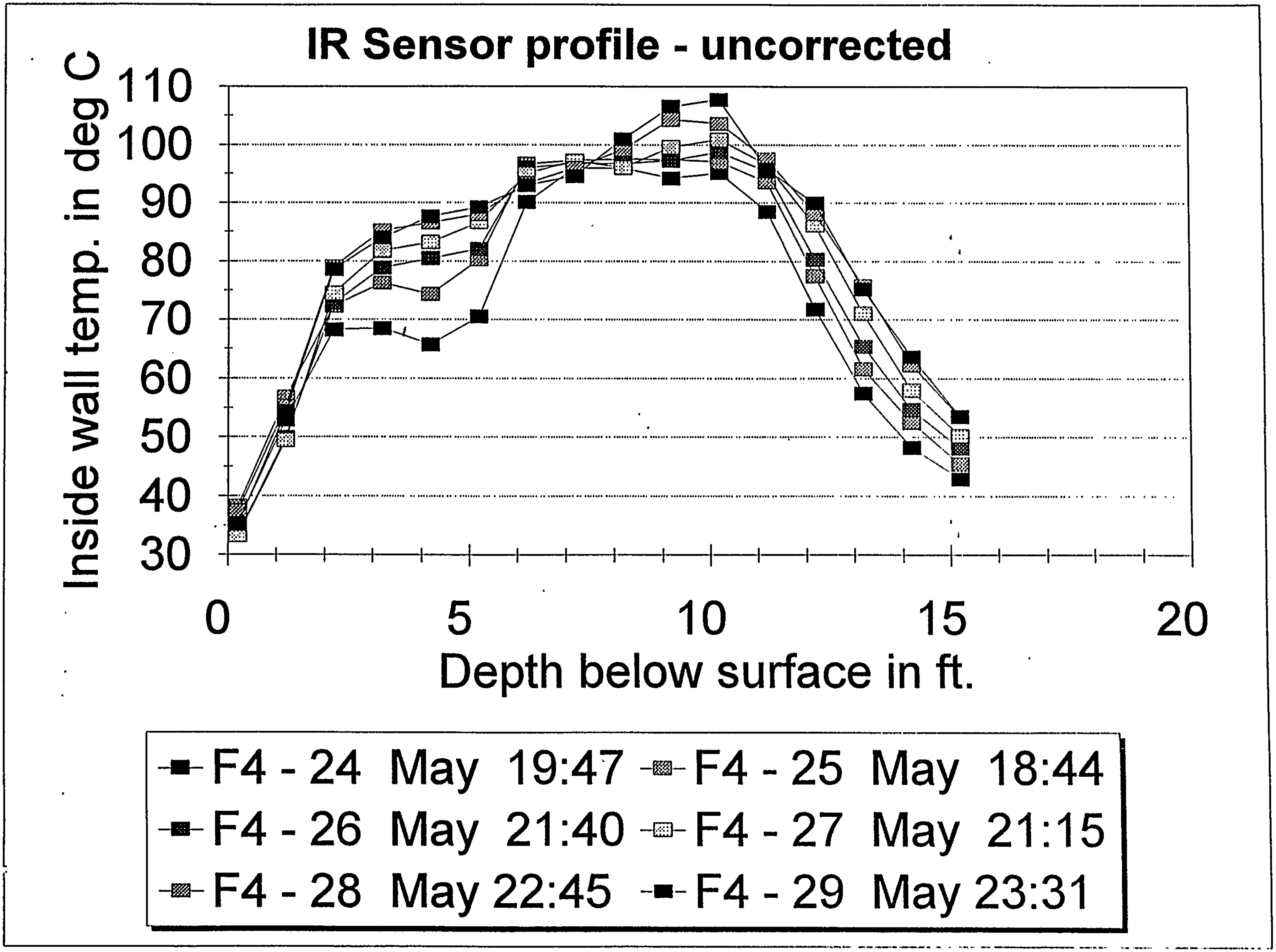

IR Sensor profile - uncorrected
Inside wall temp. in deg C
115
105
95
85
75
65
55
45
35
0
5
10
15
20
Depth below surface in ft.
F1 - 24 May 19:47
F1 - 25 May 18:44
F1 - 26 May 21:40
F1 - 27 May 21:15
F1 - 28 May 22:45
F1 - 29 May 23:31

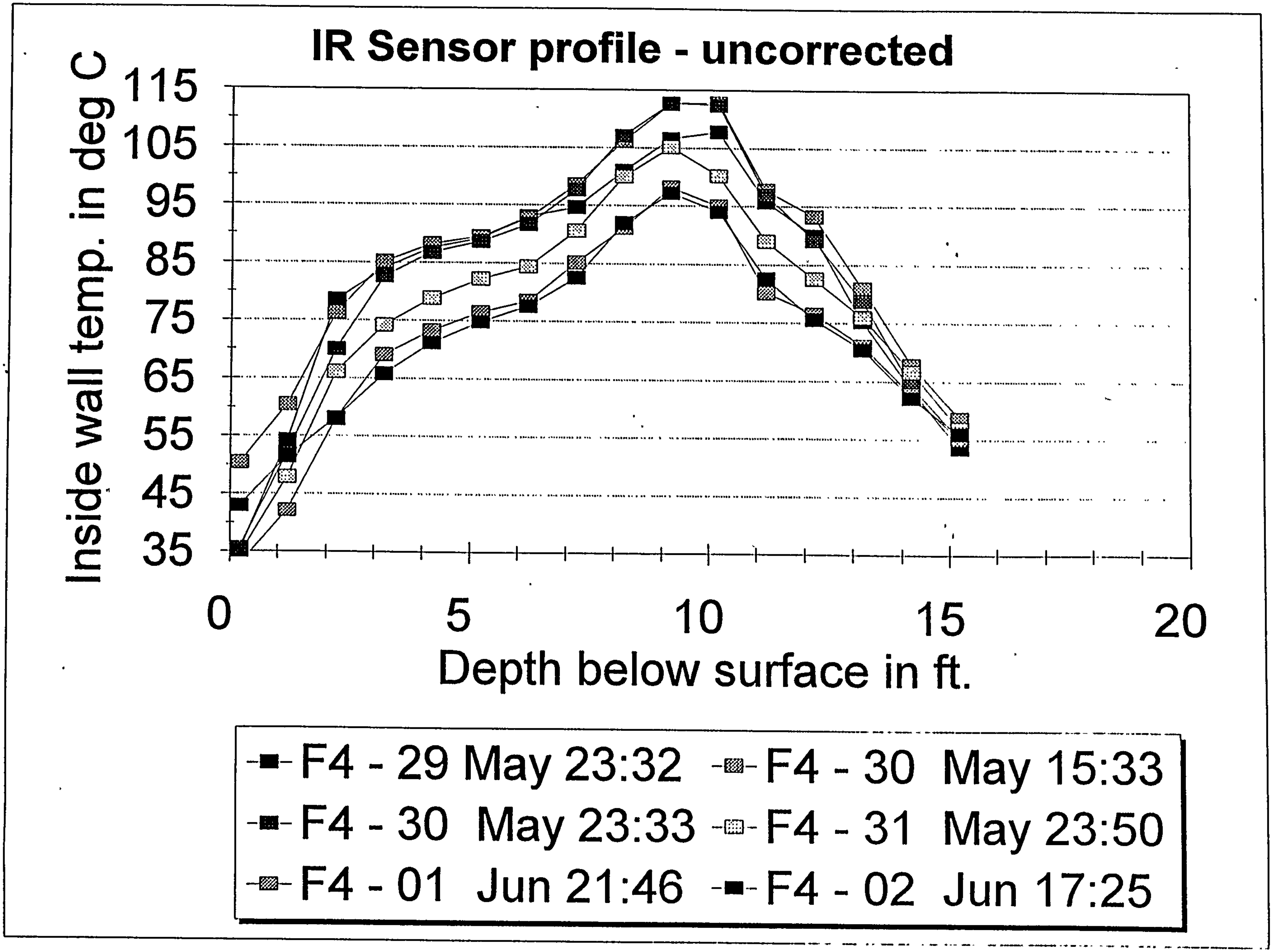

IR Sensor profile - uncorrected
Inside wall temp. in deg C
120
110
100
90
80
70
60
50
40
0
5
10
15
20
Depth below surface in ft.
F1 - 29 May 23:31
F1 - 30 May 15:33
F1 - 30 May 23:33
F1 - 31 May 22:50
F1 - 31 May 23:50
F1 - 02 Jun 17:25

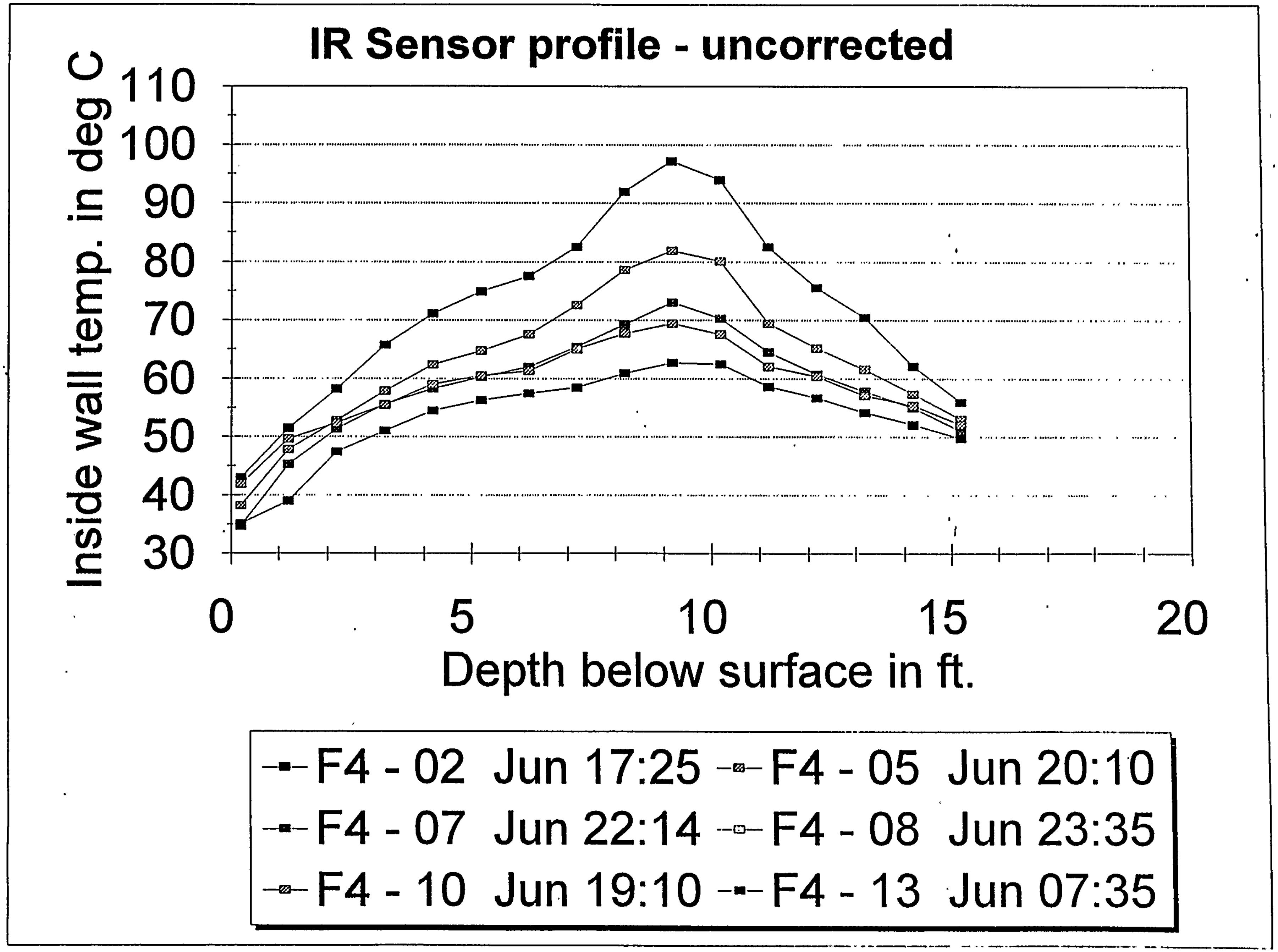

IR Sensor profile - uncorrected

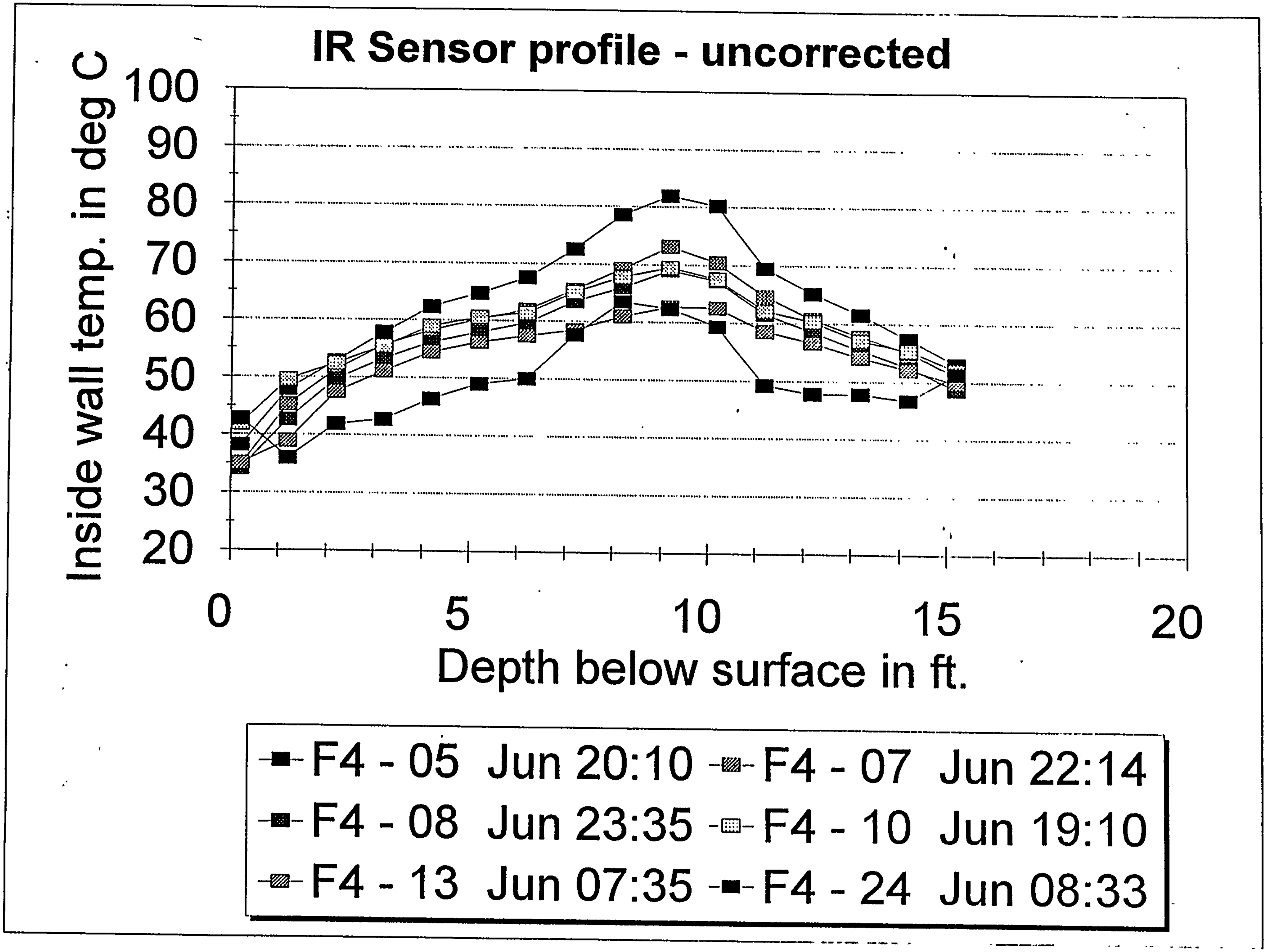


IR Sensor profile - uncorrected


IR Sensor profile - uncorrected
Inside wall temp. in deg C
110
100
90
80
70
60
50
40
30
0
5
10
15
20
Depth below surface in ft.
F4 - 24 May 19:47
F4 - 25 May 18:44
F4 - 26 May 21:40
F4 - 27 May 21:15
F4 - 28 May 22:45
F4 - 29 May 23:31


IR Sensor profile - uncorrected
Inside wall temp. in deg C
115
105
95
85
75
65
55
45
35
0
5
10
15
20
Depth below surface in ft.
F4 - 29 May 23:32
F4 - 30 May 15:33
F4 - 30 May 23:33
F4 - 31 May 23:50
F4 - 01 Jun 21:46
F4 - 02 Jun 17:25


IR Sensor profile - uncorrected


IR Sensor profile - uncorrected
Inside wall temp. in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Depth below surface in ft.
F4 - 05 Jun 20:10
F4 - 07 Jun 22:14
F4 - 08 Jun 23:35
F4 - 10 Jun 19:10
F4 - 13 Jun 07:35
F4 - 24 Jun 08:33

Infrared Measurements at F3
All Depths

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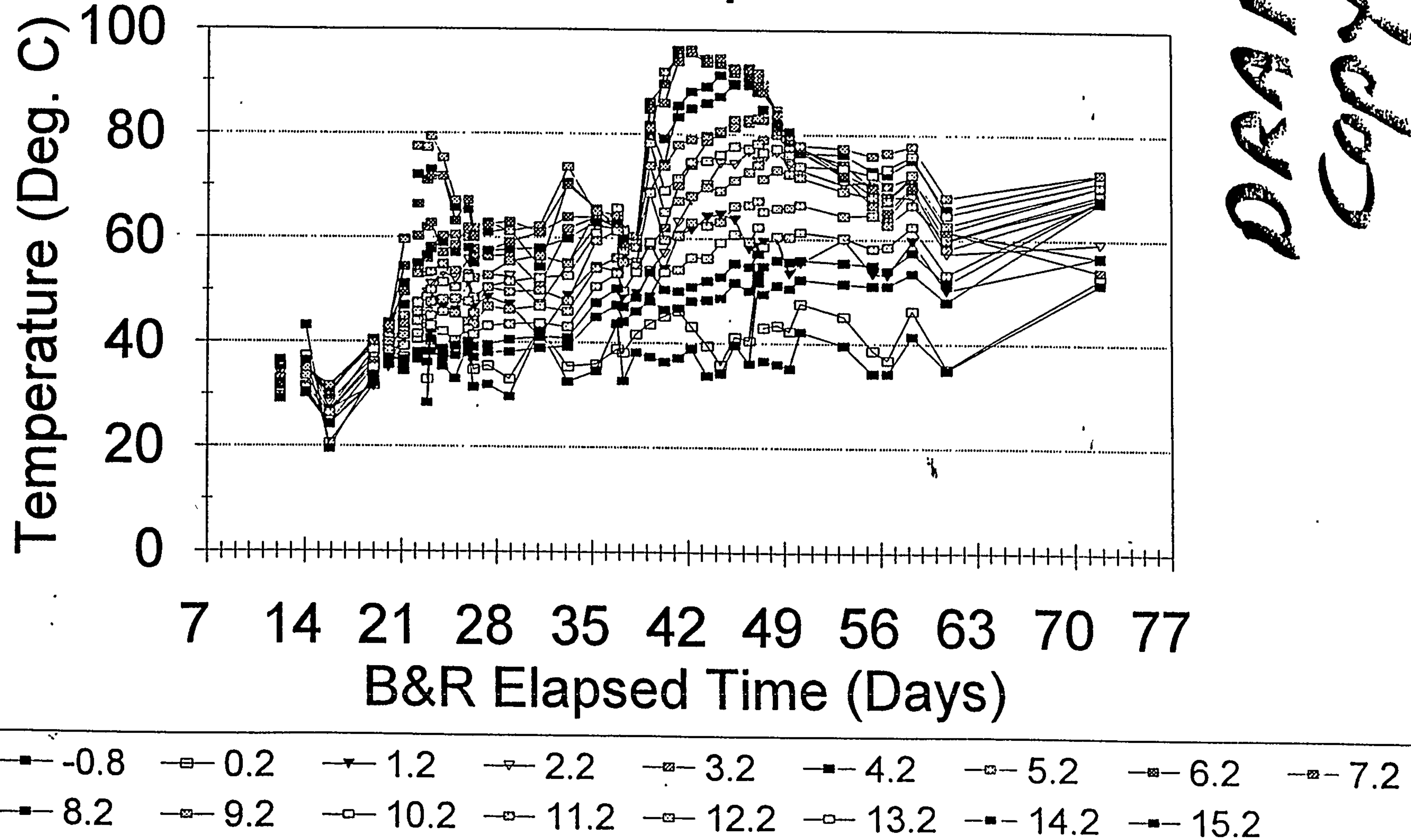

IR Sensor Profiles at F3

Five selected Depths

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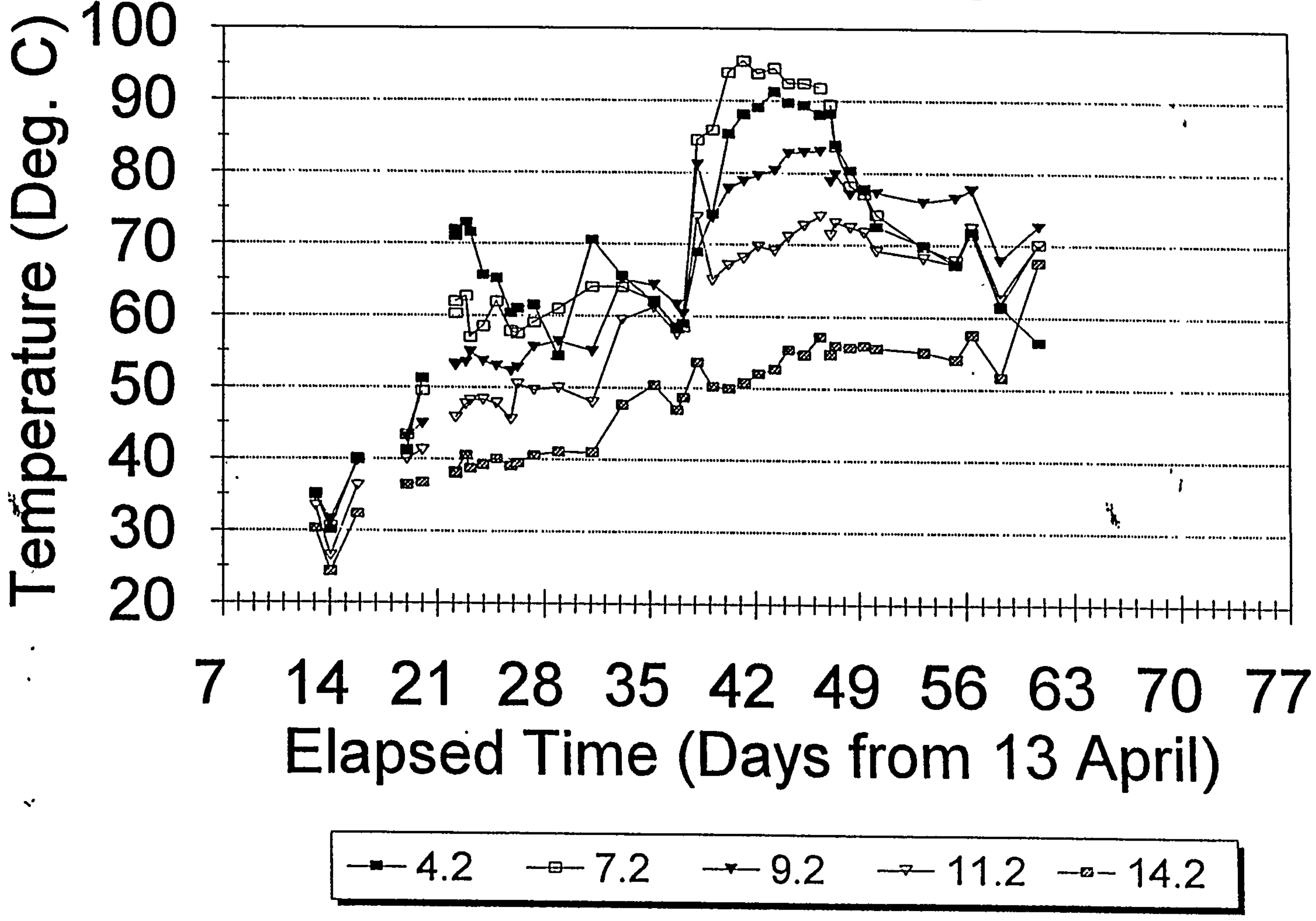
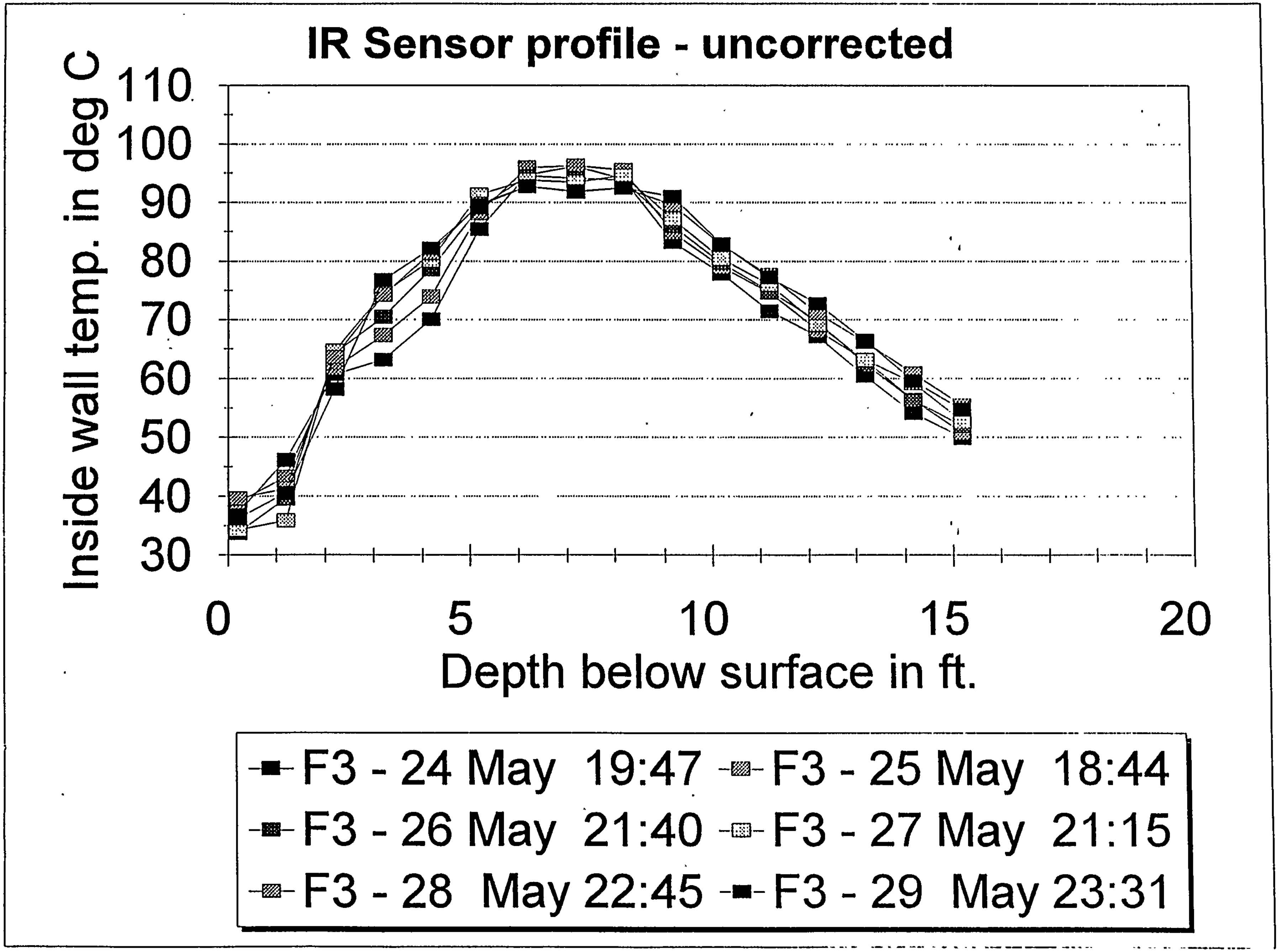
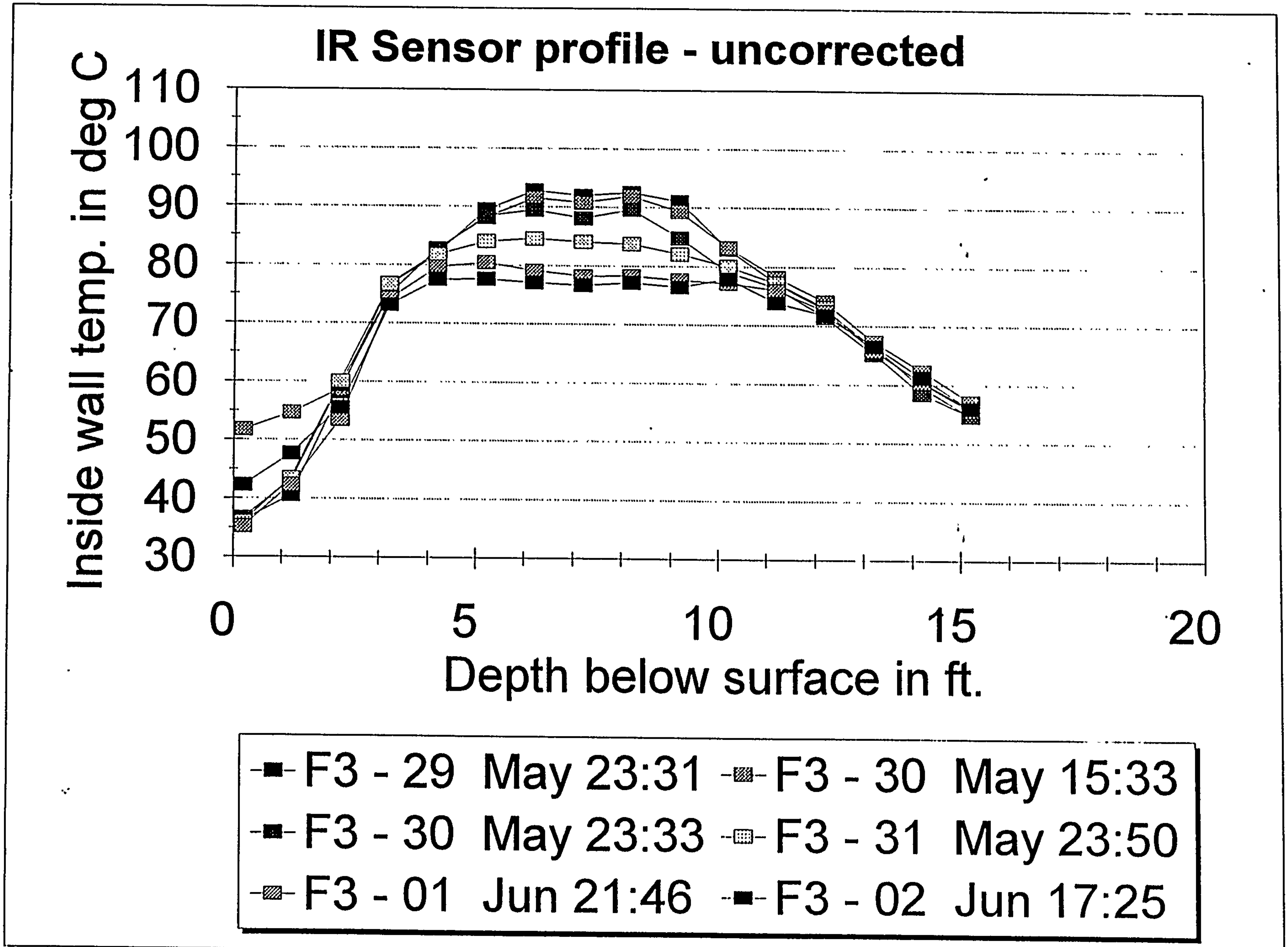
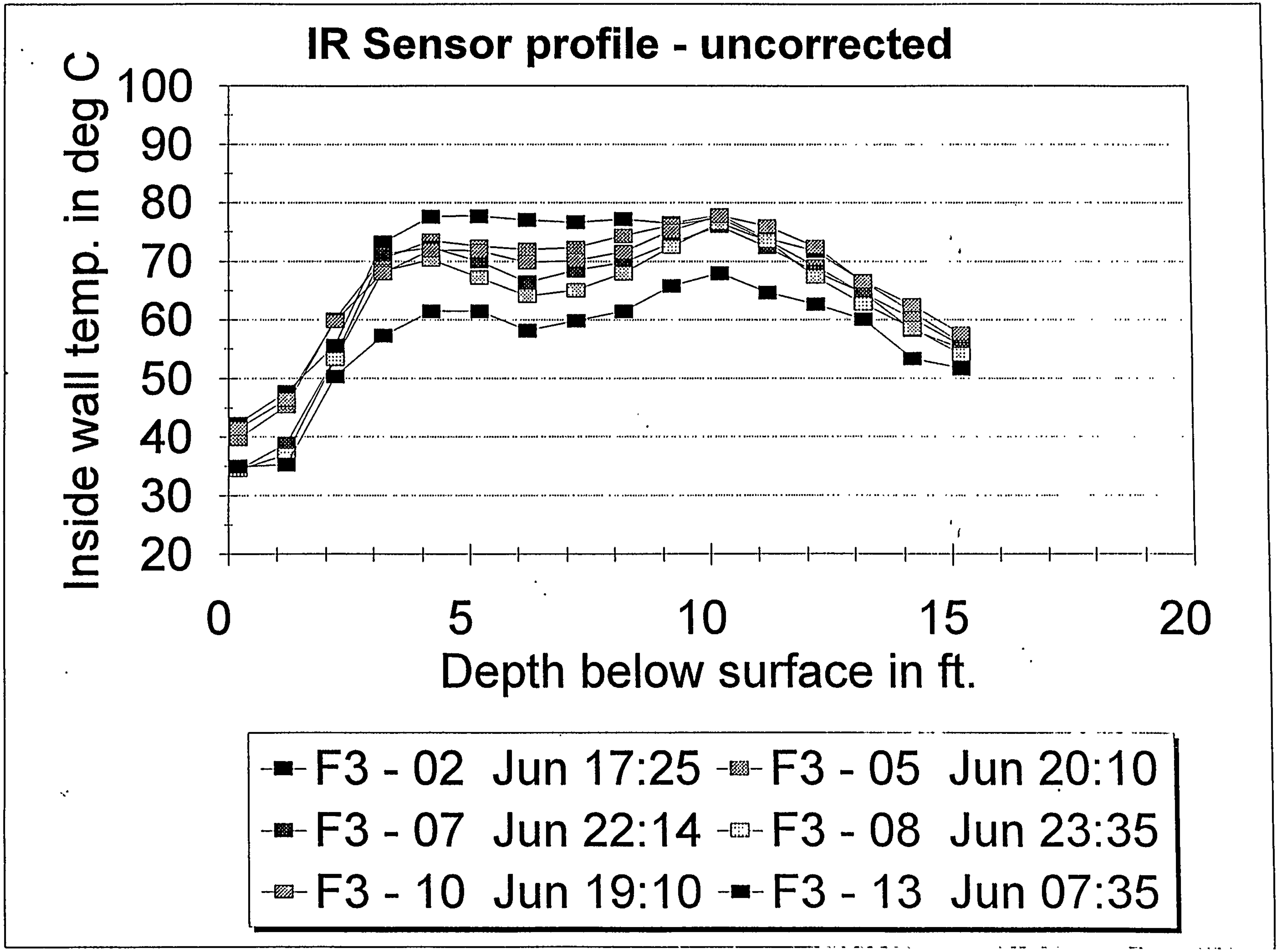
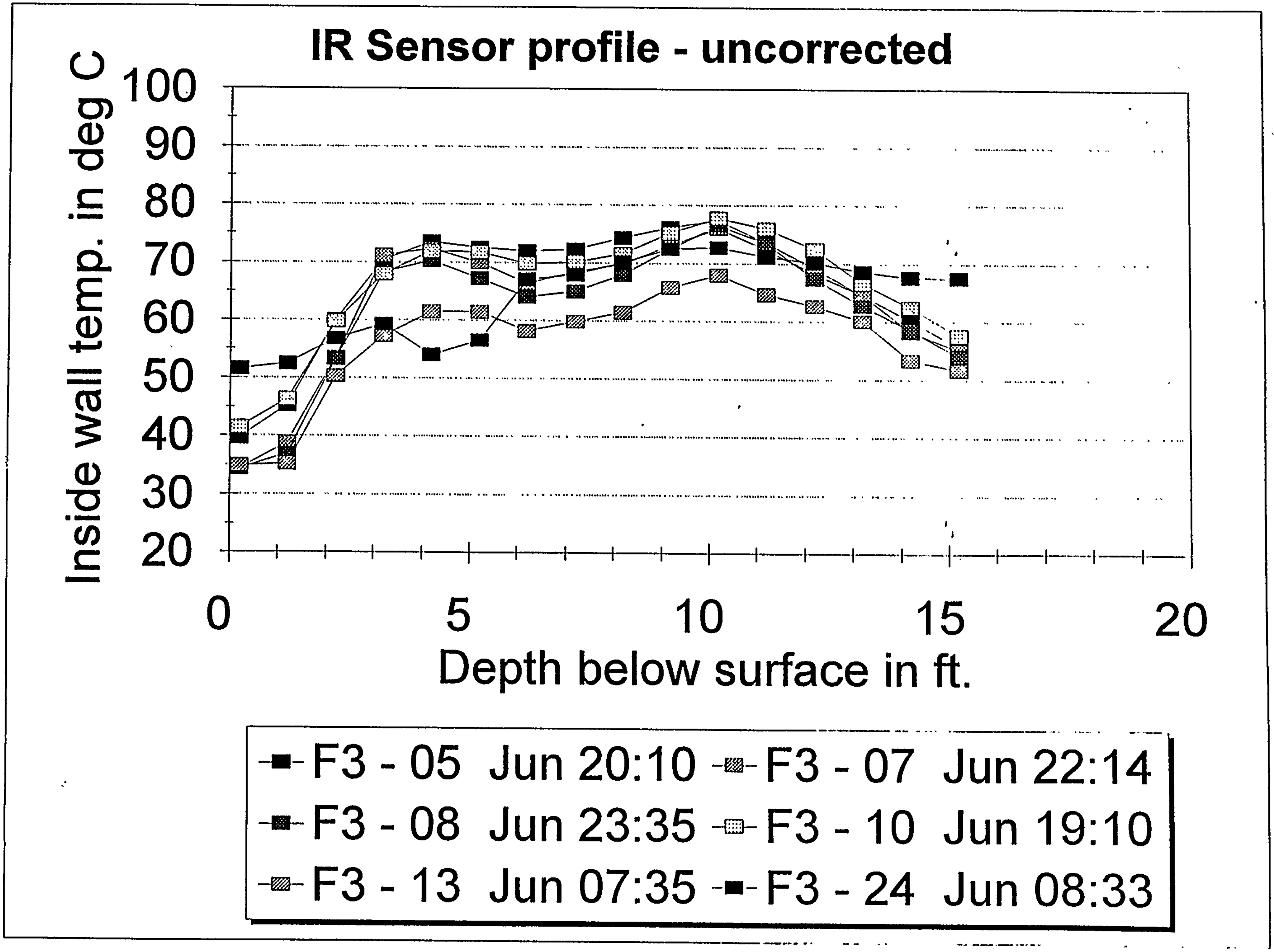



IR Sensor profile - uncorrected
Inside wall temp. in deg C
110
100
90
80
70
60
50
40
30
0
5
10
15
20
Depth below surface in ft.
F3 - 24 May 19:47
F3 - 25 May 18:44
F3 - 26 May 21:40
F3 - 27 May 21:15
F3 - 28 May 22:45
F3 - 29 May 23:31


IR Sensor profile - uncorrected
Inside wall temp. in deg C
110
100
90
80
70
60
50
40
30
0
5
10
15
20
Depth below surface in ft.
F3 - 29 May 23:31
F3 - 30 May 15:33
F3 - 30 May 23:33
F3 - 31 May 23:50
F3 - 01 Jun 21:46
F3 - 02 Jun 17:25


IR Sensor profile - uncorrected
Inside wall temp. in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Depth below surface in ft.
F3 - 02 Jun 17:25
F3 - 05 Jun 20:10
F3 - 07 Jun 22:14
F3 - 08 Jun 23:35
F3 - 10 Jun 19:10
F3 - 13 Jun 07:35


IR Sensor profile - uncorrected
Inside wall temp. in deg C
100
90
80
70
60
50
40
30
20
0
5
10
15
20
Depth below surface in ft.
F3 - 05 Jun 20:10
F3 - 07 Jun 22:14
F3 - 08 Jun 23:35
F3 - 10 Jun 19:10
F3 - 13 Jun 07:35
F3 - 24 Jun 08:33

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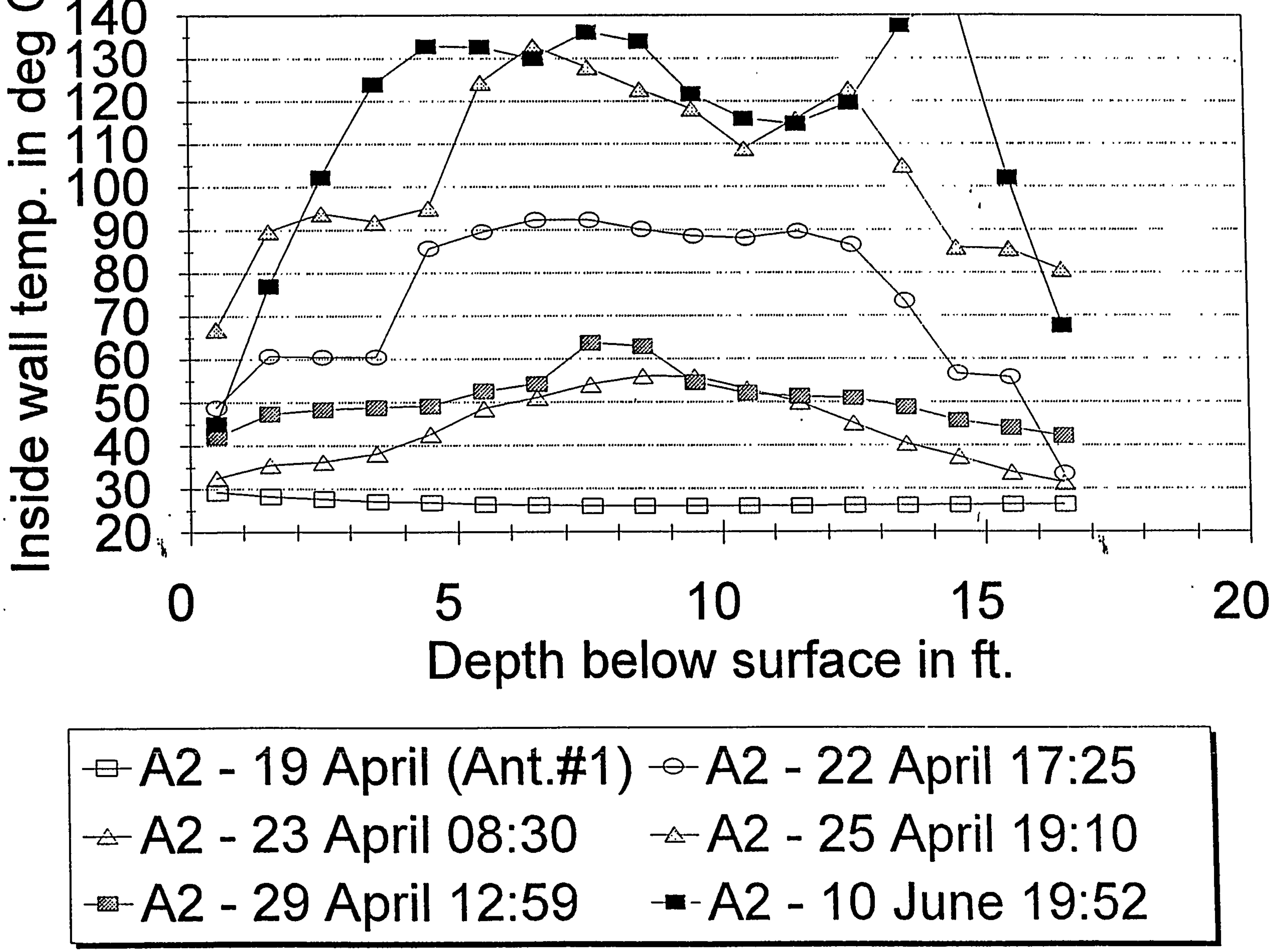
Well Liner - IR Sensor profile (rel.)



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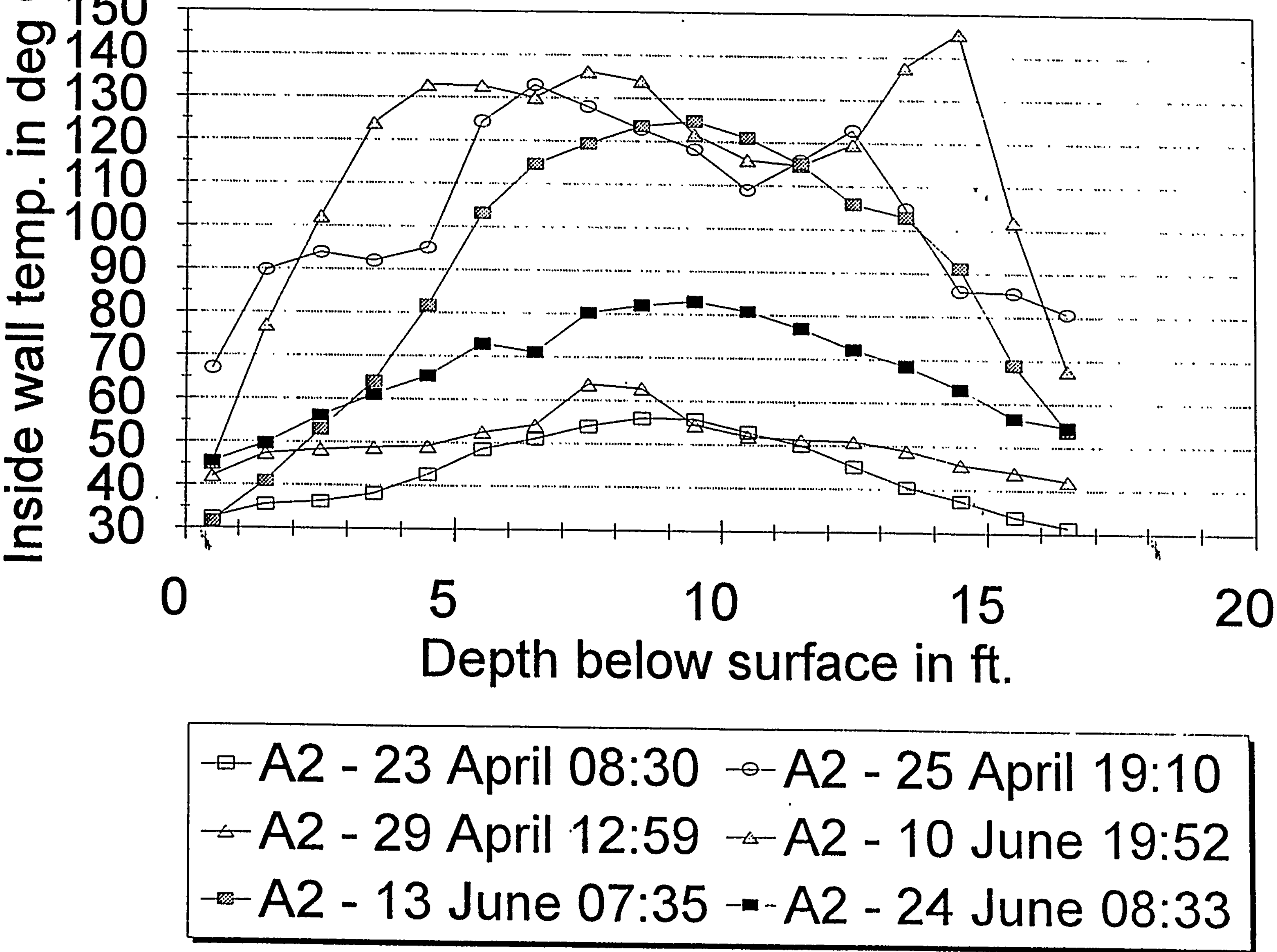
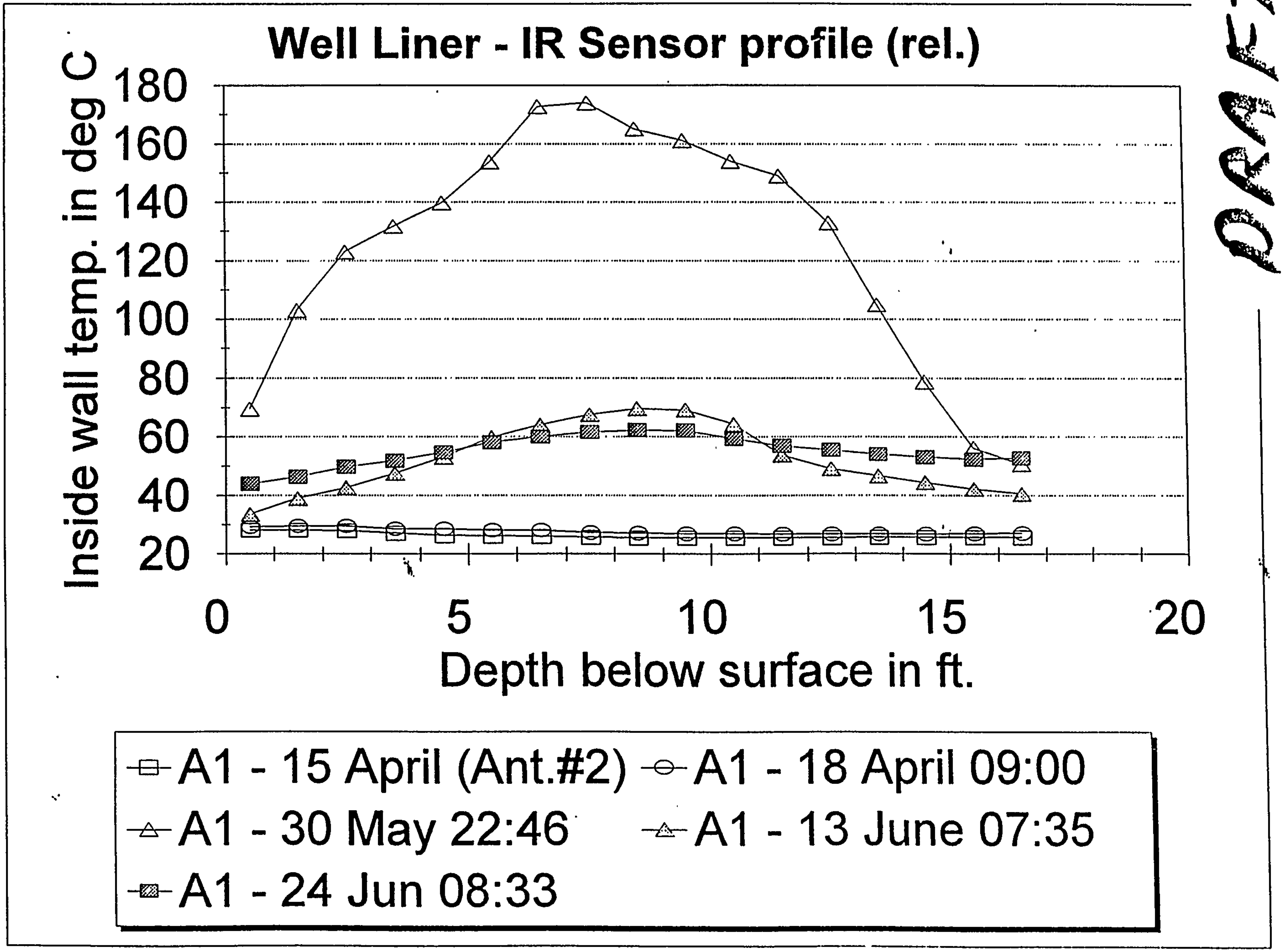
Well Liner - IR Sensor profile (rel.)



DRAFT Copy



Well Liner - IR Sensor profile (rel.)

APPENDIX G - RF System Matching Measurements

Return loss and insertion loss.

RETURN LOSS

Definitions: Return loss = $-20 \log_{10} \rho$ where ρ is the reflection coefficient. This can be used to calculate the VSWR.

$$\boxed{VSWR = voltage\quad standing\quad wave\quad ratio\quad = \frac{1+\rho}{1-\rho}}$$

The plots have been displayed in terms of return loss to better display changes in absorption of RF energy by the soil surrounding the applicator. The numbers for return loss are displayed in negative decibels (dB). The negative sign is due to the reference point of the measurement and the decibels are a logarithmic notation of reflected point. Where 3 dB indicates a 50% change in power, 10 dB a factor of 10 and 20 dB a factor of 100.

Large values of return loss indicate high levels of absorption (e.g. 32 dB) and small negative values (6.02 dB) indicate low levels of absorption which means that energy is reflected back to the tuner and the RF generator. Large amounts of energy being reflected is indicated by a high VSWR number. The goal is to have a low VSWR. The following table can be used to interpret the plots.

	VSWR	Return Loss (dB)	
	1.0	∞	
	1.05	32.25	This is an ideal practical value, it is typically the value the tuner presents to RF generator after it has been adjusted to match the load.
	1.20	20.82	
	1.5	13.98	
>>	2	9.5	This is the marker line on the plots of applicator matching. This level of return loss indicates that 10% of the power is being reflected back from applicator and approximately 90% is being delivered to the soil.
	3.0	6.02	
	5.0	3.52	Nearly 50% of the power is being reflected
	10.0	1.74	
	∞	0.00	All power is reflected back

INSERTION LOSS

This is a measurement of the power lost on the transmission path between Applicator #1 and Applicator #2. The measurement is made in decibels (dB). A 3 dB change in insertion loss indicates that the power received at on applicator has changed by 50%.

Summary of selected plots - Note that some may be in the main text with different scales

Note that in all of these charts the A1 refers to Applicator #1 and A2 to Applicator 2. In a post-test labeling correction Applicator #1 is now identified as being used to heat well A2 and Applicator #2 is used in A1.

- Tuning test plots of return loss for a test dipole antenna with a small diameter coaxial cable feed.
  - 74" test dipole at 4 depths - overlaid
  - 74" test dipole at 4 depths- 3D
  - 78" test dipole at 4 depths - overlaid
  - 78" test dipole at 4 depths - overlaid (displayed in main text, shifted freq. span)
  - 78" test dipole at 4 depths- 3D (displayed in main text, shifted freq. span)
  - 82" test dipole at 4 depths - overlaid
  - 82" test dipole at 4 depths- 3D
  - 86" test dipole at 4 depths - overlaid
  - 86" test dipole at 4 depths- 3D
  - 90" test dipole at 4 depths - overlaid
  - 90" test dipole at 4 depths- 3D

- Pre-heat, Return loss measurements on 20 April - The 27.12 MHz heating frequency is shown as a vertical dashed marker. The frequency span is the full measured sweep with using 401 measurement points. The -9.5 dB return loss is equal to a VSWR of 2.0.
  - Applicator #1 in well liner A2 (chart is labeled as A1, WKAF1001.01L)
  - Applicator #2 in well liner A1 (chart is labeled as A2, WKAF1002.01L)
  - Applicator #1 and #2 plots are overlay of WKAF1001.01L and WKAF1002.01L

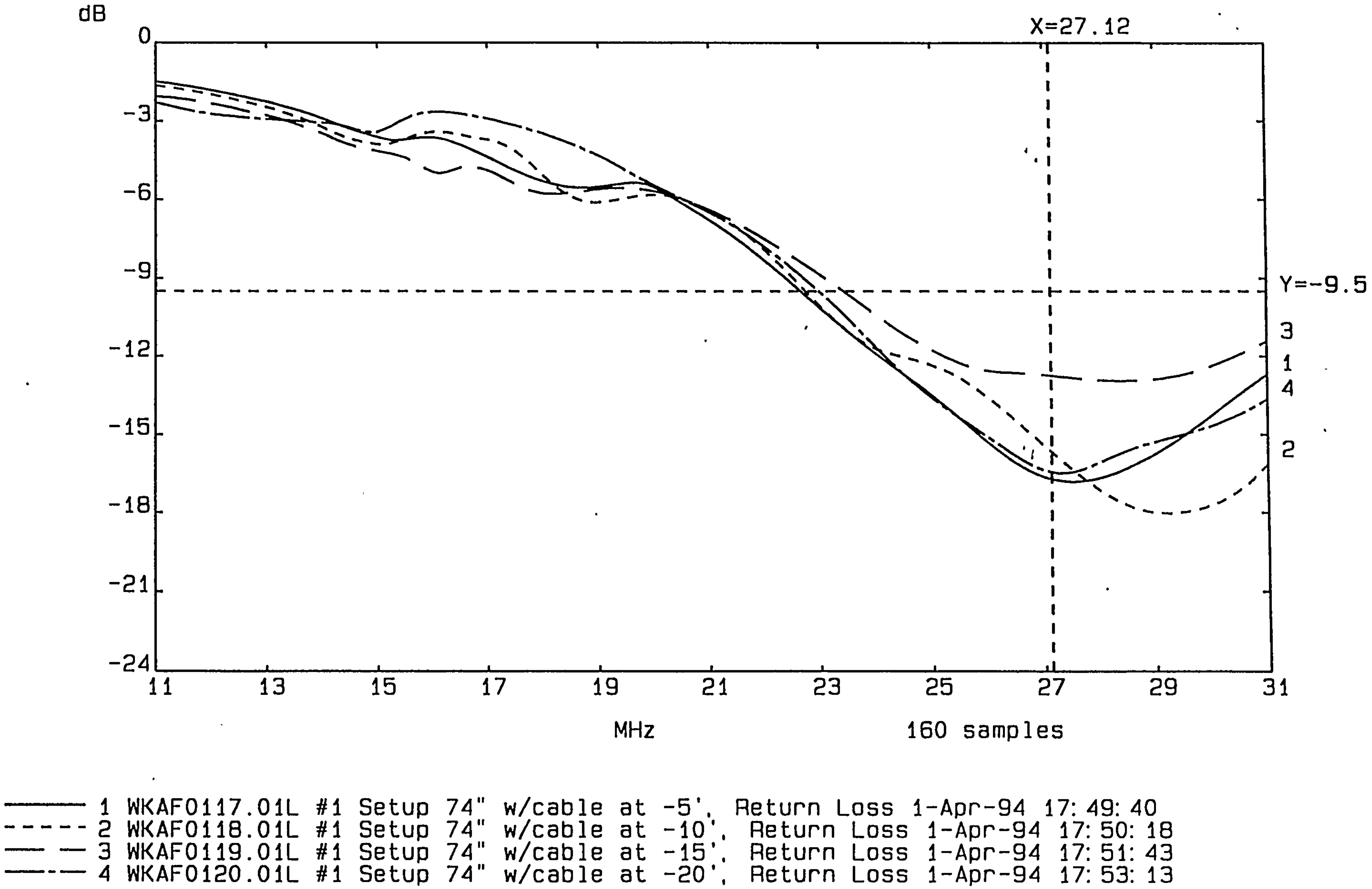
- Pre-heat, Return loss measurement on 20 April using the tuner to optimally match the RF generator to the applicator. These plots are the tuner transformation of the match presented by WKAF1001.01L and WKAF1002.01L
  - Applicator #1 and #2 plots overlaid with tuner matching (WKAF2001.01L and WKAF2002.01L)

- Return loss measurements after heating starts Heating by applicator #1 in A2
  - Applicator #1 after approx 62 KWH
  - Applicator #1 after approx 1700 KWH
  - Applicator #1 first heating period - 20 April to 20 May measurement span (displayed in main text)
  - Applicator #2 heating period - 20 May to 7 June measurement span (displayed in main text)
  - Applicator #1 second heating period - 30 May to 10 June measurement span (displayed in main text)
  - Applicator #1 on 24 May, WKAF1113.01L
  - Applicator #2 on 24 May, WKAF1114.01L

- Insertion loss measurements - without minor correction of rigid coaxial path loss for this DRAFT
  - Preheat overlay of measurements made from Applicator #1 to Applicator #2. (displayed in main text)
    (measurements should be identical and are shown as this)
  - Applicator #1 - first heating period
  - Applicator #1 and #2 heated - comparison across entire program (displayed in main text)

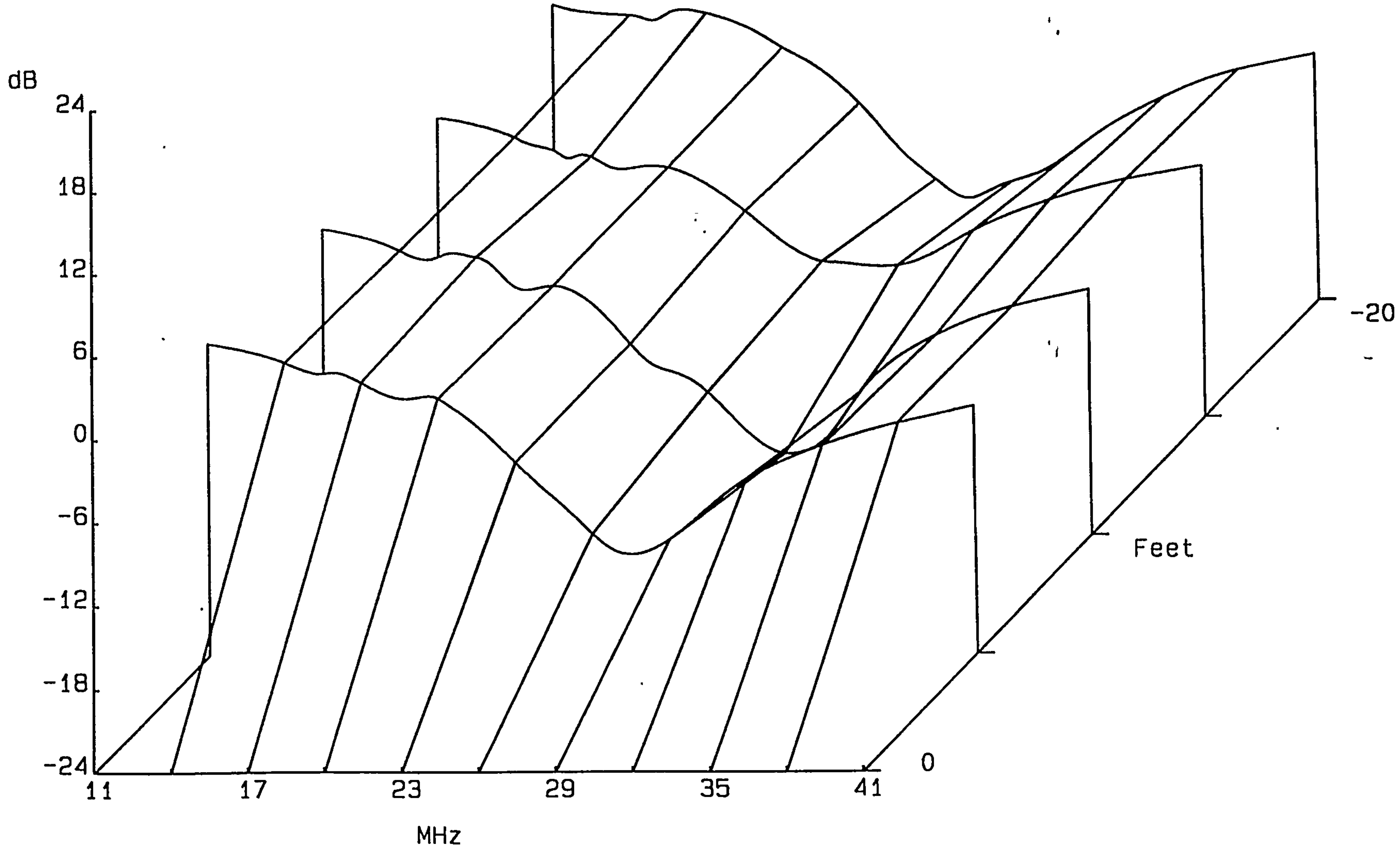
END FILE: KELLYG.A

Scan of A2



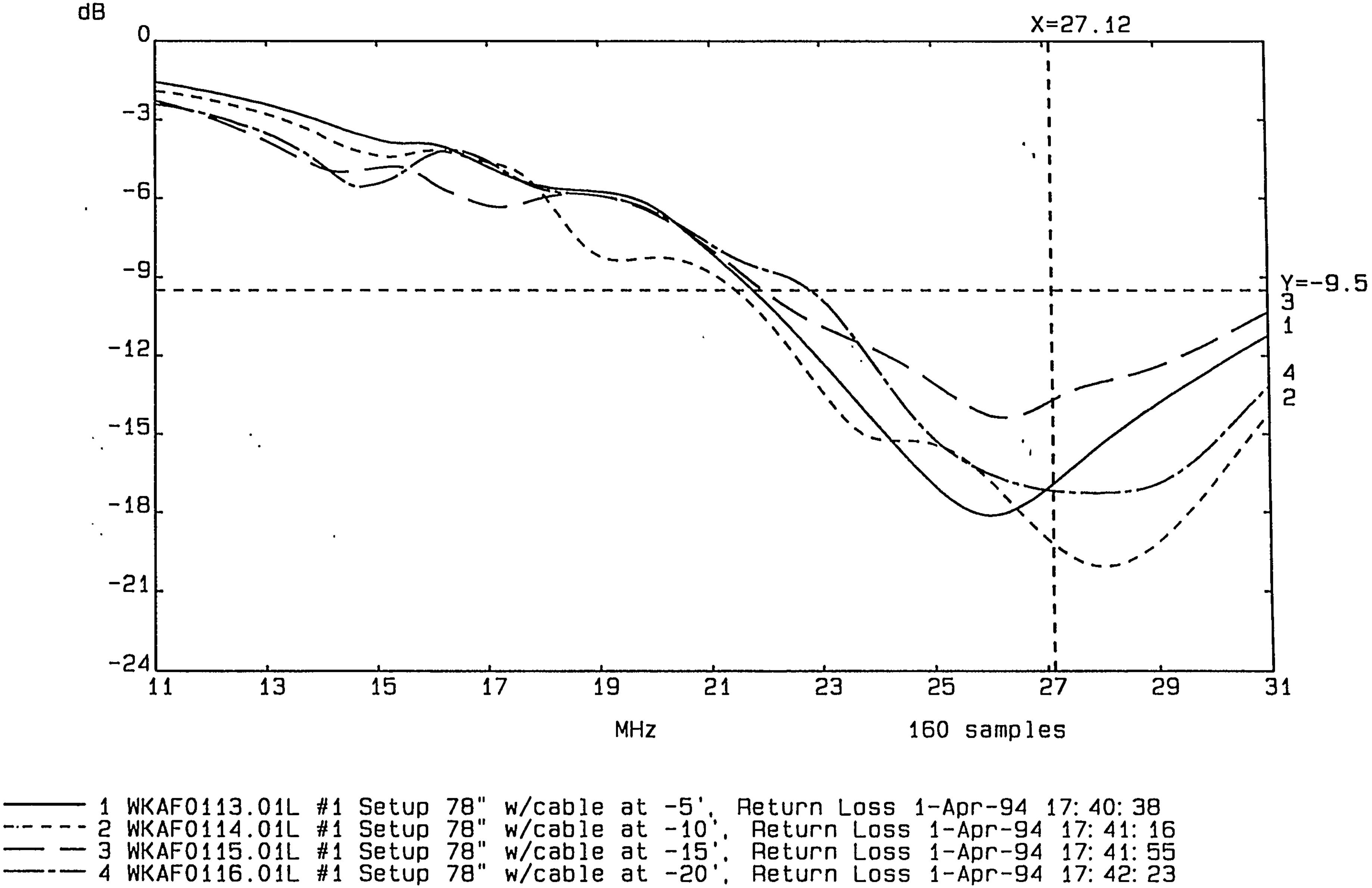
16-Dec-94

SCAN of A2 -WKAF0117.01L #1 Setup 74", Return Loss 1-Apr-94 17: 49: 40



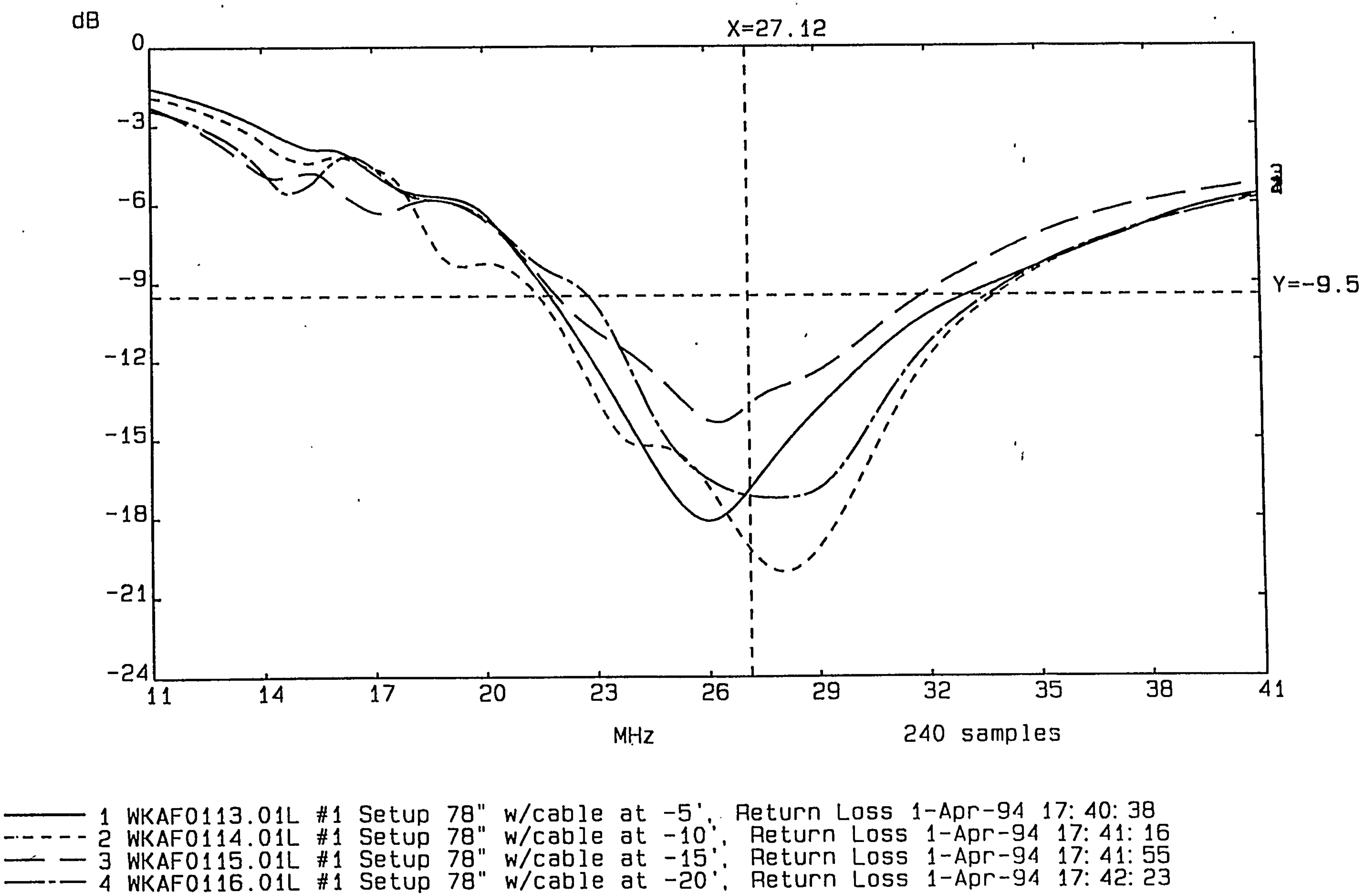
17-Dec-94

Scan of A2



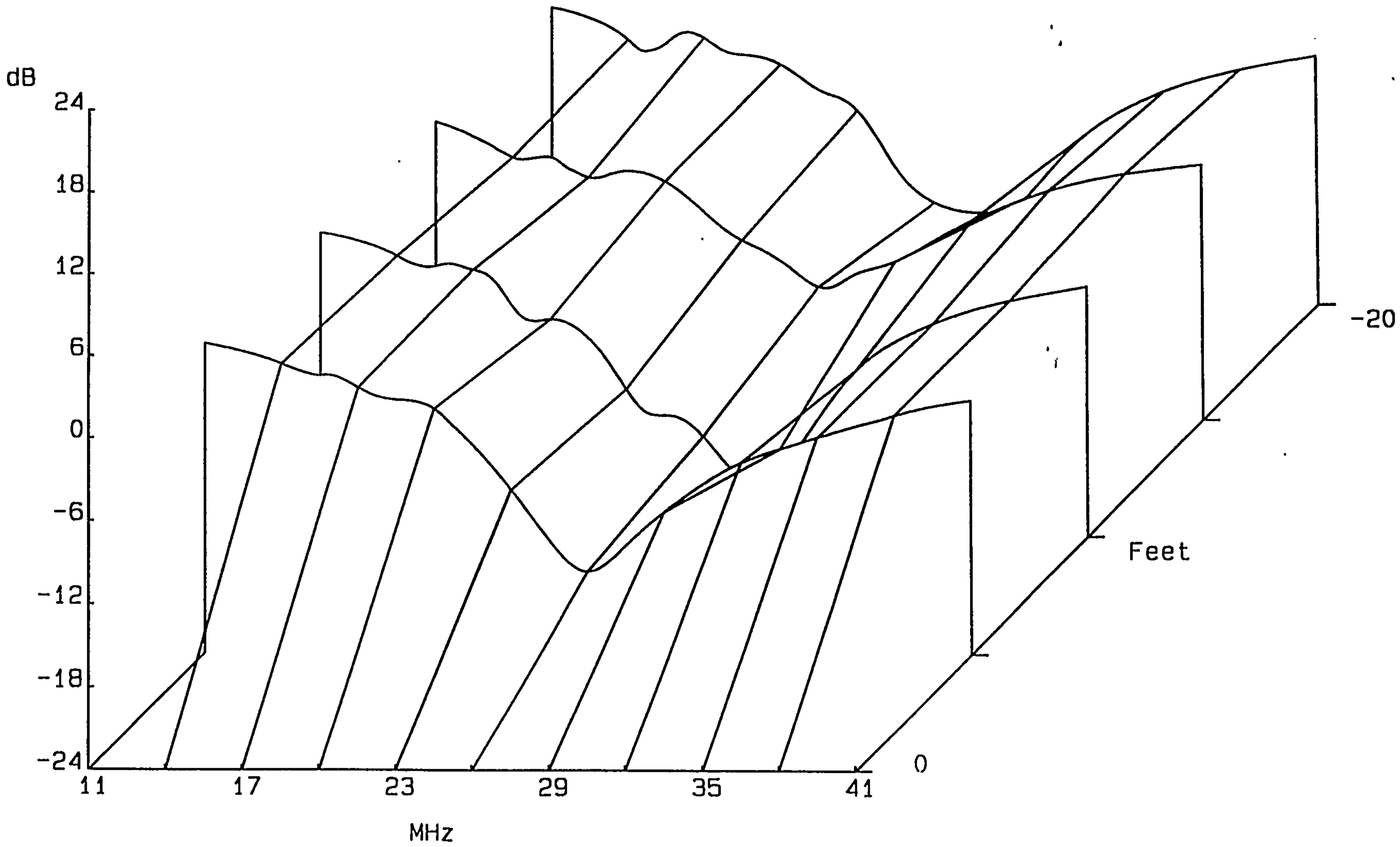
16-Dec-94

Scan of A2



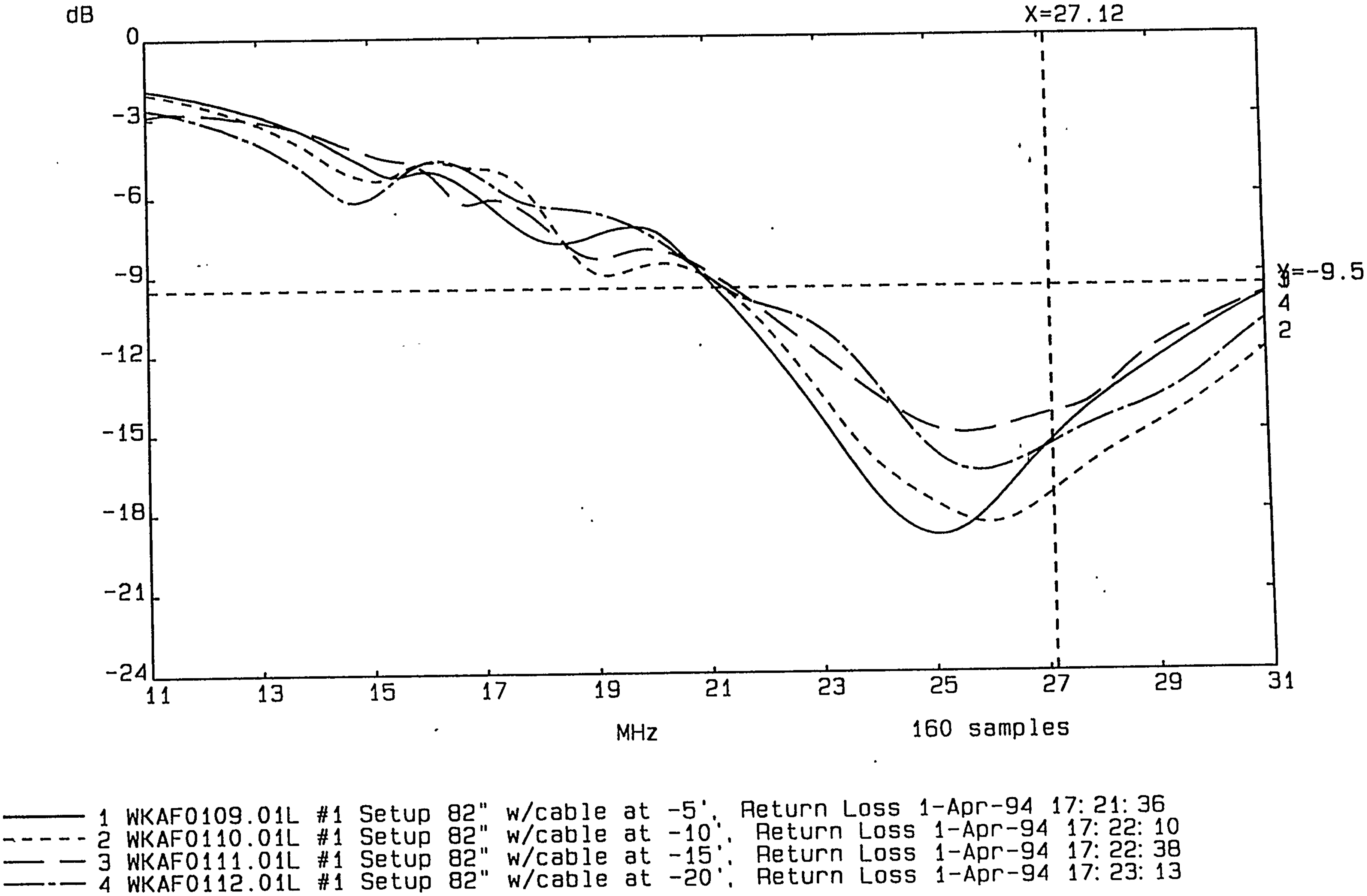
16-Dec-94

Scan of A2 -WKAF0113.01L #1 Setup 78", Return Loss 1-Apr-94 17: 40: 38



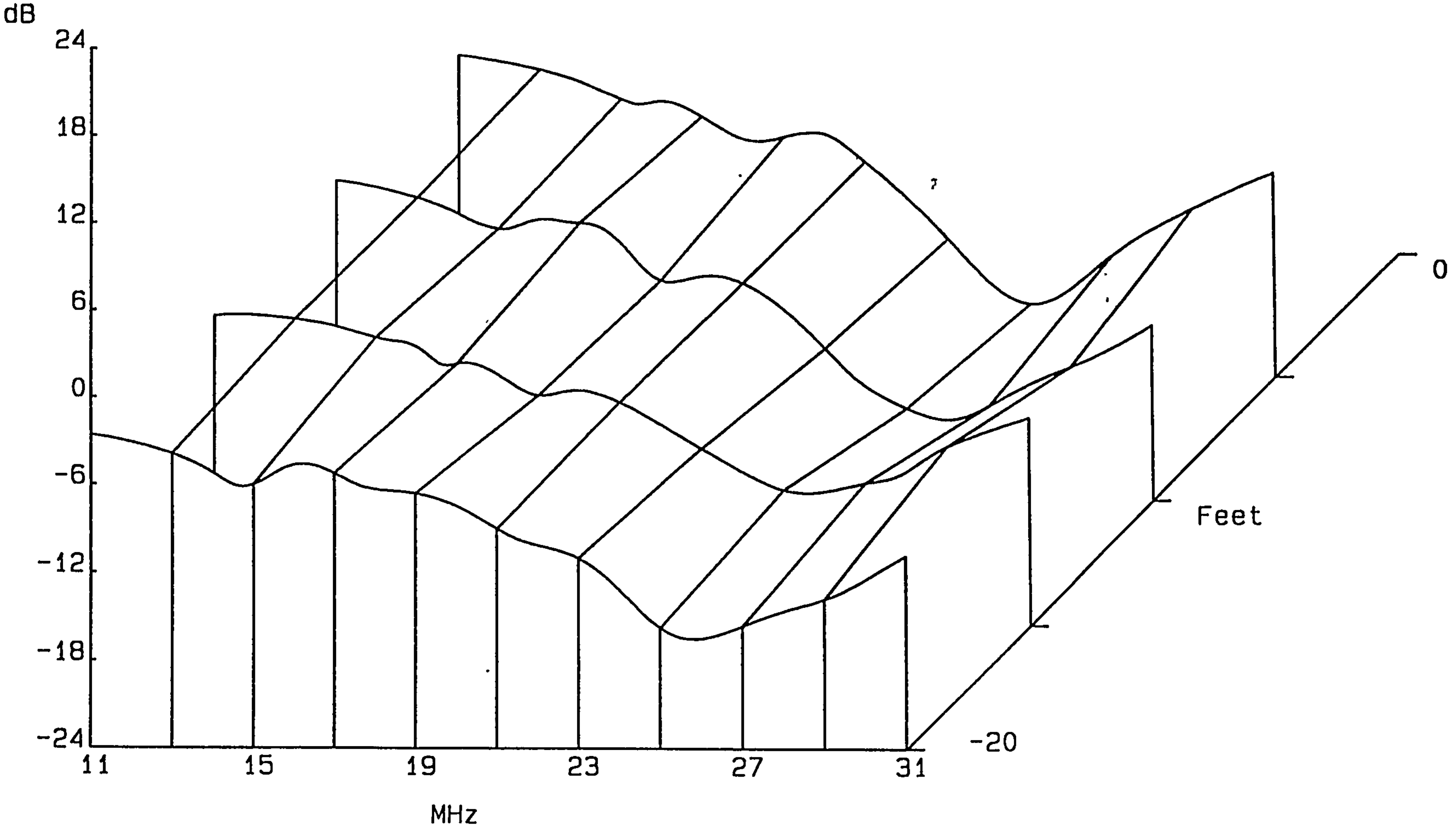
16-Dec-94

Scan of A2



16-Dec-94

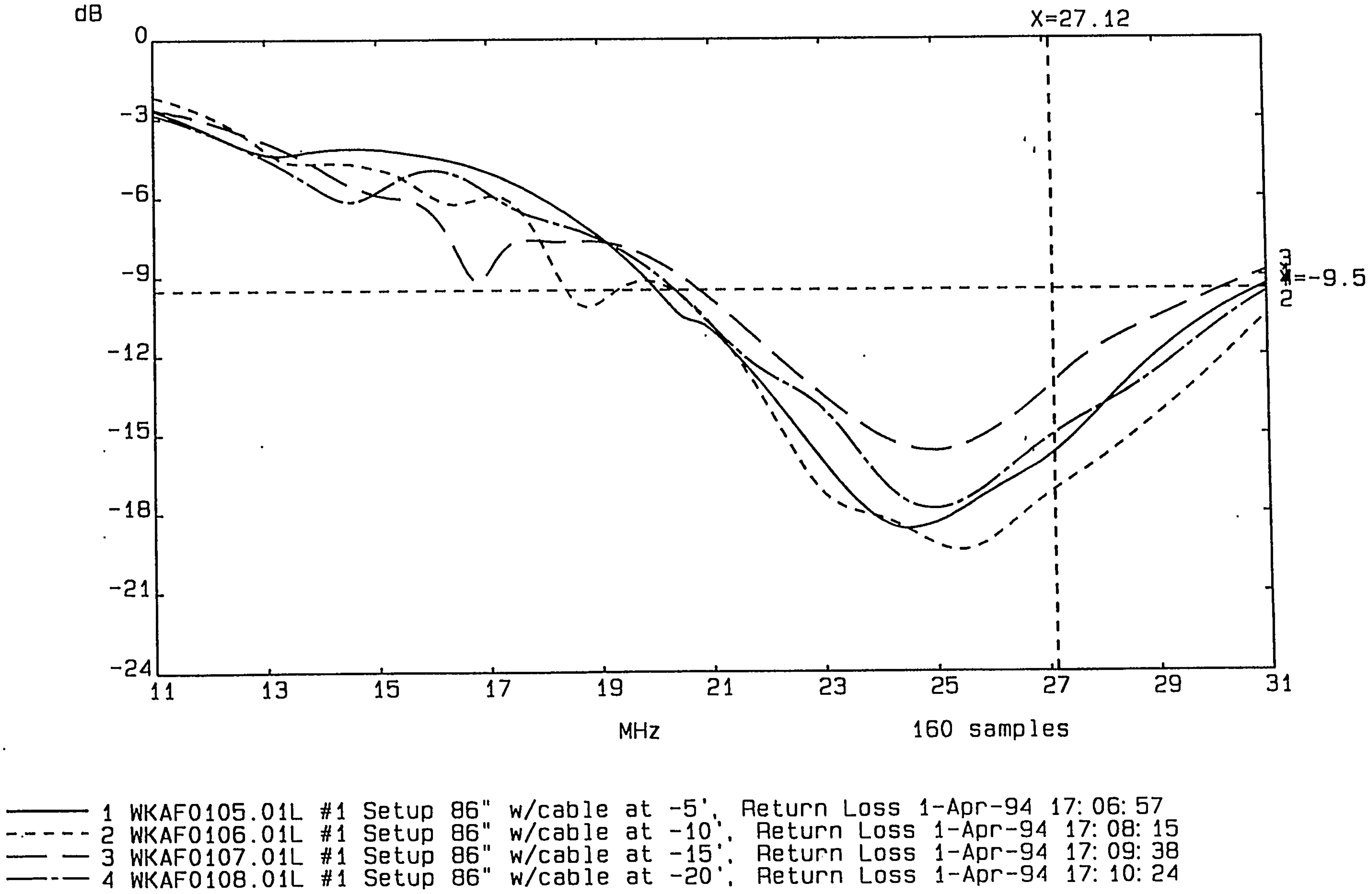
Scan of A2 - WKAF0109.01L #1 Setup 82", Return Loss 1-Apr-94 17:21:36



15-Dec-94

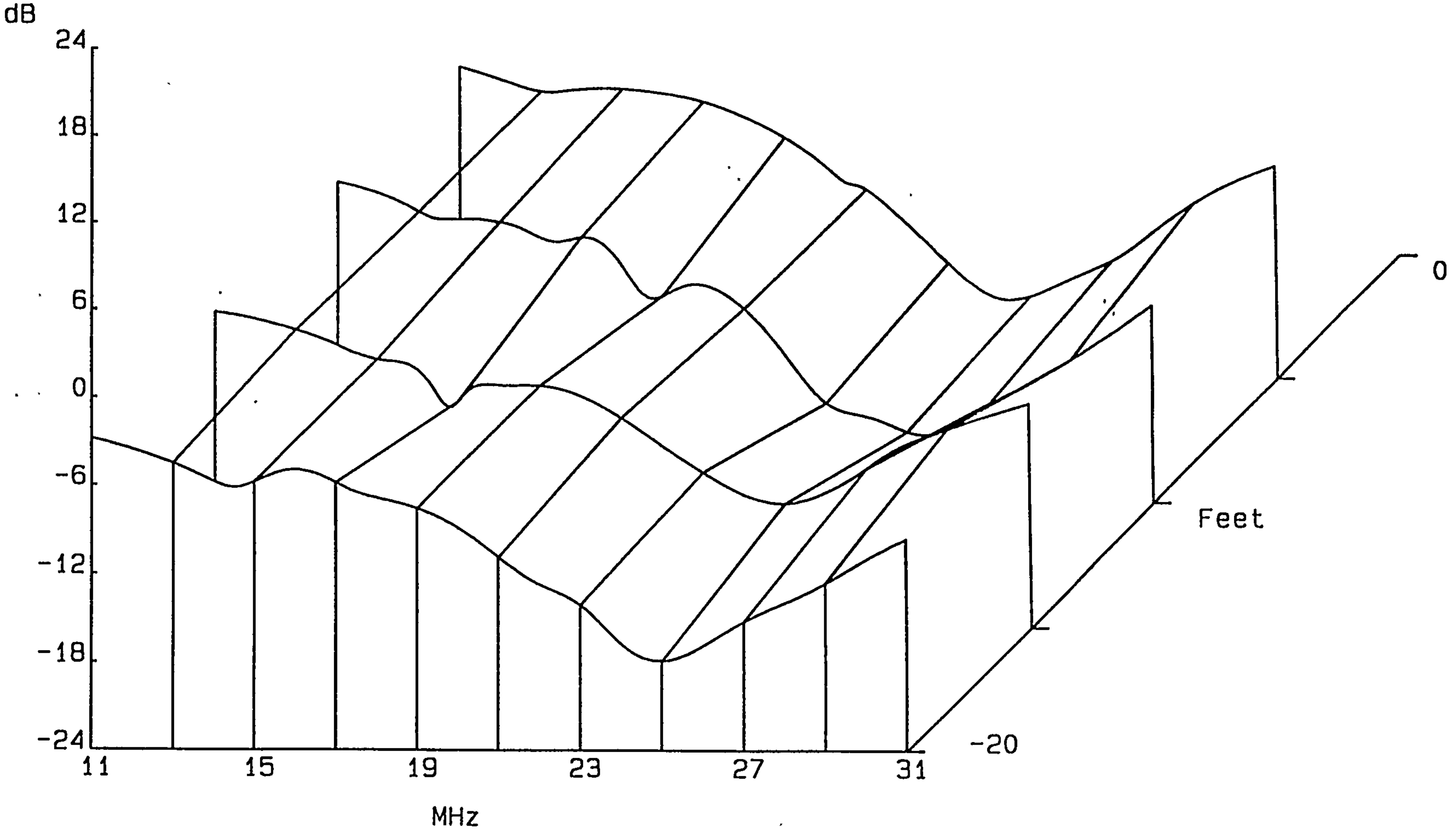
wa03.pct

Scan of A2



16-Dec-94

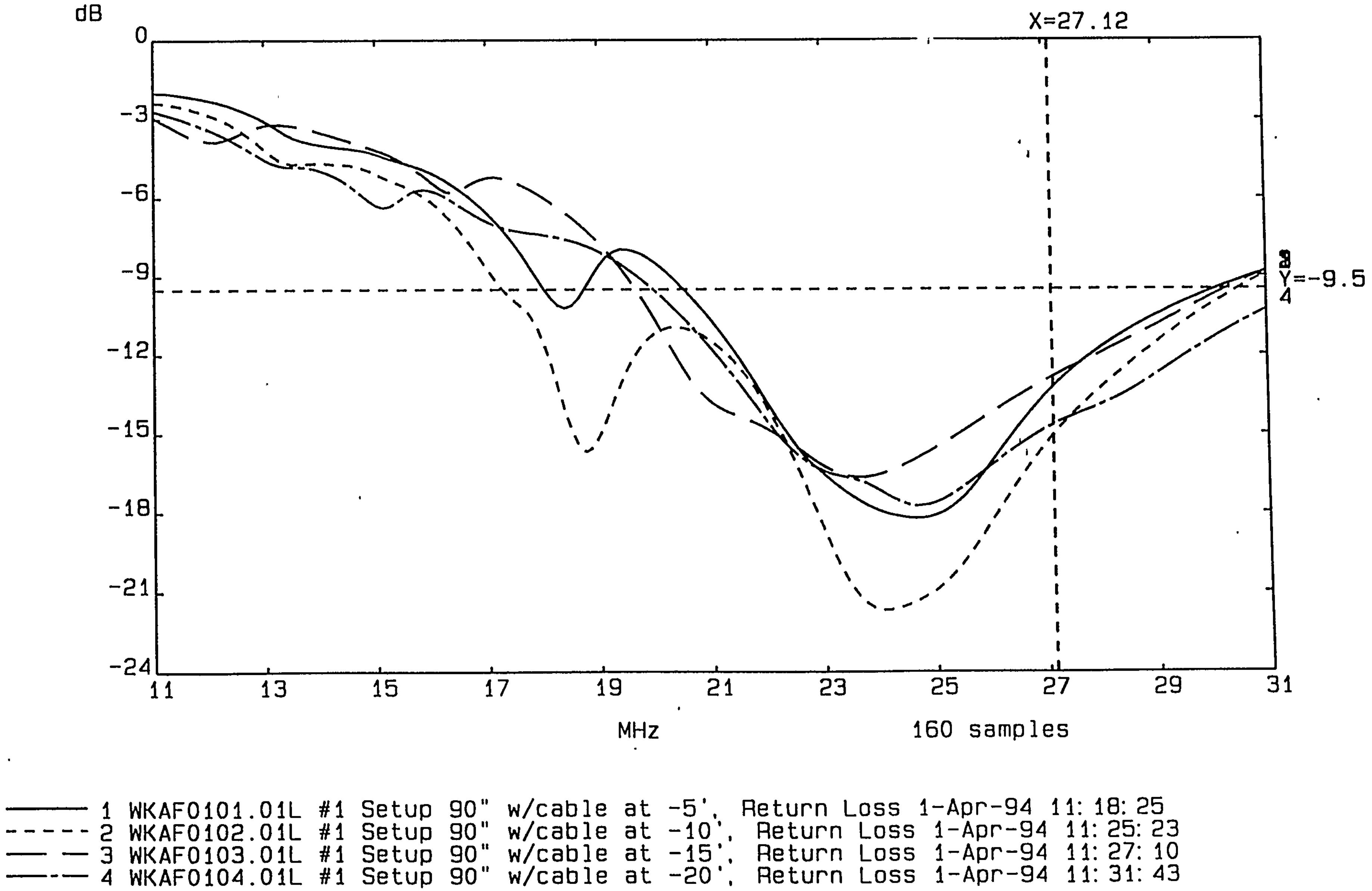
Scan of A2 - WKAF0105.01L #1 Setup 86", Return Loss 1-Apr-94 17:06:57



15-Dec-94

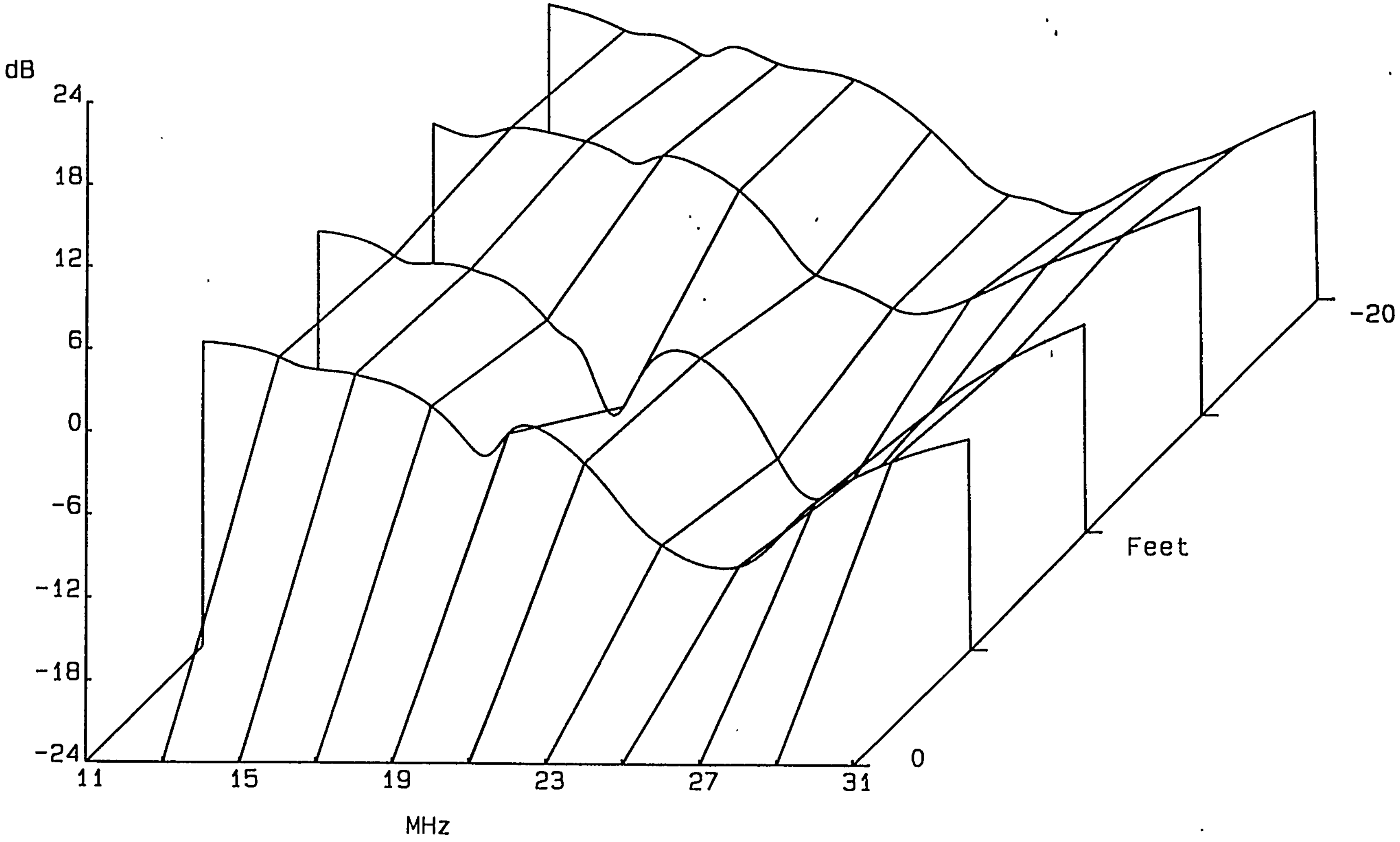
wuu2-pls

1\1000. PLT



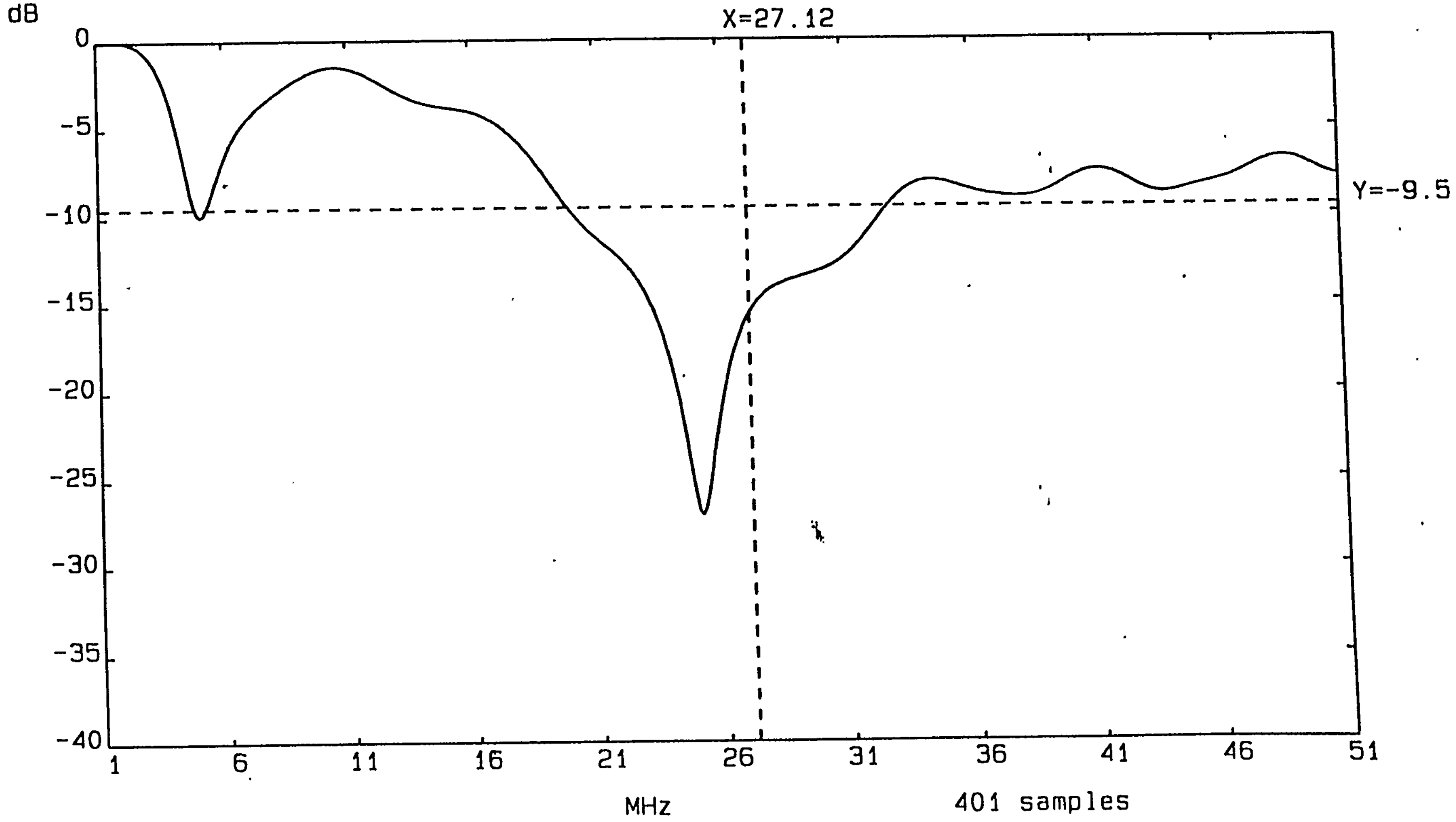
15-Dec-94

WKAF0101.01L #1 Setup 90" w/cable at -5', Return Loss 1-Apr-94 11: 18: 25



15-Dec-94

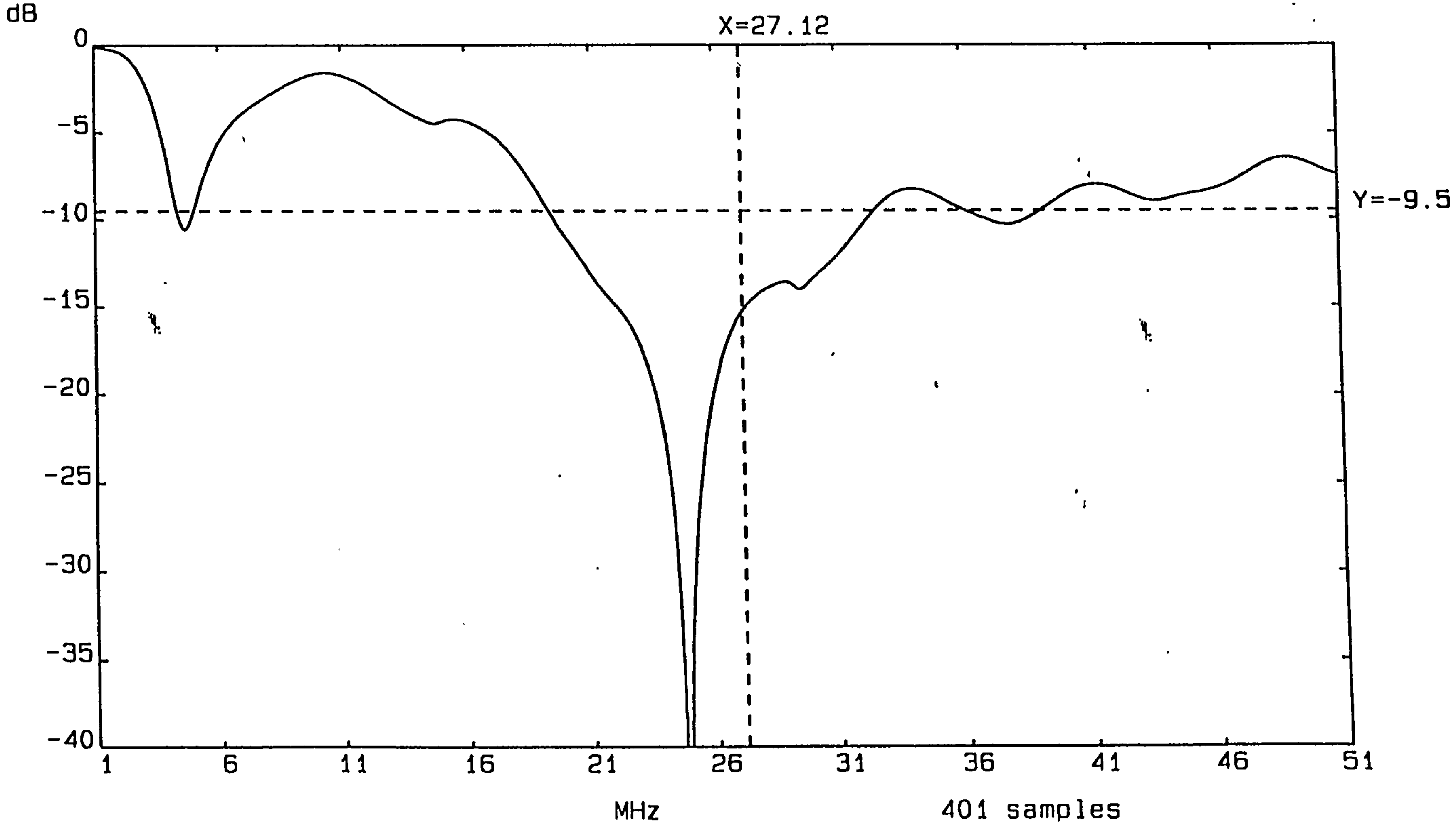
WKAF1001.01L Heat 1 feed A1-pre heat, Return Loss 20-Apr-94 16: 48: 35



Instr=HP3577A, H units=Hz, V units=dB, Npw= 401, VSCL= 10 T1,
Freq MHz= 26, H span MHz= 50, Res KHz= 1, Avg= 1, Wscale= 100,

21-May-94

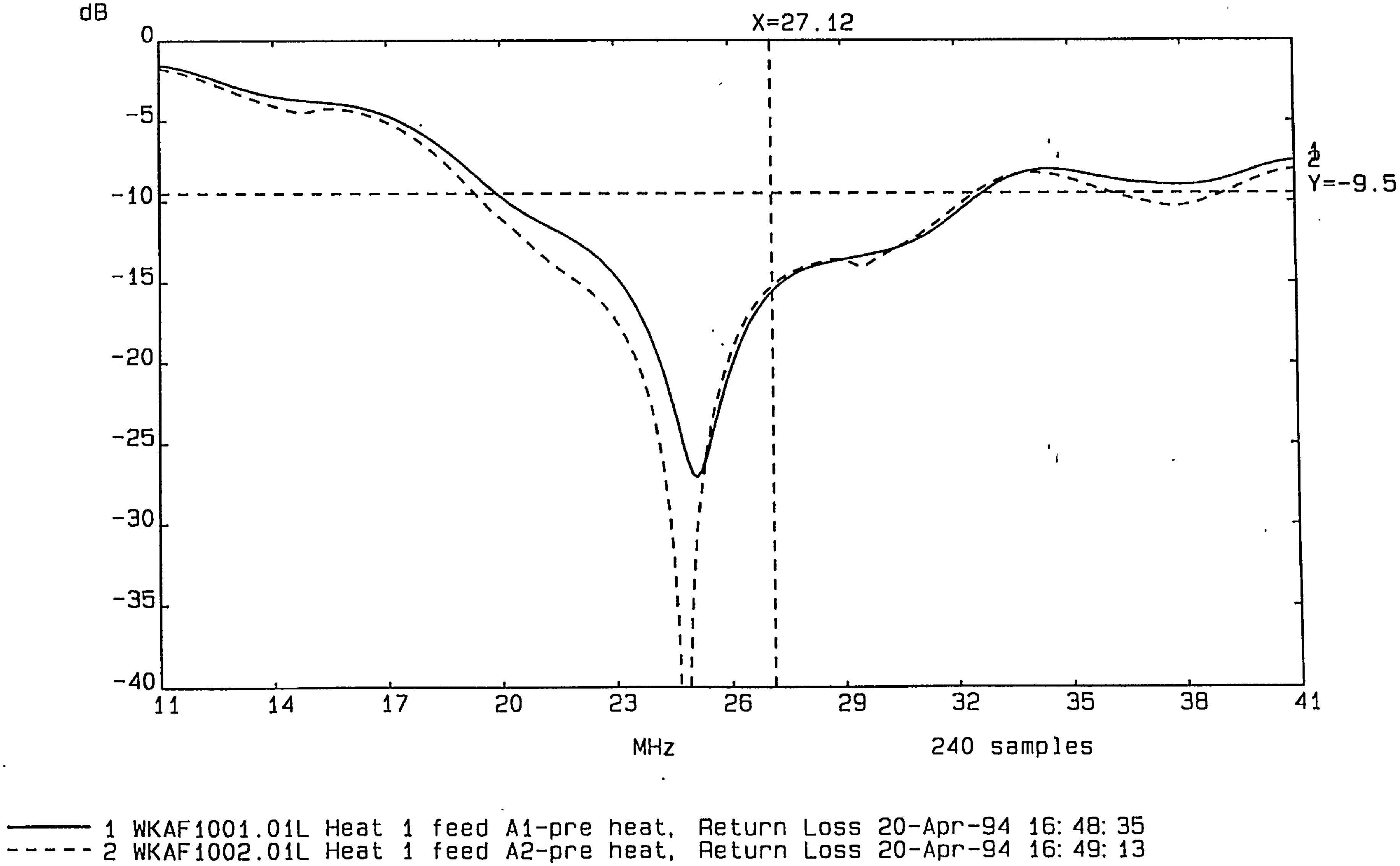
WKAF1002.01L Heat 1 feed A2-pre heat, Return Loss 20-Apr-94 16: 49: 13



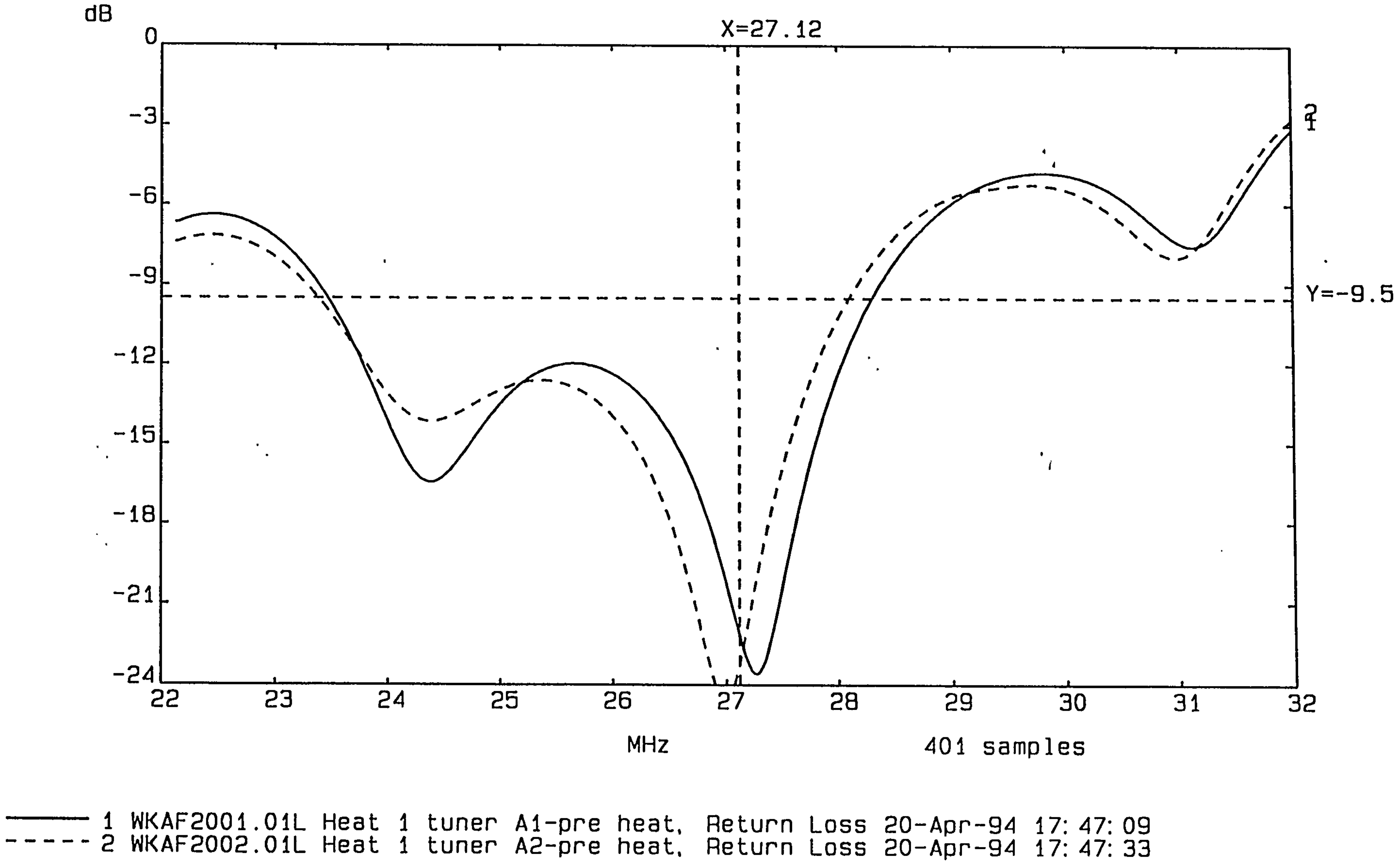
Instr=HP3577A, H units=Hz, V units=dB, Npw= 401, VSCL= 10 T1,
Freq MHz= 26, H span MHz= 50, Res KHz= 1, Avg= 1, Wscale= 100,

21-May-94

Pre-heat Return Loss Measurements of Applicator #1 (A2) and #2 (A1)

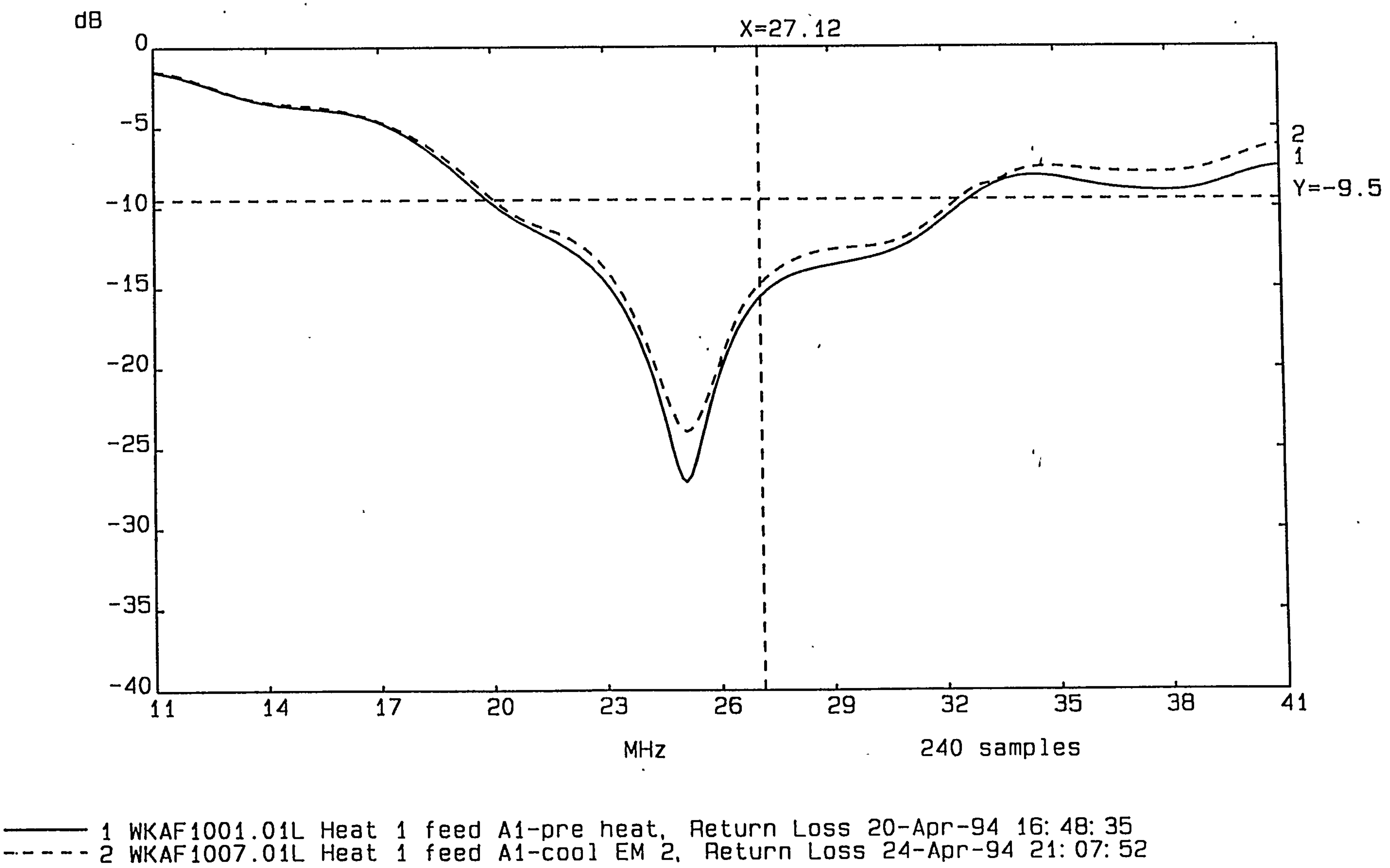


Pre-heat Return Loss Measurements of Applicator #1 (A2) and #2 (A1) w/tuner



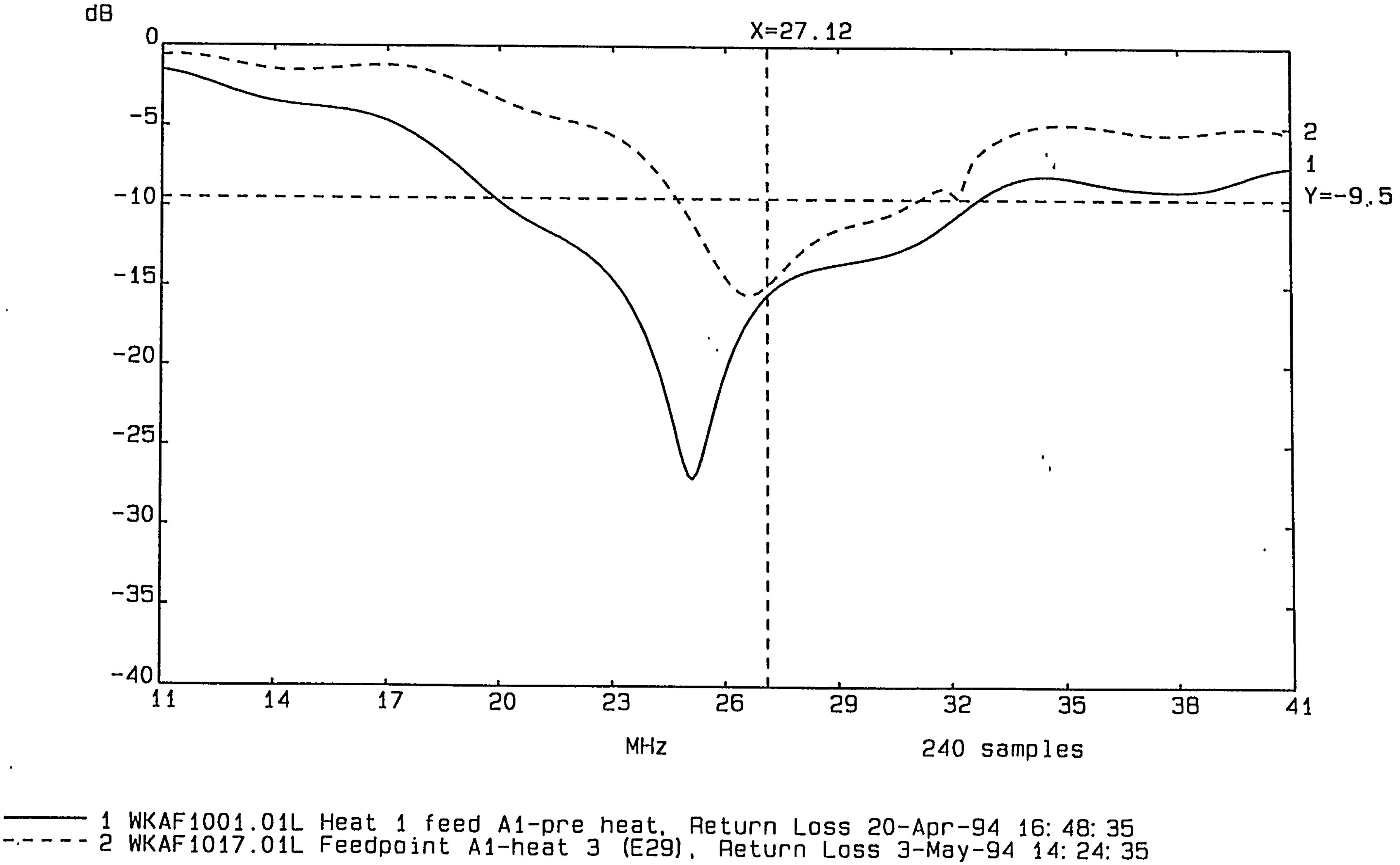
16-Dec-94

Return Loss Measurements of Applicator #1 after 62 KWH of energy to preheat



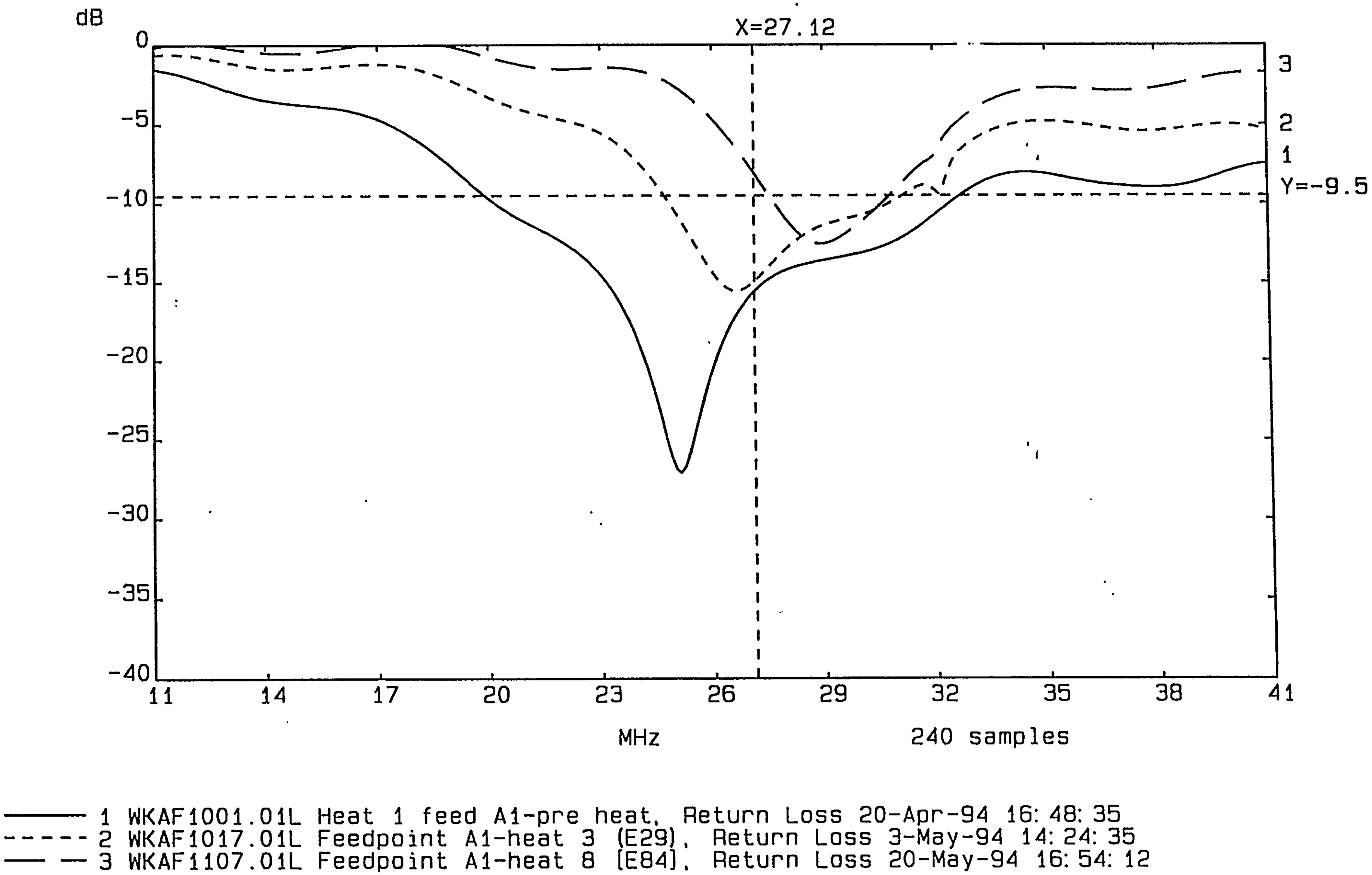
17-Dec-94

Return Loss comparison of Applicator #1 after over 1700 KWH of energy applied



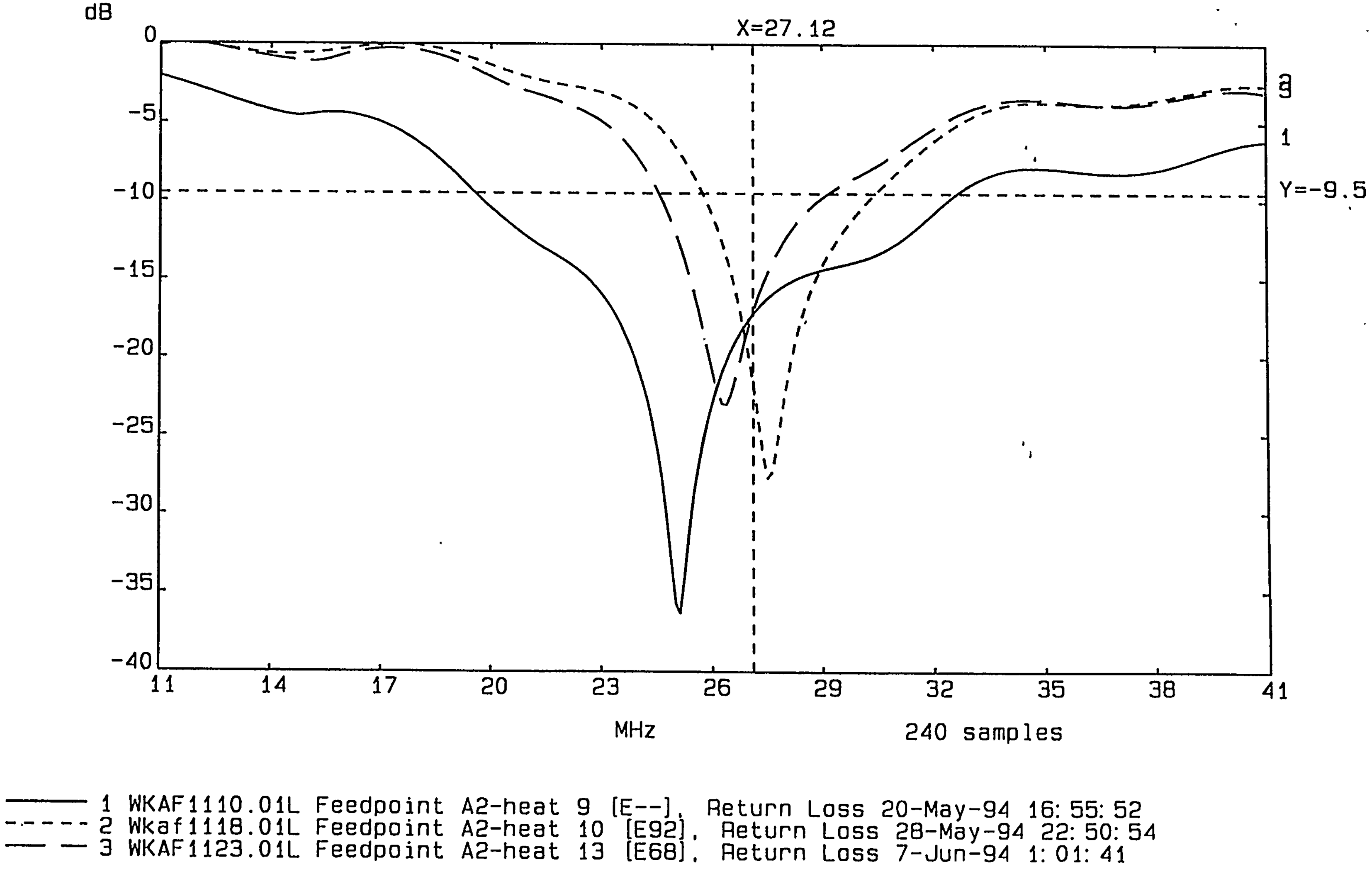
17-Dec-94

Applicator #1 - First heating period



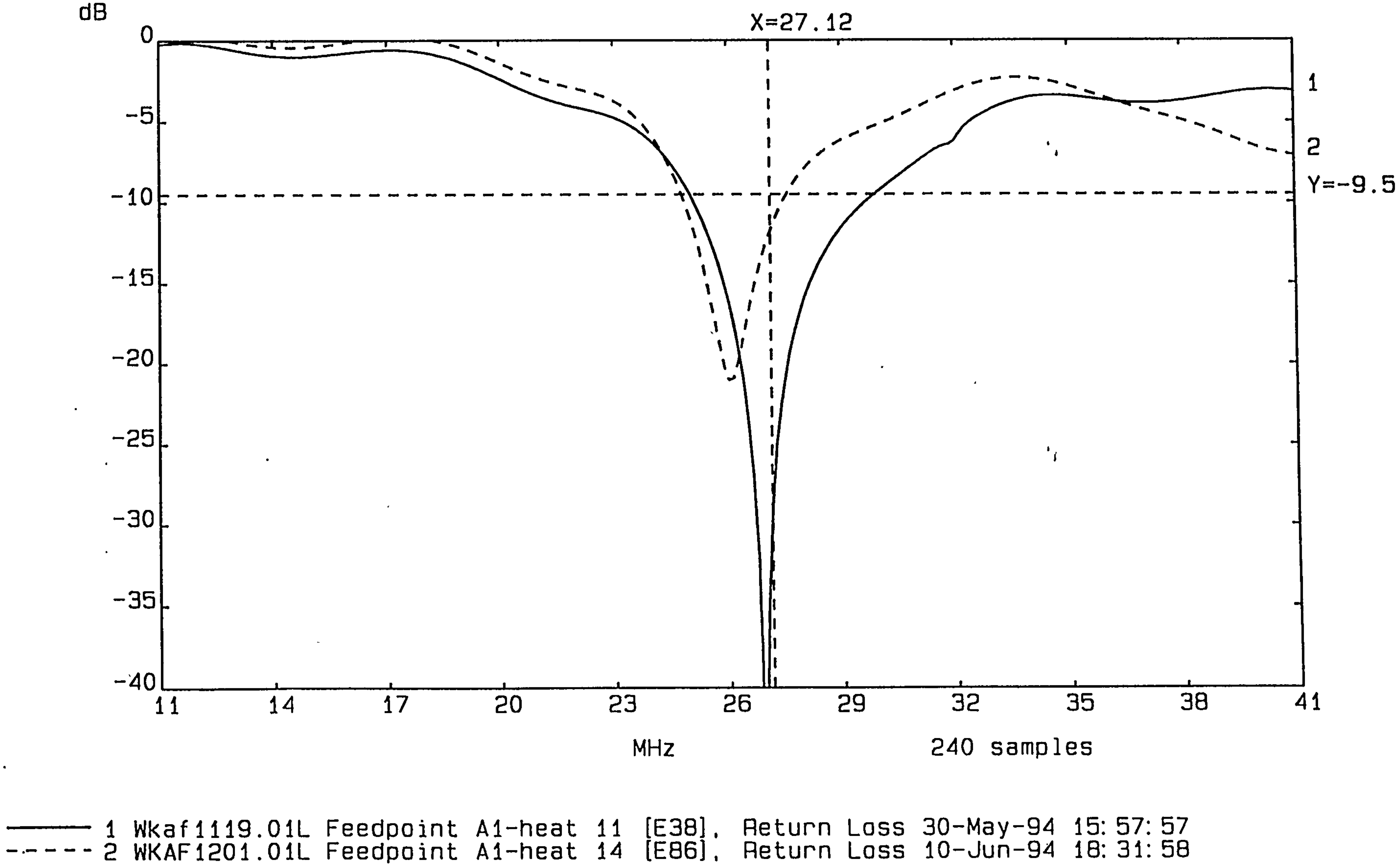
17-[illegible]-94

Applicator #2 - heating period

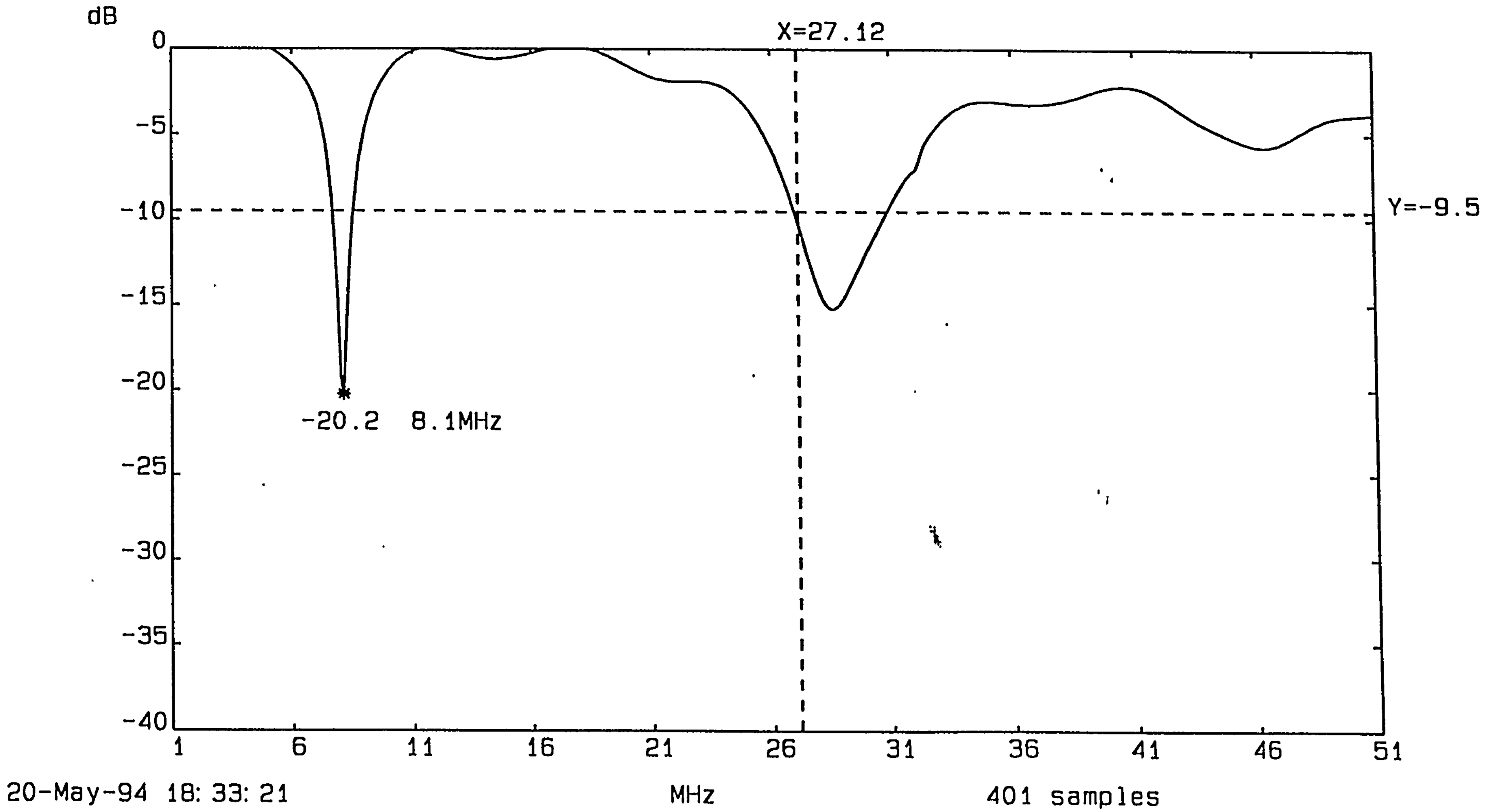


17-Dec-94

Applicator #1 - Second heating period



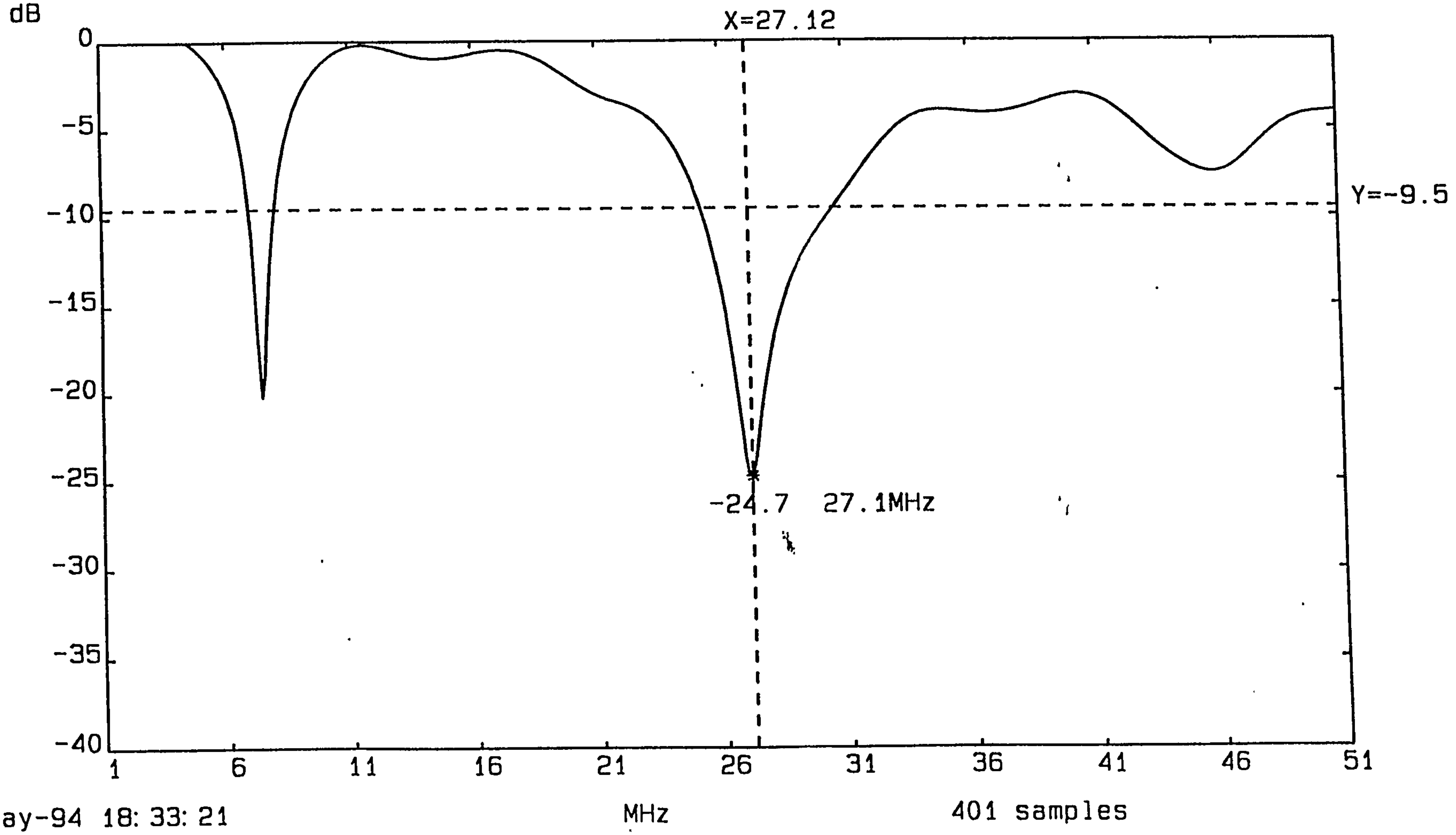
WKAF1113.01L Feedpoint A1-heat 9 [E93], Return Loss 24-May-94 21: 13: 23



Instr=HP3577A, H units=Hz, V units=dB, Npw= 401, VSCL= 10 T1,
Freq MHz= 26, H span MHz= 50, Res KHz= 1, Avg= 1, Wscale= 100,

25-May-94

WKAF1114.01L Feedpoint A2-heat 9 [E93], Return Loss 24-May-94 21:12:16

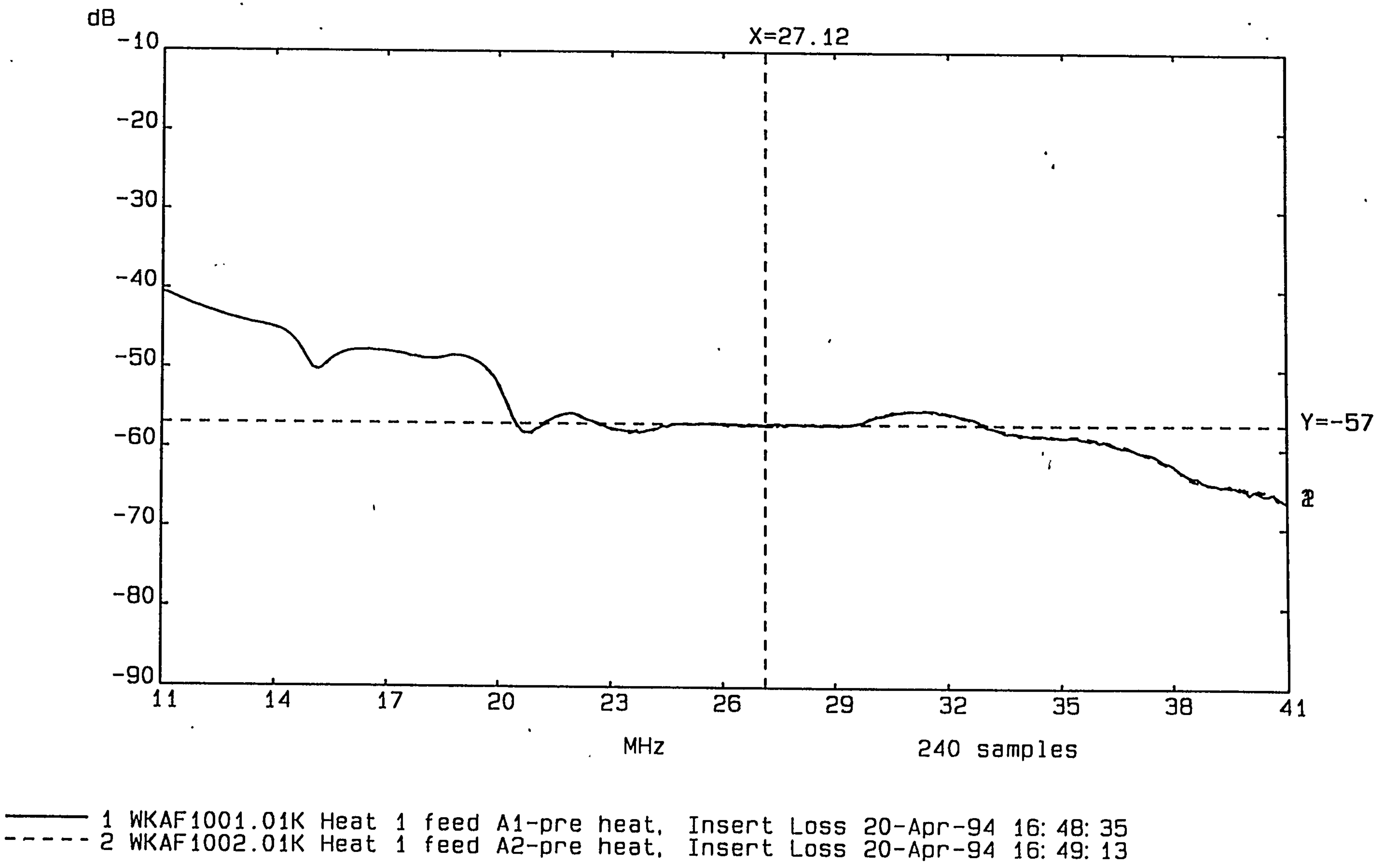


20-May-94 18:33:21

Instr=HP3577A, H units=Hz, V units=dB, Npw= 401, VSCL= 10 T1,
Freq MHz= 26, H span MHz= 50, Res KHz= 1, Avg= 1, Wscale= 100.

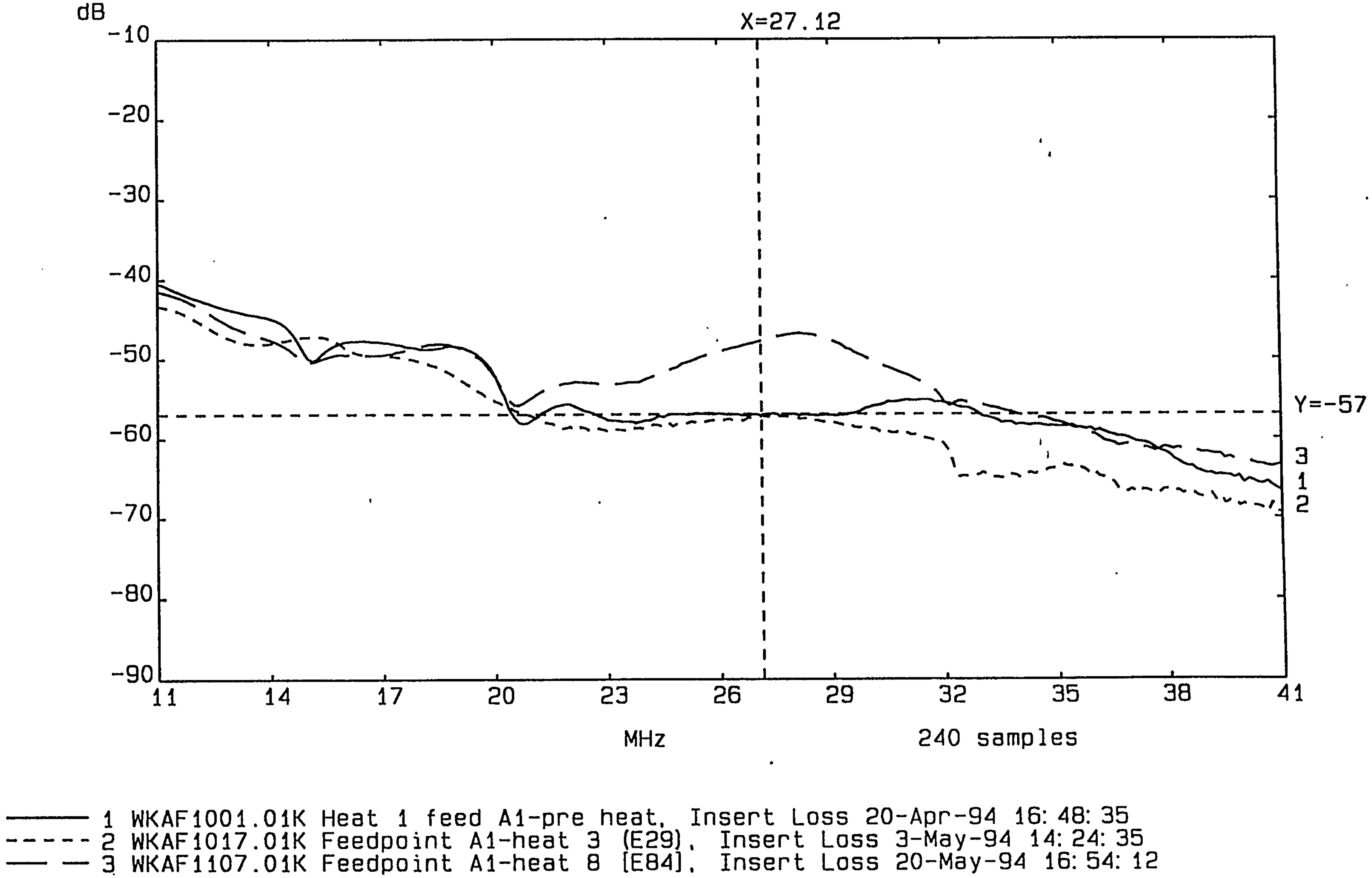
25-May-94

Pre-heat Insert Loss Measurements of Applicator #1 (A2) and #2 (A1)



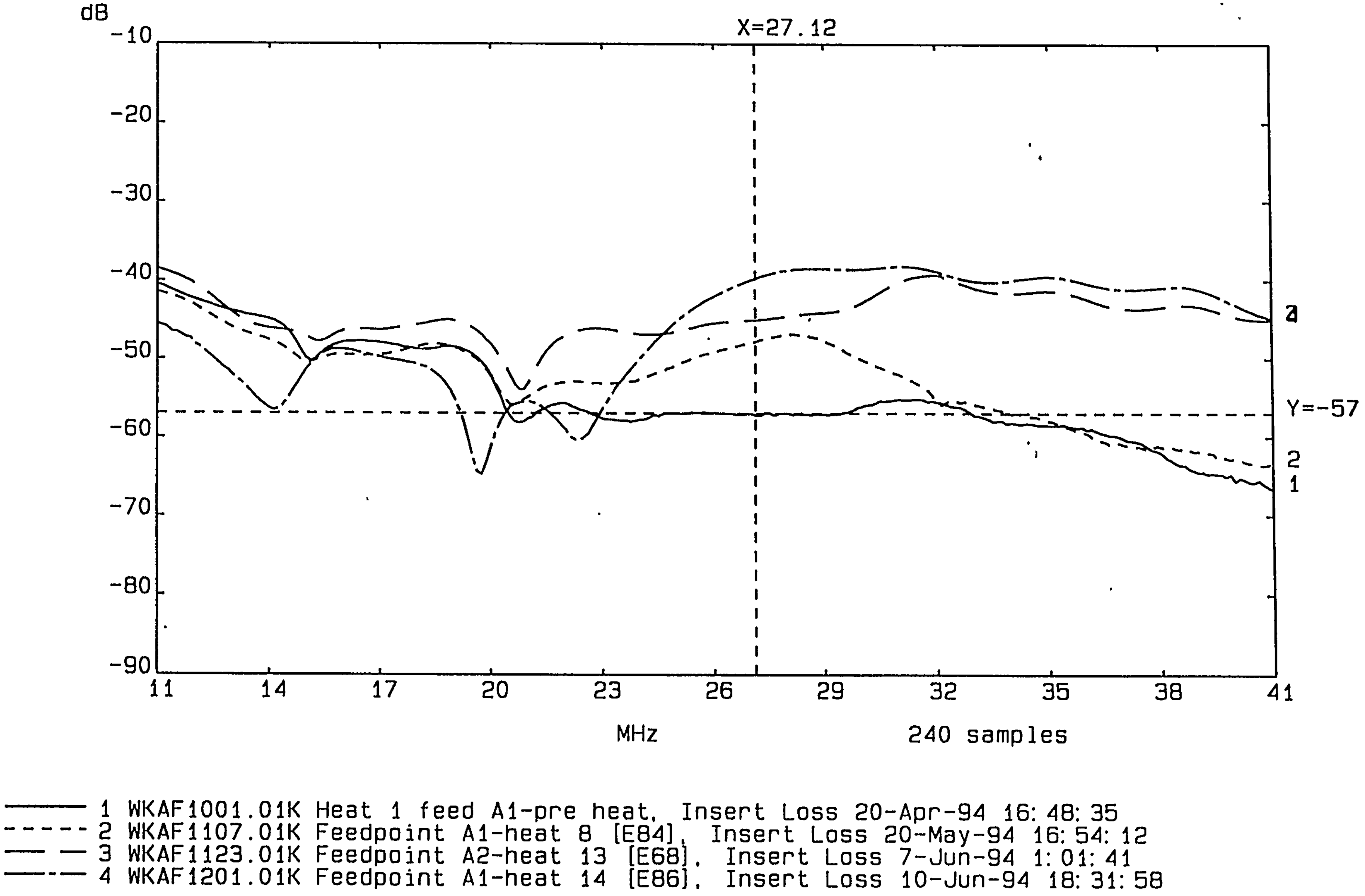
16-Dec-94

Applicator #1 - First heating period



17-Dec-94

Applicator #1 to Applicator #2 insertion loss - across entire program



17-Dec-94

APPENDIX H - RF System Emission Measurements

RF emission compliance under FCC part 18.301 and surface field strength compliance under (IEEE standard C95.1-1991).

- RF emission measurements

  Measurements for compliance under FCC part 18.305 (b) - Initial submission to USAF WPAFB on 25 April 1994.

  Measurements for compliance under FCC part 18.305 (b) for: 3 May, 18 May, 24 May, 6 June, 7 June, 8 June, and 10 June. Submitted to USAF WPAFB at close of program.

  Plot of Radiated E-Field over 7 to 77 day span - fundamental and harmonics at 300 m
  Plot of Radiated E-Field over 7 to 77 day span - fundamental and harmonics at 10 m and 300 m
  Plot of Radiated E-Field over 7 to 77 day span - fundamental and harmonics at 10 m

- Electric and Magnetic Field Measurements

  Table summary of Isotropic probe safety measurements from 13 April to 9 June 1994.
  Plot of Radiated E-Field over 7 to 77 day span - isotropic probe measurements at 1 m and 3 m

END FILE: KELLYH.A

Measurements for compliance under FCC part 18.305 (b)

Kelly AFB, San Antonio TX, RF Heating site S-1
Reference files: TKEL03, labled HEAT 1, EM 3 measurements.
Start: 13:32 on 25 April 1994, Complete 14:45
Measured by : D. Faust, Sgt. Johnson

Measured values that address compliance with FCC regulations are boxed

Frequency: ISM frequency 27.12 MHz +/- 163.0 kHz

ISM Frequency (MHz)		Frequency measured by HP 8591E Sectrum Analyzer.
27.12	Fundamental	27.1335 (-13.5 kHz from center of ISM operating band)
54.24	1st harmonic	54.2685
81.36	2nd harmonic	81.402
108.48	3rd harmonic	108.5355
135.6	4th harmonic	135.6685
162.72	5th harmonic	162.802
189.84	6th harmonic	189.931

Initial Field strength summary after approximately 14 hours of heating time.
Measured with: EMCO 3104C Biconical antenna, vertical polarization at 2 m height and HP 8591E spectrum analyzer w/EMC measurement option.

Near field 10 meter measurements - baseline for harmonic attenuation measurements.
Measurement of fundamental & harmonics w/ 9 kHz EMI bandwidth w/100 AVG

RF Gen. Power kW	**Spectrum Analyzer** dBuV	**80 ft feed Cable** dB attn.	**Biconical A.F. cal** dB/m	**Corrected E-Field** dBuV/m	**Correcte E-Field** uV/m	**Measured Freq.** MHz	**Biconical Location** Range & path
13	95.2	0.745	14.1	110.045	317,870	27.1335	10 m East
13	19.45	1.01	10	30.46	33	54.2685	10 m East
13	44.6	1.234	6.86	52.694	431	81.402	10 m East
13	23.45	1.427	12.91	37.787	78	108.5355	10 m East
13	34.5	1.624	13.1	49.224	289	135.6685	10 m East
13	34.8	1.761	14.8	51.361	370	162.802	10 m East
13	16.5	1.897	16.9	35.297	58	189.931	10 m East
13	95.65	0.745	14.1	110.495	334,773	27.1335	10m South
13	22.8	1.01	10	33.81	49	54.2685	10m South
13	46.4	1.234	6.86	54.494	531	81.402	10m South
13	26.2	1.427	12.91	40.537	106	108.5355	10m South
13	23.45	1.624	13.1	38.174	81	135.6685	10m South
13	39.19	1.761	14.8	55.751	613	162.802	10m South
13	11.38	1.897	16.9	30.177	32	189.931	10m South
13	84.5	0.745	14.1	99.345	92,736	27.1335	10 m North
13	21.9	1.01	10	32.91	44	54.2685	10 m North
13	47.1	1.234	6.86	55.194	575	81.402	10 m North
13	19	1.427	12.91	33.337	46	108.5355	10 m North
13	27.4	1.624	13.1	42.124	128	135.6685	10 m North
13	34.4	1.761	14.8	50.961	353	162.802	10 m North
13	35.12	1.897	16.9	53.917	496	189.931	10 m North

Far field, 300 meter measurements, Part 18.305(b) specific.

The following measurements established a noise floor with a 200 Hz bandwidth & 5 AVG

NOTE: if the signal is not detectable to the noise floor (N.F.) the spectrum analyzer.
column is the noise floor level and the field level is corrected to estimate the ambient noi

RF Gen. Power kW	Spectrum Analyzer dBuV	80 ft feed Cable dB attn.	Biconical A.F. cal dB/m	Corrected E-Field dBuV/m	Correcte E-Field uV/m	Measured Freq. MHz	Biconical Location Range & path
13	40.2	0.745	14.1	55.045	565	27.1335	300 m West
13	*-11*	1.01	10	*0.01*	1	54.2685	300 m West
13	*-9.7*	1.234	6.86	*-1.606*	1	81.402	300 m West
13	*-14.19*	1.427	12.91	*0.147*	1	108.5355	300 m West
13	*-11.49*	1.624	13.1	*3.234*	1	135.6685	300 m West
13	*-12.65*	1.761	14.8	*3.911*	2	162.802	300 m West
13	*-13.13*	1.897	16.9	*5.667*	2	189.931	300 m West
	N.F.			*N.F.*			

Note above that harmonics were not detectable
The values listed are the noise floor signal levels o

NOTE: harmonic levels for the 27.12 MHz ISM frequency are to be 169 uV/m or 44.58 dBuV/m. When the power is increased from 13 kW to 23 kW the field values listed above will increase by 2.47 dB.

Far field, 1600 m measurements, Part 18(b)(1) specific.

This measurement is to be performed for full compliance, however, due to the low fundamental and unmeasurable harmonic components observed at the 300 m West site, it is unlikely that significant signal levels will be detected at this point.
NOTE: The allowed harmonic levels for this frequency are not to exceed 10 uV/m which is 20 dBuV/
The fundamental frequency of 27.12 MHz is not predicted to be greater than this level.
Therefore the harmonics are unlikely to be measurable.

NOTE: The 300 m West path is the least electromagnetically obstructed of all of the measurement paths surrounding the test site.

Measurements for compliance under FCC part 18.305 (b)

Continued Electromagnetic Emission Monitoring

RF Heating site S-1
Kelly AFB, TX

Date of Measurement	**Tuesday May 3, 1994, 14:01**
Data logging file name:	TKEL04
Measurements by:	David L. Faust, KAI Technologies Inc.

Near field 10 meter measurements **Applicator #1**

Measurement of fundamental & harmonics w/ 9 kHz EMI bandwidth w/100 AVG

RF Gen.	**Spectrum**	**80 ft feed**	**Biconical**	**Corrected**	**Corrected**	**Measured**	**Biconical**
Power	**Analyzer**	**Cable**	**A.F. cal**	**E-Field**	**E-Field**	**Freq.**	**Location**
kW	dBuV	dB attn.	dB/m	dBuV/m	uV/m	MHz	Range & path
18.58	99.82	0.745	14.1	114.665	541,066	27.1345	10 m East
18.58	32.7	1.01	10	43.71	153	54.2683	10 m East
18.58	47.2	1.234	6.86	55.294	582	81.401	10 m East
18.58	32.4	1.427	12.91	46.737	217	108.5355	10 m East
18.58	42.56	1.624	13.1	57.284	731	135.6685	10 m East
18.58	45.2	1.761	14.8	61.761	1,225	162.802	10 m East
18.58	15.8	1.897	16.9	34.597	54	189.931	10 m East

Date of Measurement	**Wednesday, May 18, 1994, 18:31**
Data logging file name:	TKEL08
Measurements by:	David L. Faust, KAI Technologies Inc.

Near field 10 meter measurements **Applicator #1**

Measurement of fundamental & harmonics w/ 9 kHz EMI bandwidth w/100 AVG

RF Gen.	**Spectrum**	**80 ft feed**	**Biconical**	**Corrected**	**Corrected**	**Measured**	**Biconical**
Power	**Analyzer**	**Cable**	**A.F. cal**	**E-Field**	**E-Field**	**Freq.**	**Location**
kW	dBuV	dB attn.	dB/m	dBuV/m	uV/m	MHz	Range & path
20	102.7	0.745	14.1	117.545	753,789	27.135	10 m East
20	39.64	1.01	10	50.65	341	54.2685	10 m East
20	37.35	1.234	6.86	45.444	187	81.402	10 m East
20	31.94	1.427	12.91	46.277	206	108.5355	10 m East
20	40	1.624	13.1	54.724	545	135.6685	10 m East
20	39	1.761	14.8	55.561	600	162.802	10 m East
20	30.46	1.897	16.9	49.257	290	189.931	10 m East

Vector Voltmeter reading w/70 dB coupler

108.1 dBuV Forward + 70 dB coupling factor
100.4 dBuV Reverse + 70 dB coupling factor

Date of Measurement **Wednesday, May 24, 1994, 21:57**
Data logging file name TKEL10
Measurements by: David L. Faust, KAI

Near field 10 meter measurements **Applicator #2**
Measurement of fundamental & harmonics w/ 9 kHz EMI bandwidth w/100 AVG

RF Gen. Power kW	**Spectrum Analyzer** dBuV	**80 ft feed Cable** dB attn.	**Biconical A.F. cal** dB/m	**Corrected E-Field** dBuV/m	**Corrected E-Field** uV/m	**Measured Freq.** MHz	**Biconical Location** Range & path
21.5	95.65	0.745	14.1	110.495	334,773	27.1343	10 m East
21.5	34.82	1.01	10	45.83	196	54.2675	10 m East
21.5	45.01	1.234	6.86	53.104	452	81.402	10 m East
21.5	38.96	1.427	12.91	53.297	462	108.5345	10 m East
21.5	45.85	1.624	13.1	60.574	1,068	135.6683	10 m East
21.5	50	1.761	14.8	66.561	2,128	162.8018	10 m East
21.5	49.27	1.897	16.9	68.067	2,531	189.9353	10 m East

Vector Voltmeter reading w/70 dB coupler
109.5 dBuV Forward + 70 dB coupling factor
dBuV Reverse + 70 dB coupling factor

Date of Measurement **Monday, June 6, 1994, 21:23**
Data logging file name TKEL13
Measurements by: D. Faust

Near field 10 meter measurements **Applicator #1**
Measurement of fundamental & harmonics w/ 9 kHz EMI bandwidth w/100 AVG

RF Gen. Power kW	**Spectrum Analyzer** dBuV	**80 ft feed Cable** dB attn.	**Biconical A.F. cal** dB/m	**Corrected E-Field** dBuV/m	**Corrected E-Field** uV/m	**Measured Freq.** MHz	**Biconical Location** Range & path
23.57	105.27	0.745	14.1	120.115	1,013,328	27.1343	10 m East
23.57	40.35	1.01	10	51.36	370	54.2685	10 m East
23.57	40.68	1.234	6.86	48.774	275	81.402	10 m East
23.57	31.76	1.427	12.91	46.097	202	108.5355	10 m East
23.57	34.3	1.624	13.1	49.024	283	135.6685	10 m East
23.57	30.09	1.761	14.8	46.651	215	162.802	10 m East
23.57	30.57	1.897	16.9	49.367	294	189.931	10 m East

Vector Voltmeter reading of applicator transmission line w/70 dB coupler
109.9 dBuV Forward + 70 dB coupling factor
101.6 dBuV Reverse + 70 dB coupling factor

Date of Measurement	**Tuesday, June 7, 1994, 00:15 (continued from 6 June)**
Data logging file name	TKEL13
Measurements by:	D. Faust

Far field, 300 meter measurements, Part 18.305(b) specific.

The following measurements established a noise floor with a 200 Hz bandwidth & 5 AVG

NOTE: A harmonic signal was not detectable to the noise floor (N.F.) of these settings. The corrected field levels estimte the strength of the ambient noise.

RF Gen. Power kW	**Spectrum Analyzer** dBuV	**80 ft feed Cable** dB attn.	**Biconical A.F. cal** dB/m	**Corrected E-Field** dBuV/m	**Corrected E-Field** uV/m	**Measured Freq.** MHz	**Biconical Location** Range & path
23.21	63.06	0.745	14.1	77.905	7,857	27.1335	300 m West
23.21	*-1*	-1.01	10	*10.01*	3	54.2685	300 m West
23.21	*1.35*	1.234	6.86	*9.444*	3	81.402	300 m West
23.21	*1*	1.427	12.91	*15.337*	6	108.5355	300 m West
23.21	*0.98*	1.624	13.1	*15.704*	6	135.6685	300 m West
23.21	*-0.42*	1.761	14.8	*16.141*	6	162.802	300 m West
23.21	*0.56*	1.897	16.9	*19.357*	9	189.931	300 m West
	N.F.			*N.F. - no detectable harmonics*			

The following measurement was the only signal detected in the noise floor.

The measurement used a 200 Hz RBW with a 20 kHz span and 100 AVG

23.21	*-4.16*	1.234	6.86	*3.934*	2	81.402	300 m West

Vector Voltmeter reading of applicator transmission line w/70 dB coupler

109.9 dBuV Forward + 70 dB coupling factor

101.6 dBuV Reverse + 70 dB coupling factor

Date of Measurement	**Wednesday, June 8, 1994, 22:45**
Data logging file name	TKEL14
Measurements by:	D. Faust

Near field 10 meter measurements **Applicator #1 (lowered 1.87 ft.)**

Measurement of fundamental & harmonics w/ 9 kHz EMI bandwidth w/100 AVG

RF Gen. Power kW	**Spectrum Analyzer** dBuV	**80 ft feed Cable** dB attn.	**Biconical A.F. cal** dB/m	**Corrected E-Field** dBuV/m	**Corrected E-Field** uV/m	**Measured Freq.** MHz	**Biconical Location** Range & path
23	96.51	0.745	14.1	111.355	369,615	27.1343	10 m East
23	32.6	1.01	10	43.61	152	54.2686	10 m East
23	45.7	1.234	6.86	53.794	489	81.4014	10 m East
23	44.2	1.427	12.91	58.537	845	108.535	10 m East
23	43.9	1.624	13.1	58.624	853	135.6715	10 m East
23	43.65	1.761	14.8	60.211	1,025	162.8058	10 m East
23	34.8	1.897	16.9	53.597	478	189.9353	10 m East

Vector Voltmeter reading of applicator transmission line w/70 dB coupler

109.8 dBuV Forward + 70 dB coupling factor

97.51 dBuV Reverse + 70 dB coupling factor

Date of Measurement **Monday, June 10, 1994, 00:05**
Data logging file name TKEL14
Measurements by: D. Faust

Near field 10 meter measurements **Applicator #1**

Measurement of fundamental & harmonics w/ 9 kHz EMI bandwidth w/100 AVG

RF Gen. Power kW	**Spectrum Analyzer** dBuV	**80 ft feed Cable** dB attn.	**Biconical A.F. cal** dB/m	**Corrected E-Field** dBuV/m	**Corrected E-Field** uV/m	**Measured Freq.** MHz	**Biconical Location** Range & path
23	93.2	0.745	14.1	108.045	252,493	27.1348	10 m East
23	31.03	1.01	10	42.04	126	54.2684	10 m East
23	53.49	1.234	6.86	61.584	1,200	81.4046	10 m East
23	43.3	1.427	12.91	57.637	762	108.5396	10 m East
23	43.75	1.624	13.1	58.474	839	135.6689	10 m East
23	40.9	1.761	14.8	57.461	747	162.8028	10 m East
23	29.89	1.897	16.9	48.687	272	189.9358	10 m East

Vector Voltmeter reading of applicator transmission line w/70 dB coupler

dBuV Forward + 70 dB coupling factor
dBuV Reverse + 70 dB coupling factor

Date of Measurement **Friday, June 10, 1994, 13:48**
Data logging file name TKEL14
Measurements by: David L. Faust, KAI Technologies Inc.
TSGT James Lewis, 651 CCSG/SCSML Kelly AFB

Near field 10 meter measurements **Applicator #1**

Measurement of fundamental & harmonics w/ 9 kHz EMI bandwidth w/100 AVG

RF Gen. **Power** kW	**Spectrum** **Analyzer** dBuV	**80 ft feed** **Cable** dB attn.	**Biconical** **A.F. cal** dB/m	**Corrected** **E-Field** dBuV/m	**Corrected** **E-Field** uV/m	**Measured** **Freq.** MHz	**Biconical** **Location** Range & path
20	99.75	0.745	14.1	114.595	536,723	27.1343	10 m East
20	37.45	-1.01	10	48.46	265	54.2685	10 m East
20	56.85	1.234	6.86	64.944	1,767	81.402	10 m East
20	36.65	1.427	12.91	50.987	354	108.5355	10 m East
20	35.9	1.624	13.1	50.624	340	135.6685	10 m East
20	33.89	1.761	14.8	50.451	333	162.802	10 m East
20	29.82	1.897	16.9	48.617	270	189.931	10 m East

Vector Voltmeter reading of applicator transmission line w/70 dB coupler

109.2 dBuV Forward + 70 dB coupling factor
dBuV Reverse + 70 dB coupling factor

Far field, 300 meter measurements, Part 18.305(b) specific.

The following measurements established a noise floor with a 200 Hz bandwidth & 5 AVG

NOTE: A harmonic signal was not detectable to the noise floor (N.F.) of these settings. The corrected field levels estimate the strength of the ambient noise.

RF Gen. **Power** kW	**Spectrum** **Analyzer** dBuV	**80 ft feed** **Cable** dB attn.	**Biconical** **A.F. cal** dB/m	**Corrected** **E-Field** dBuV/m	**Corrected** **E-Field** uV/m	**Measured** **Freq.** MHz	**Biconical** **Location** Range & path
20	57.7	0.745	14.1	72.545	4,239	27.1343	300 m West
20	*-11.8*	1.01	10	*-0.79*	1	54.26865	300 m West
20	*-12.64*	1.234	6.86	*-4.546*	1	81.4011	300 m West
20	*-14.32*	1.427	12.91	*0.017*	1	108.5372	300 m West
20	*-14.39*	1.624	13.1	*0.334*	1	135.6715	300 m West
20	*-13.29*	1.761	14.8	*3.271*	1	162.94	300 m West
20	*-13.75*	1.897	16.9	*5.047*	2	189.9356	300 m West
	N.F.			*N.F. - no detectable harmonics*			

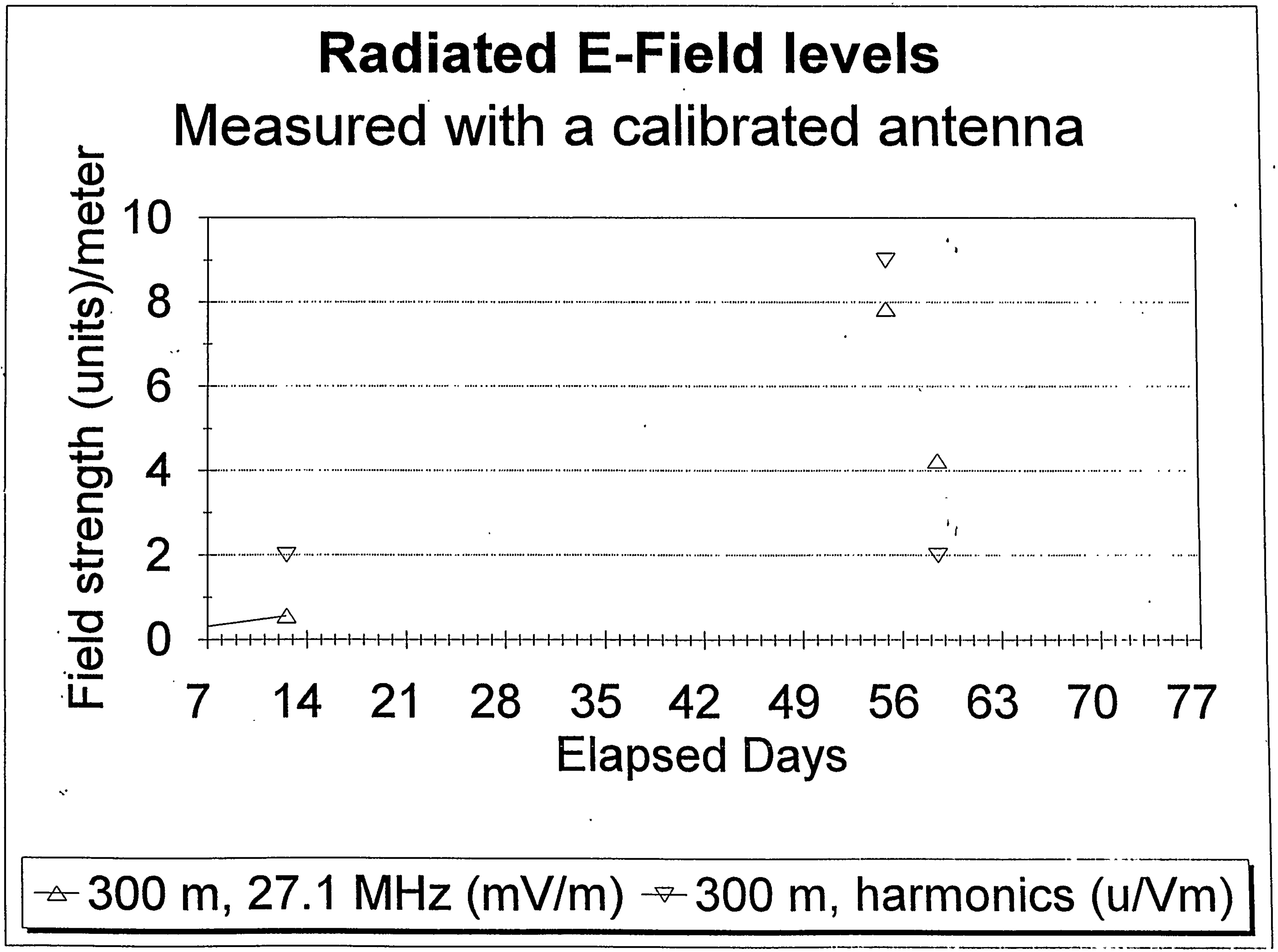
Vector Voltmeter reading of applicator transmission line w/70 dB coupler

109.9 dBuV Forward + 70 dB coupling factor
101.6 dBuV Reverse + 70 dB coupling factor

+++ END OF RF HEATING PROGRAM +++

SUMMARY

Corrected measurements suggest that that both applicators at power levels up to 25 kW operated within FCC part !8.305 (b) requirements.

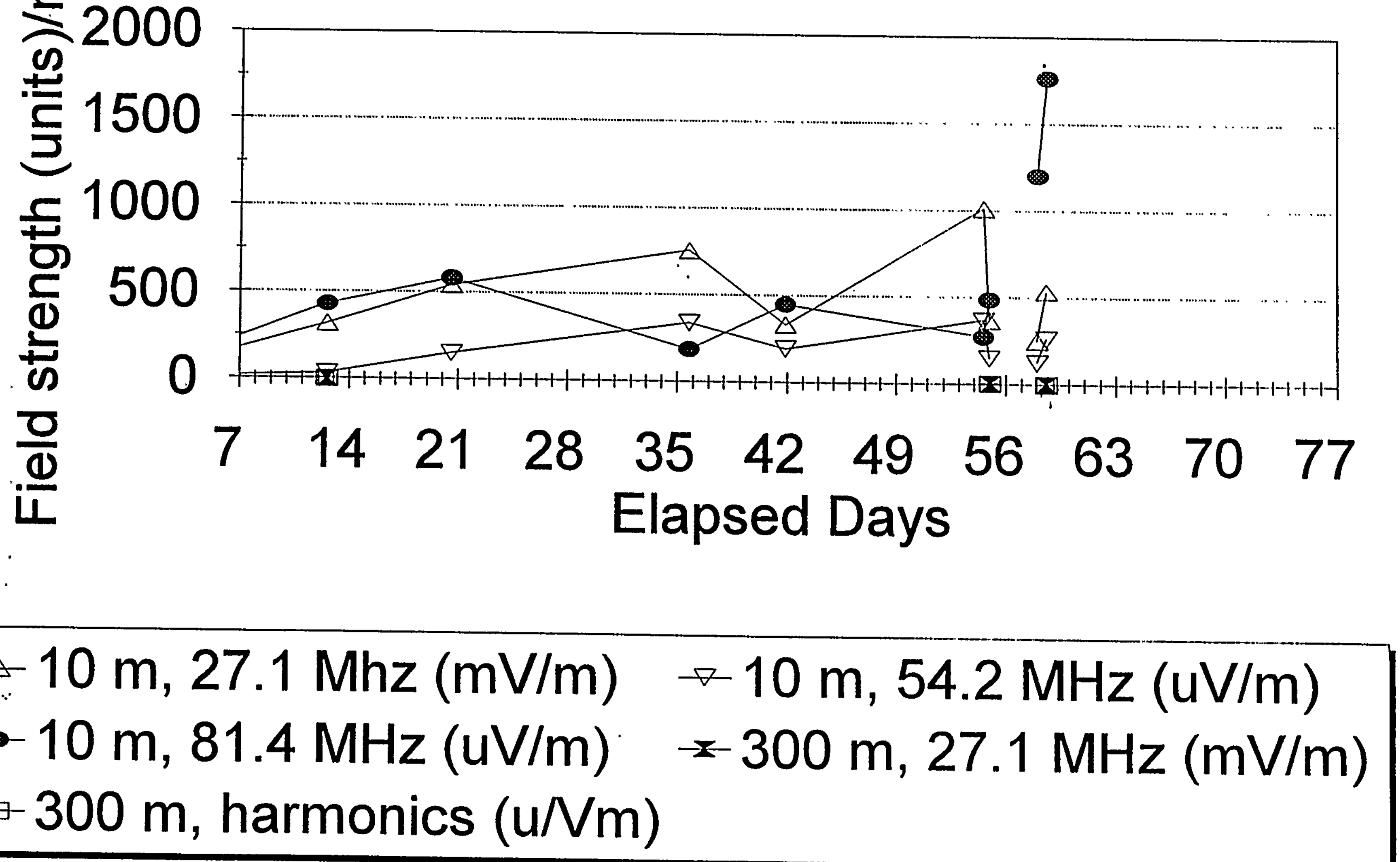


Radiated E-Field levels

Measured with a calibrated antenna

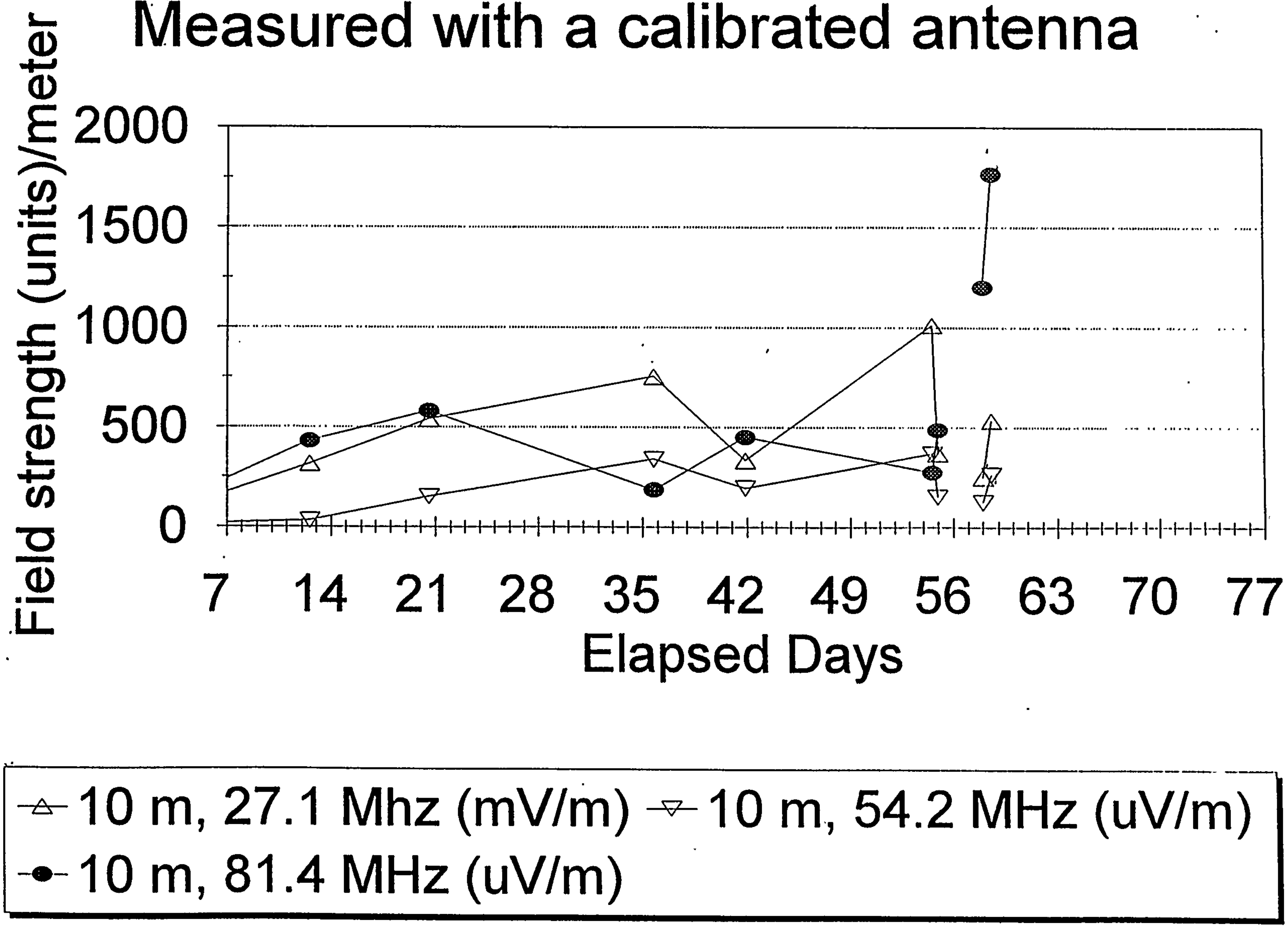
Radiated E-Field levels

Measured with a calibrated antenna



Radiated E-Field levels

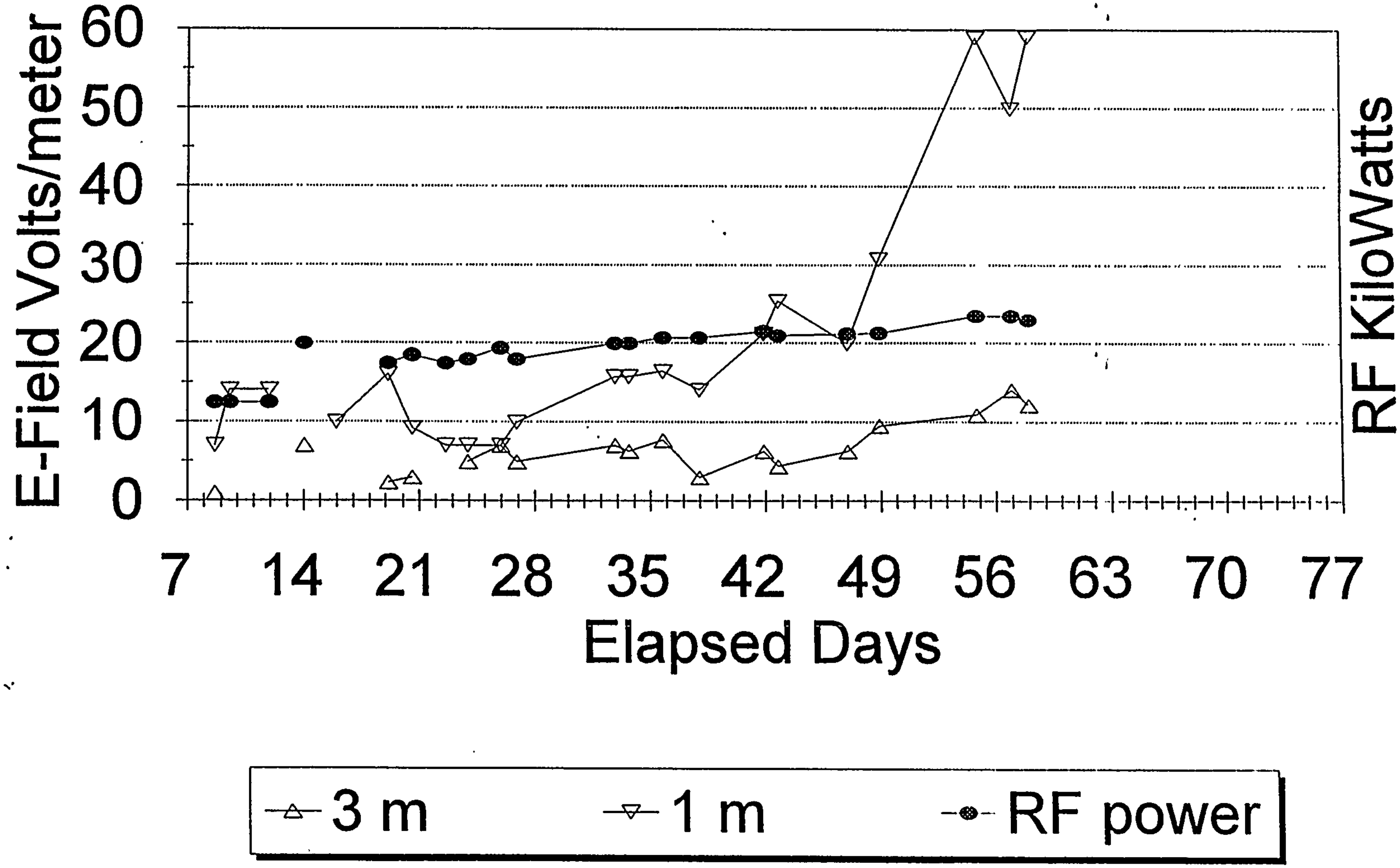
Measured with a calibrated antenna



Isotropic Probe Safety Measuremet
Holiday

Date	Time	RF power	Standard measurement locations @ 1 m ht to West				
			3 m	1 m	contact	Location	Applicator
		KiloWatts	V/M	V/M	V/M		
13-Apr-94	12:00 AM						
21-Apr-94	03:44 PM	12.5	1	7	25		
22-Apr-94	01:00 PM	12.5		14.1	63.24	A2	Ant. 1
24-Apr-94	11:30 PM	12.5		14.1	63.24	A2	Ant. 1
25-Apr-94	10:16 AM	13					
27-Apr-94	01:37 AM	20	7		50	A2	Ant. 1
28-Apr-94	11:45 PM	18		10		A2	Ant. 1
02-May-94	03:12 AM	17.5	2.3	16.1	81.24	A2	Ant. 1
03-May-94	02:01 PM	18.5	3	9.2	77.45	A2	Ant. 1
05-May-94	02:47 PM	17.5		7	86.6	A2	
06-May-94	11:25 PM	18	5	7	77.45	A2	
08-May-94	11:02 PM	19.4	7	7	77.45	A2	
09-May-94	10:15 PM	18	5	10	77.45	A2	
15-May-94	08:10 PM	20	7	15.8	100	A2	
16-May-94	05:00 PM	20	6.3	15.8	132.28	A2	
18-May-94	06:31 PM	20.7	7.7	16.43	77.4	A2	
20-May-94	11:54 PM	20.7	3	14.1	44.72	A1	Ant. 2
24-May-94	09:48 PM	21.5	6.3	21.2	31.62	A1	Ant. 2
25-May-94	06:36 PM	21	4.4	25.4	50	A1	Ant. 2
30-May-94	12:27 AM	21.2	6.3	20	59.1	A1	Ant. 2
31-May-94	10:25 PM	21.3	9.5	30.8	54.7	A2	Ant. 1
06-Jun-94	08:50 PM	23.5	10.9	59	70.7	A2	Ant. 1
08-Jun-94	11:12 PM	23.5	14.1	50	89.4	A2	Ant. 1
09-Jun-94	11:23 PM	23	12.2	59.1	94.8	A2	Ant. 1

Standard E-Field Sample location
West side of Applicators at 1 m ht



APPENDIX I - Plots of SVE and RF system data

This section presents plots of selected SVE and Heating System data displayed on a time line compatible with the temperature data.

KAI RF HEATING SYSTEM DATA (recorded by B&R personnel)

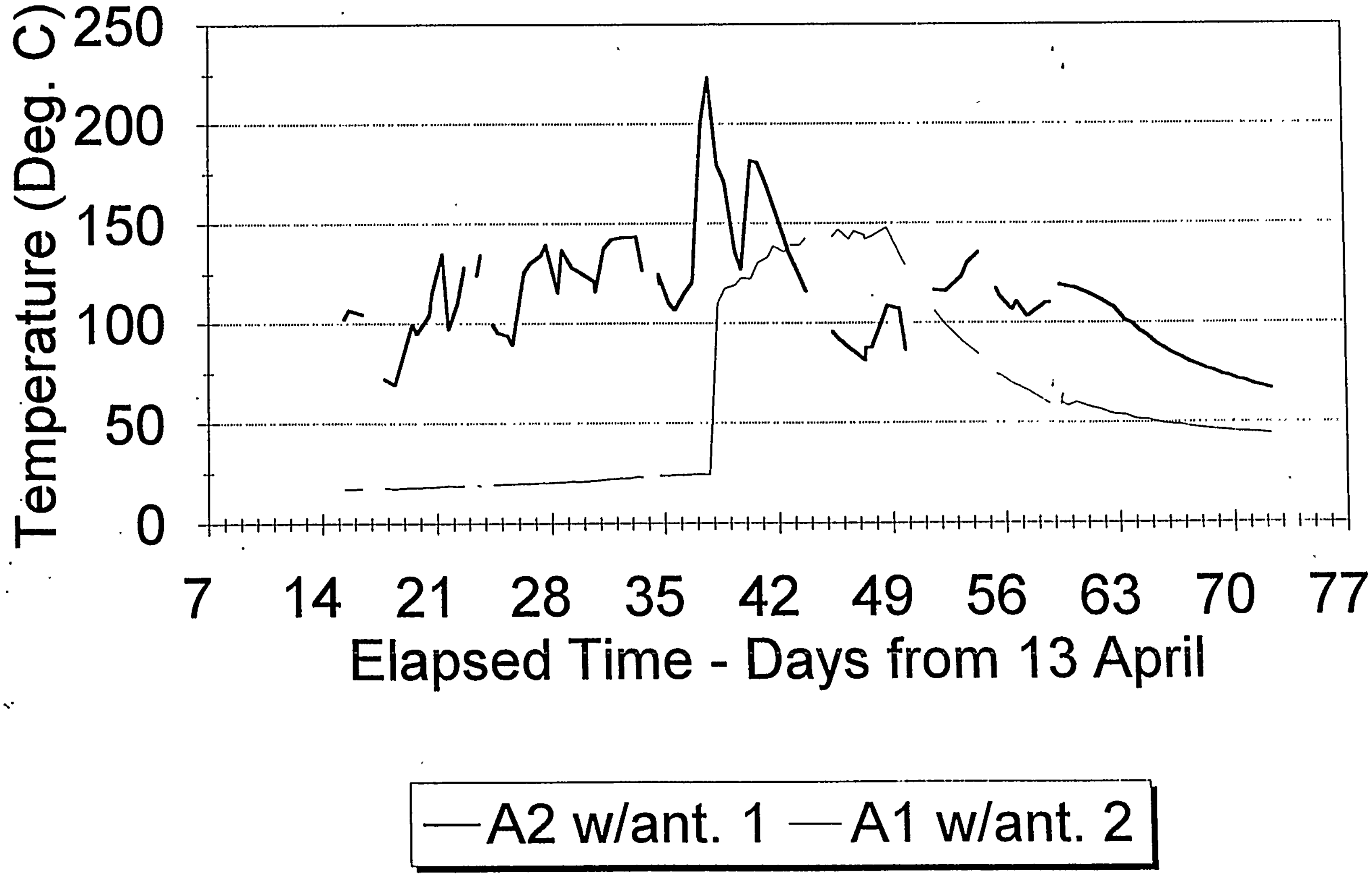
- Plot of Applicator Wall Fiber optic probes over a 7 to 77 day span
  - Wells A2 and A1
- Plot of Applicator RF power (sampled 1 to 2 times per day)
  - Antenna 1 and Antenna 2 Power Generation

SVE SYSTEM DATA

- Plots of SVE Pressures over a 7 to 77 day span (120 PSI points cut off)
  - Suction, Discharge and Compressor
- Plots of SVE Vacuum over a 7 to 77 day span
  - E1 through E8 extraction wells
  - Center extraction wells E4 and E5
- Plots of SVE Temperatures over a 7 to 77 day span
  - Xmas tree and Mixed Vapor in degrees C
  - E1 through E8 extraction well thermocouple measurements at entrance to the SVE manifold.
  - E4 and E5 extraction well temperatures (10 ft. to 20 ft. screened extraction on the center line between wells A1 and A2).
  - E1, E2 and E3 east side extraction well temperatures

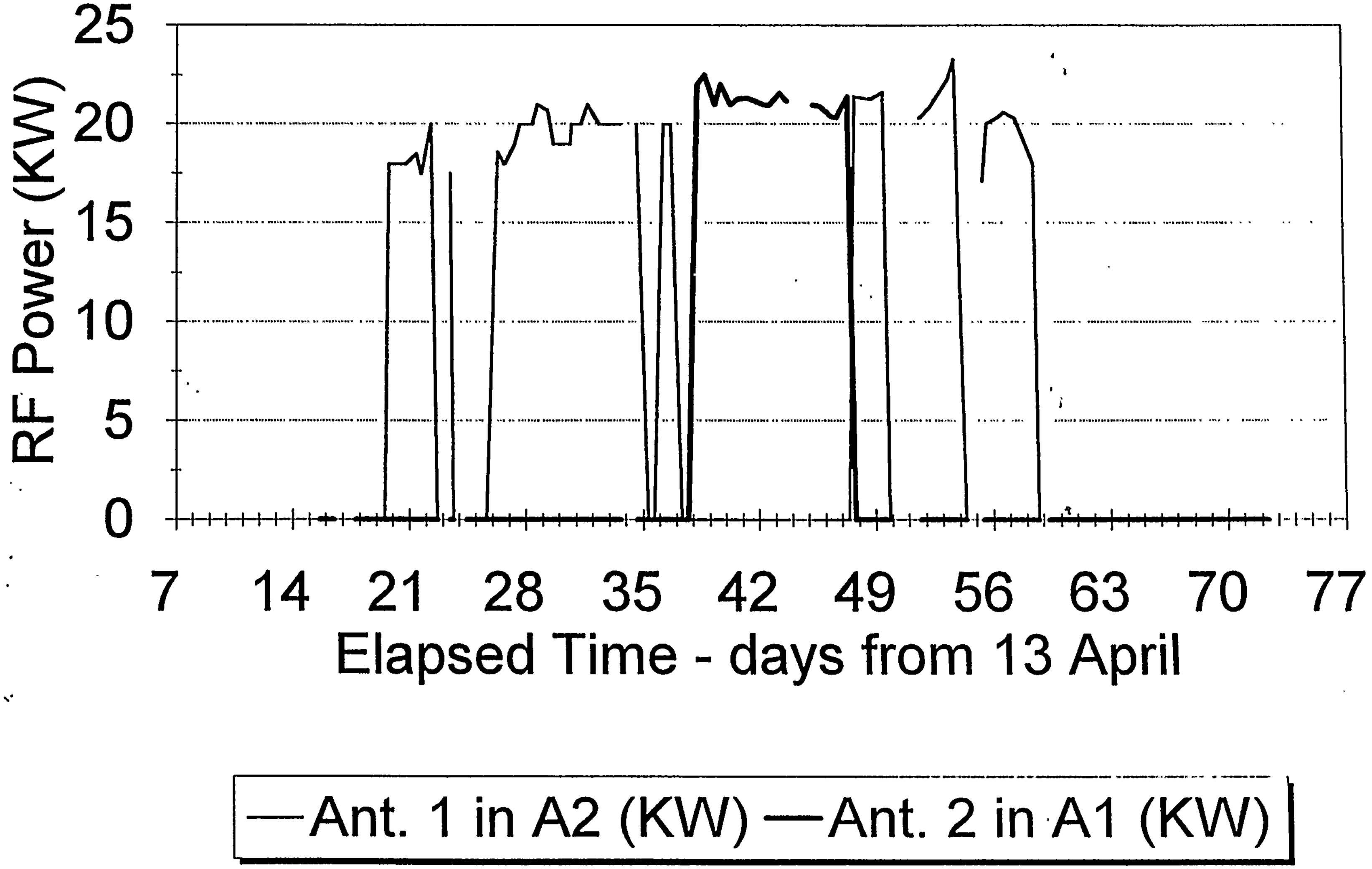
Applicator liner temp. (B&R logging)

Fiber optic temp. measurement of wall



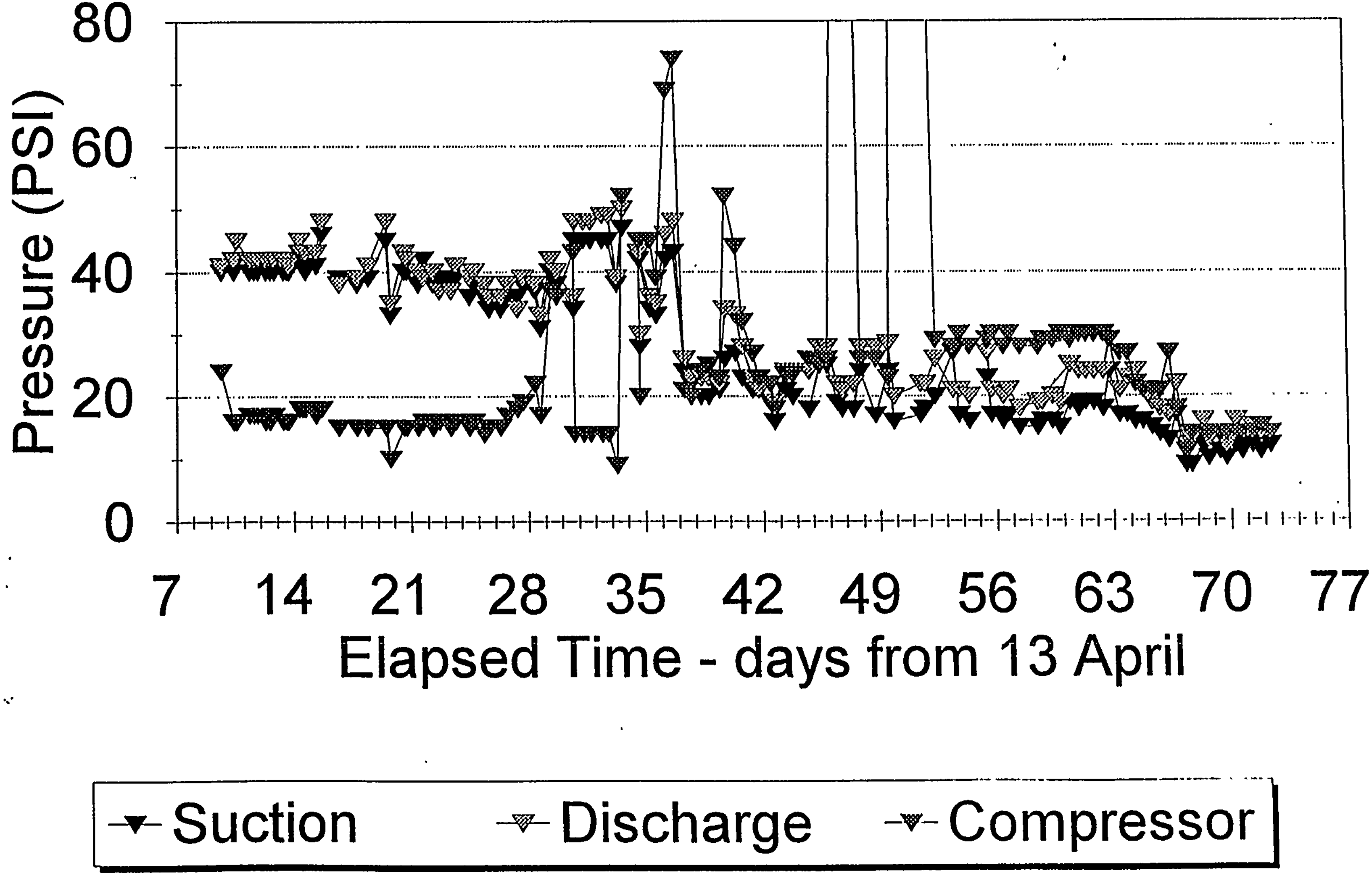
Applicator RF power. (B&R logging)

RF Output Meter on RF Generator



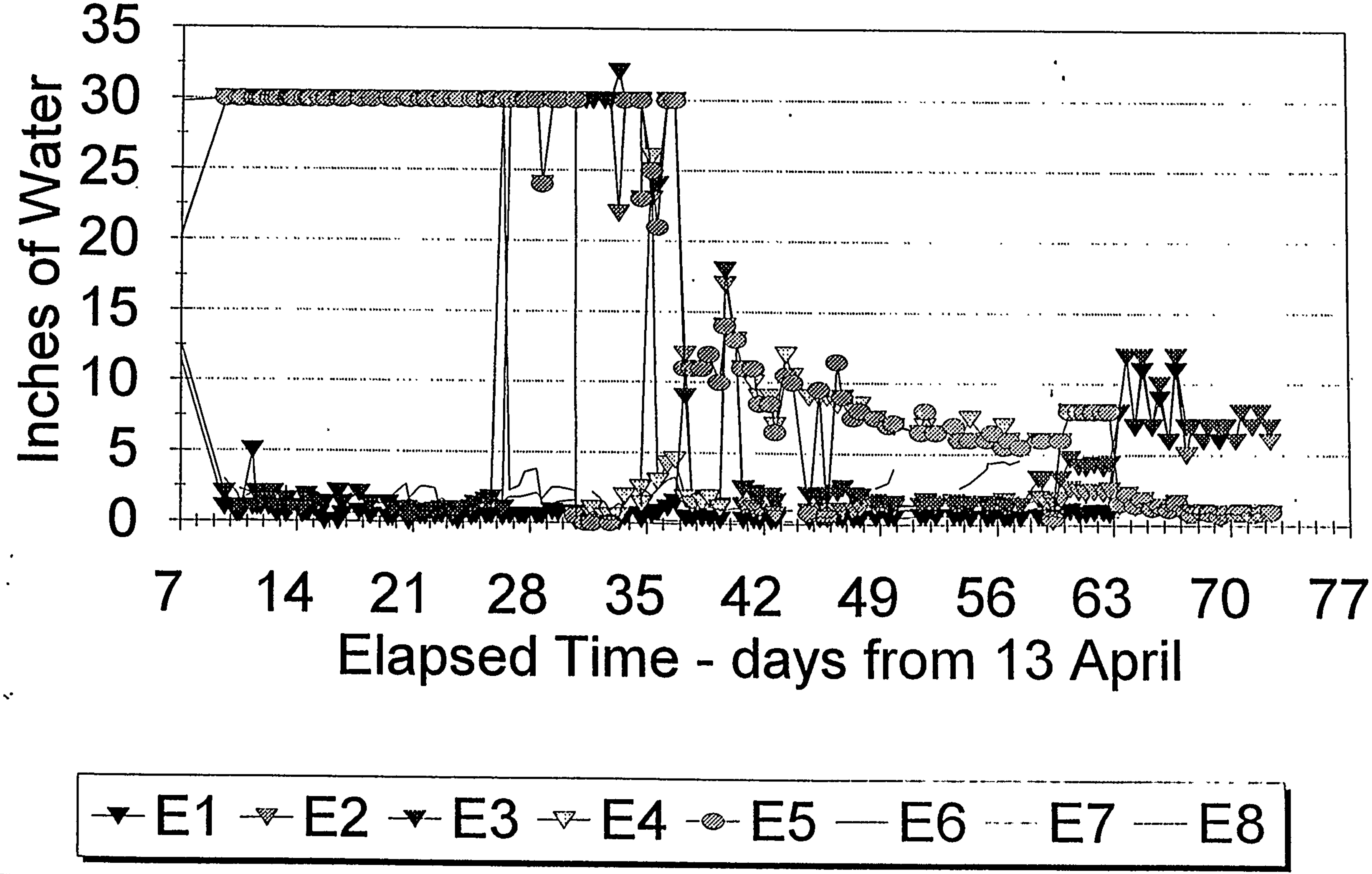
SVE Pressures (B&R logging)

Pressure guages



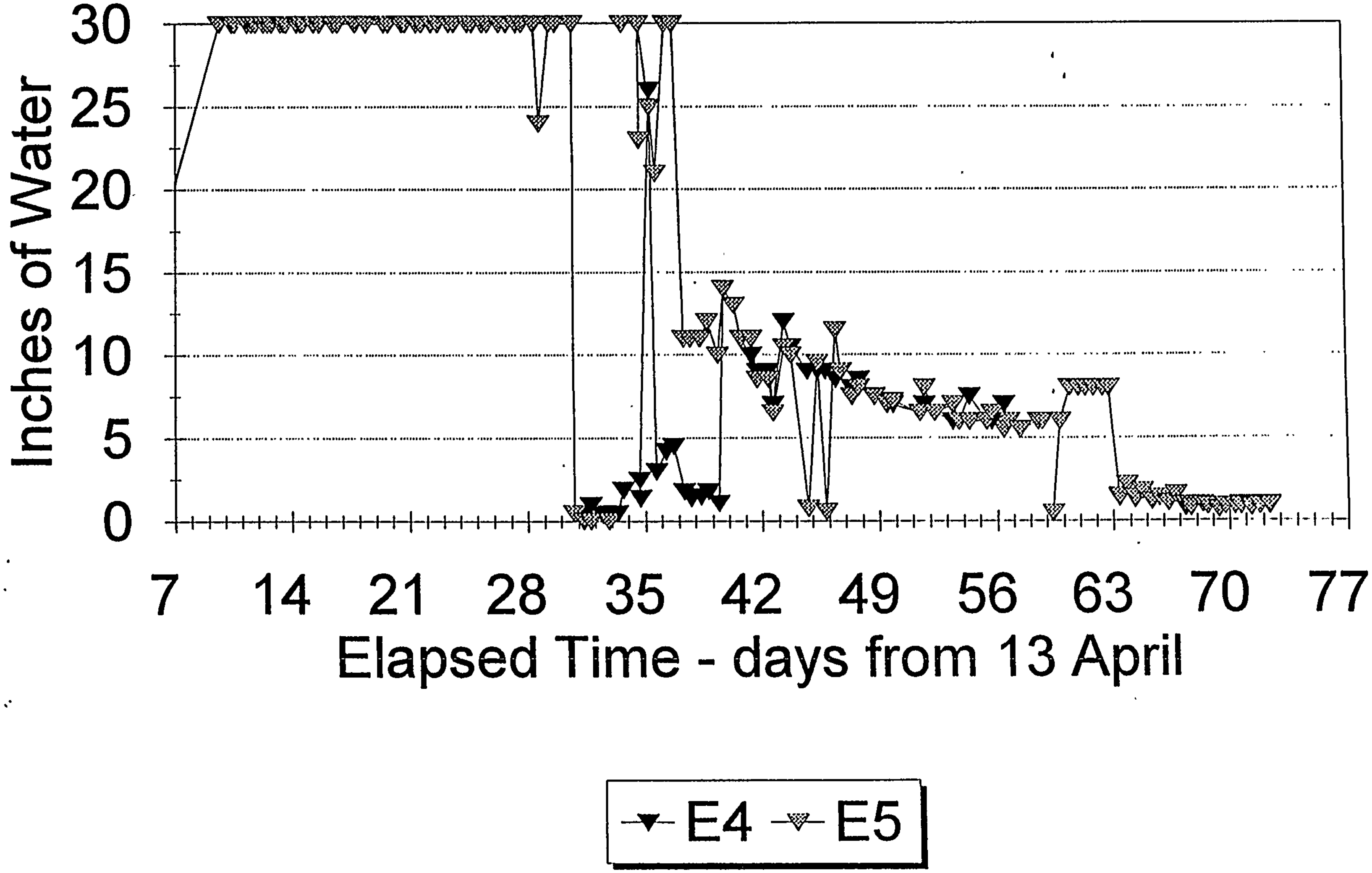
SVE Vacuum (B&R logging)

Magnehelic gages

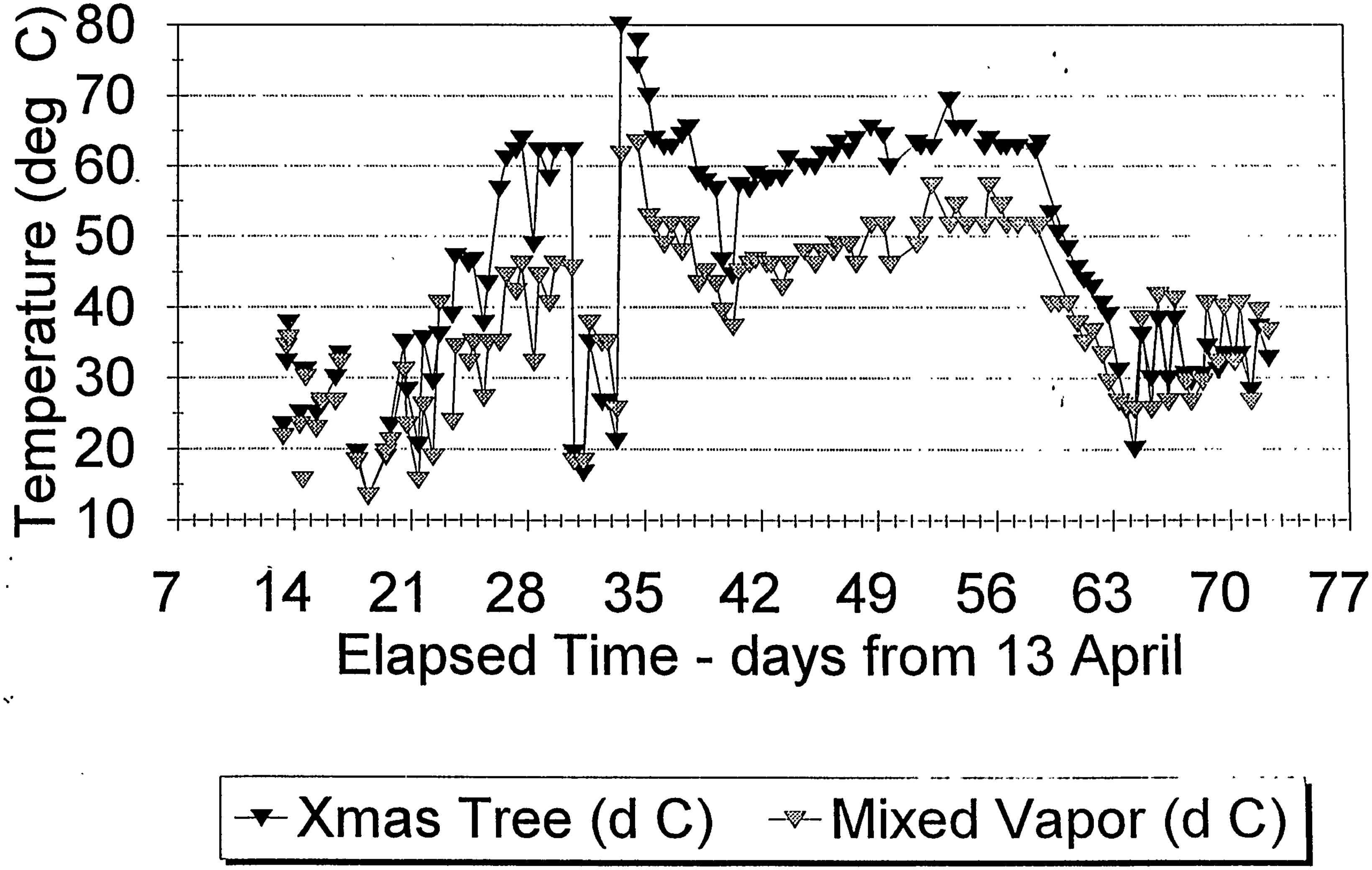


SVE Vacuum (B&R logging)

Center extraction wells

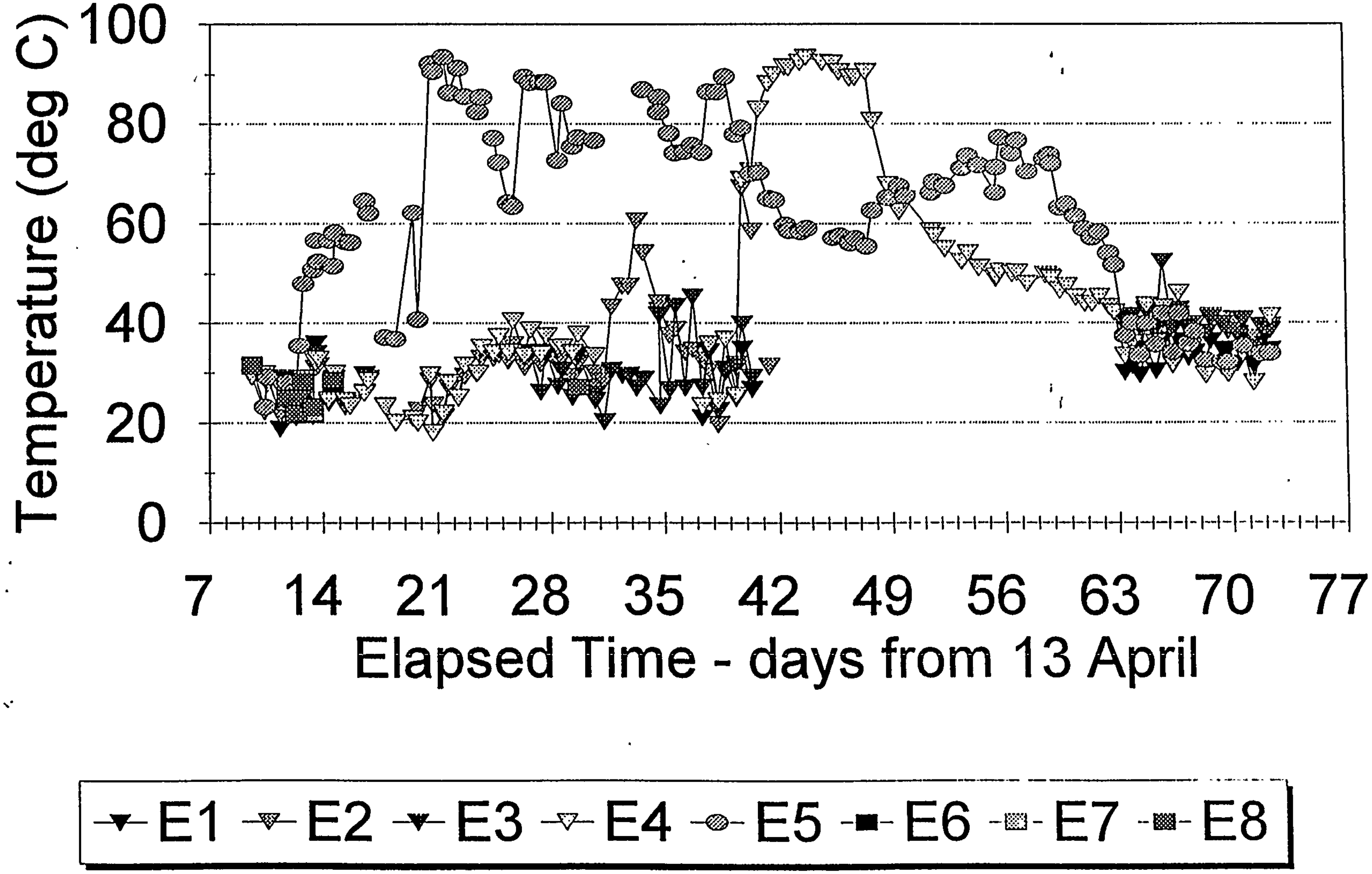


SVE Output temps. (B&R logging)
System points



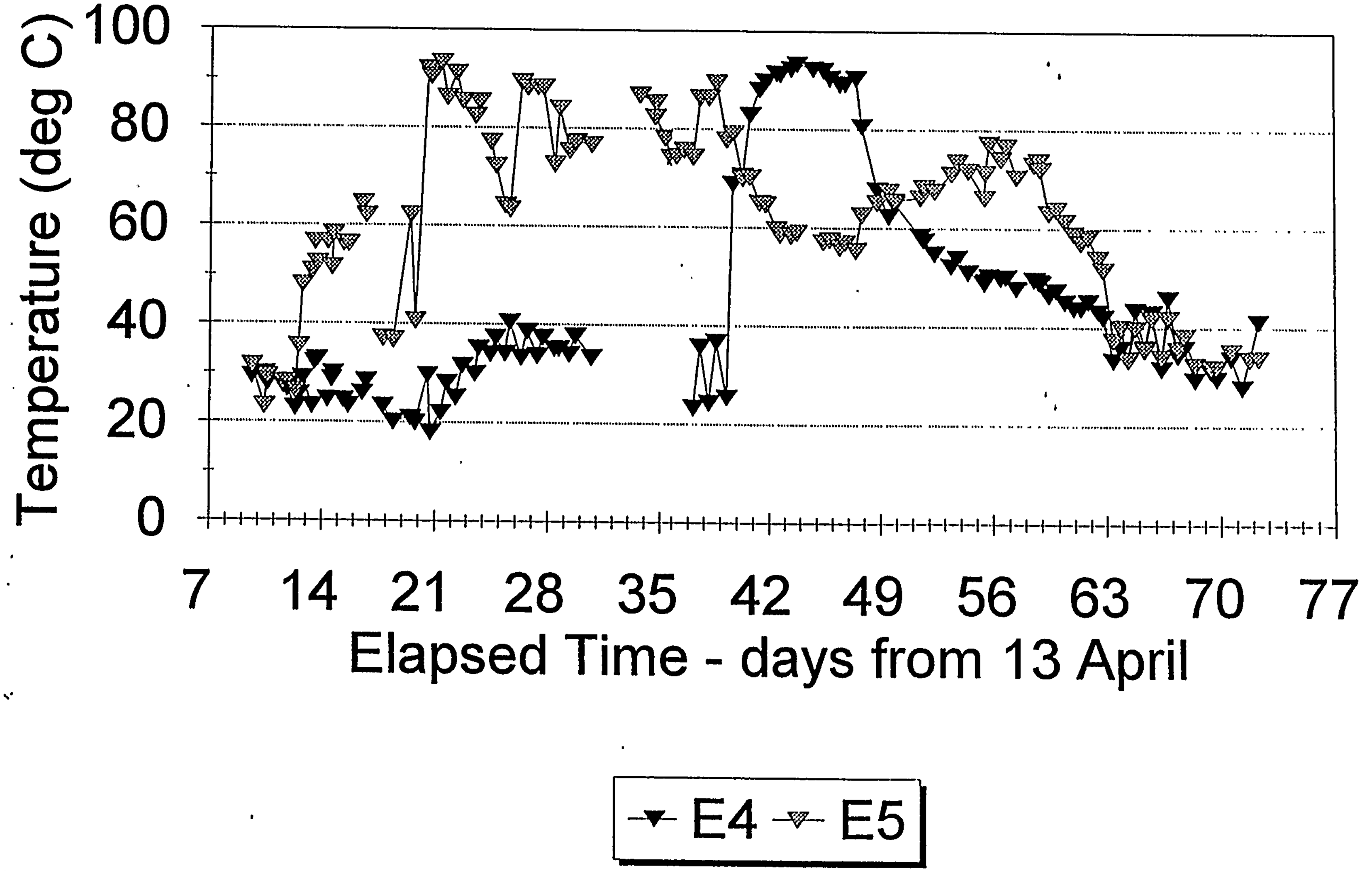
SVE Output temps. (B&R logging)

Thermocouple measurements



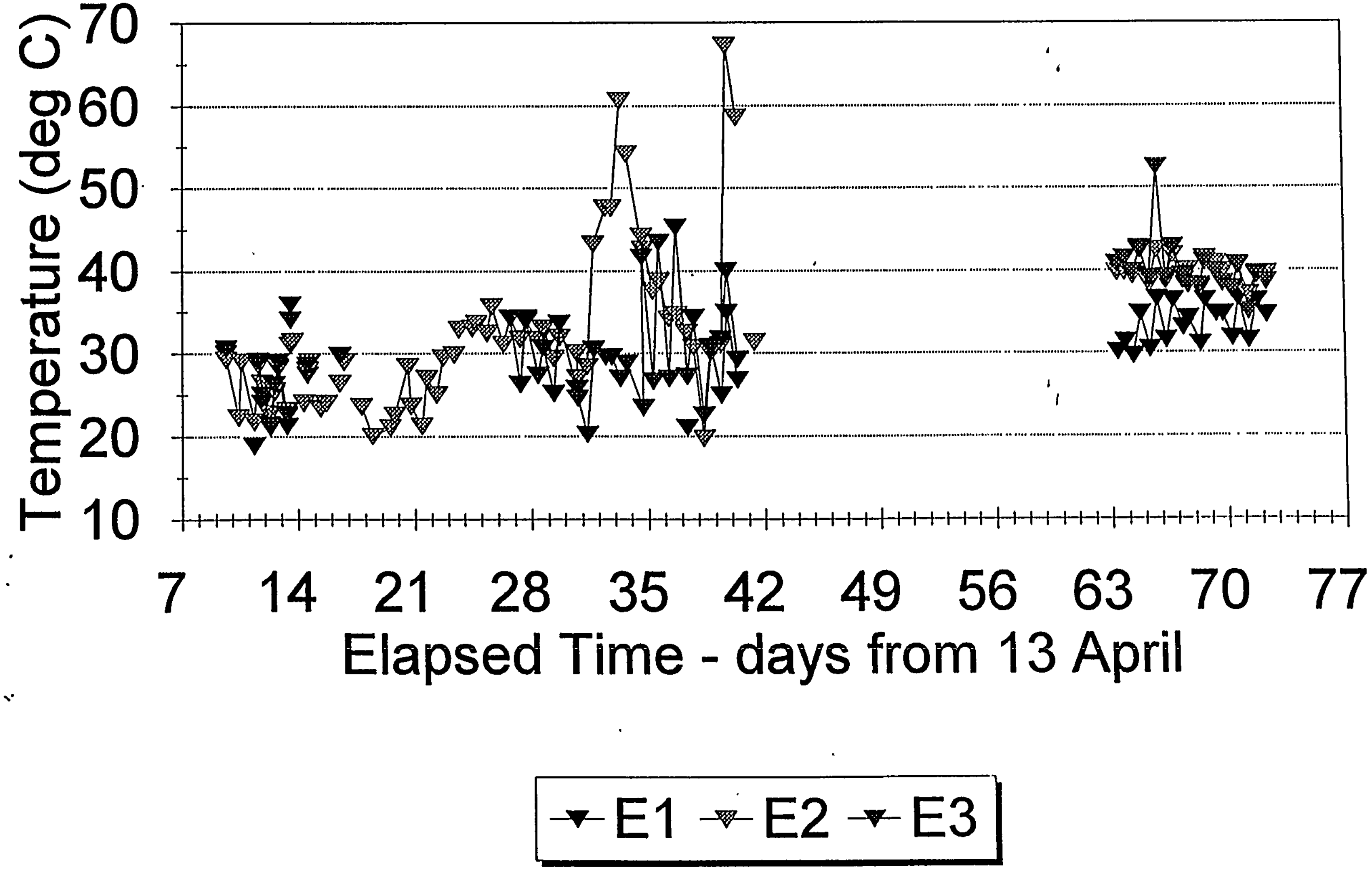
SVE Output temps. (B&R logging)

Center extraction well output temps



SVE Output temps. (B&R logging)

East side extraction temps

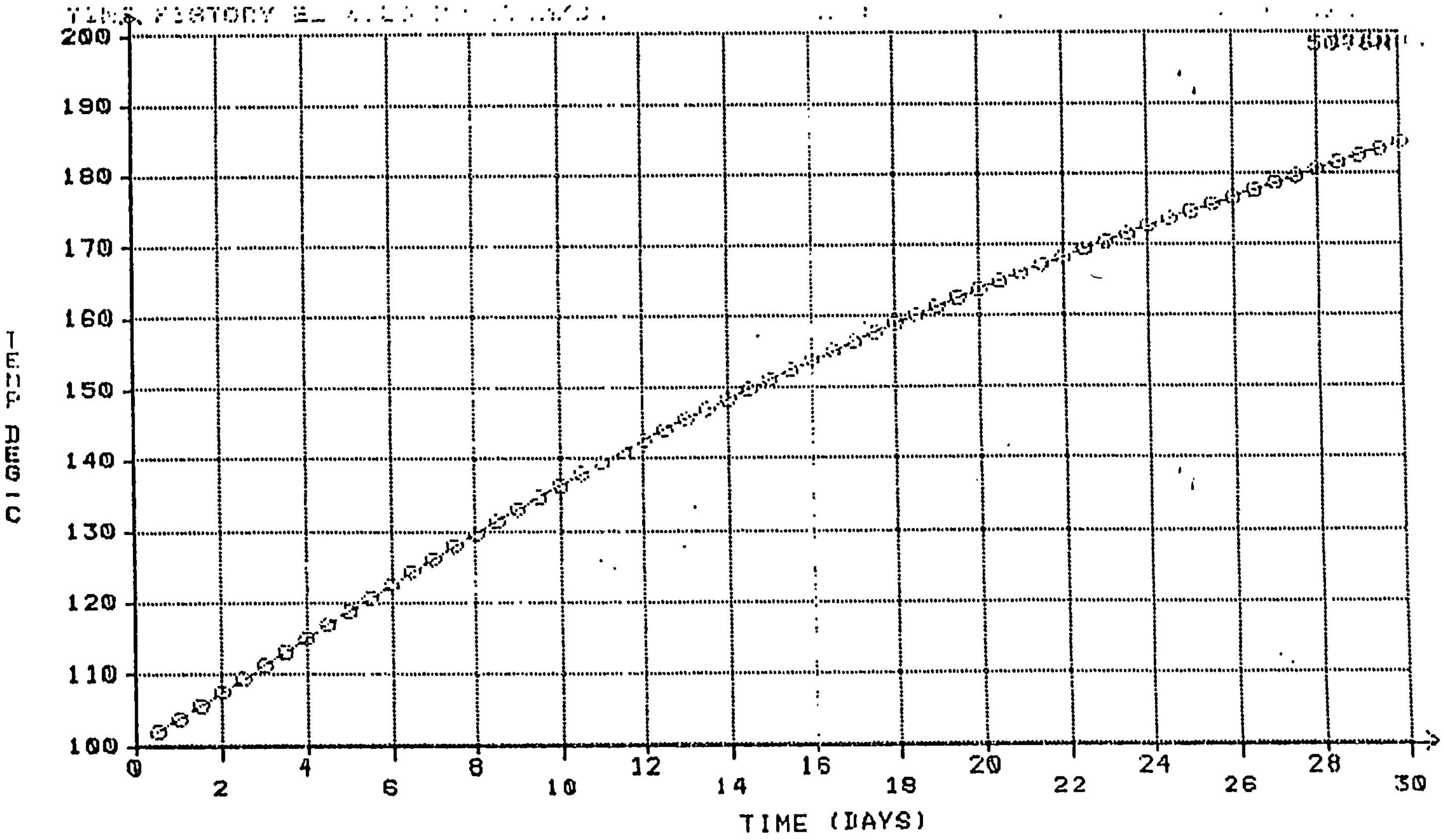


APPENDIX J - Thermal Modeling Data

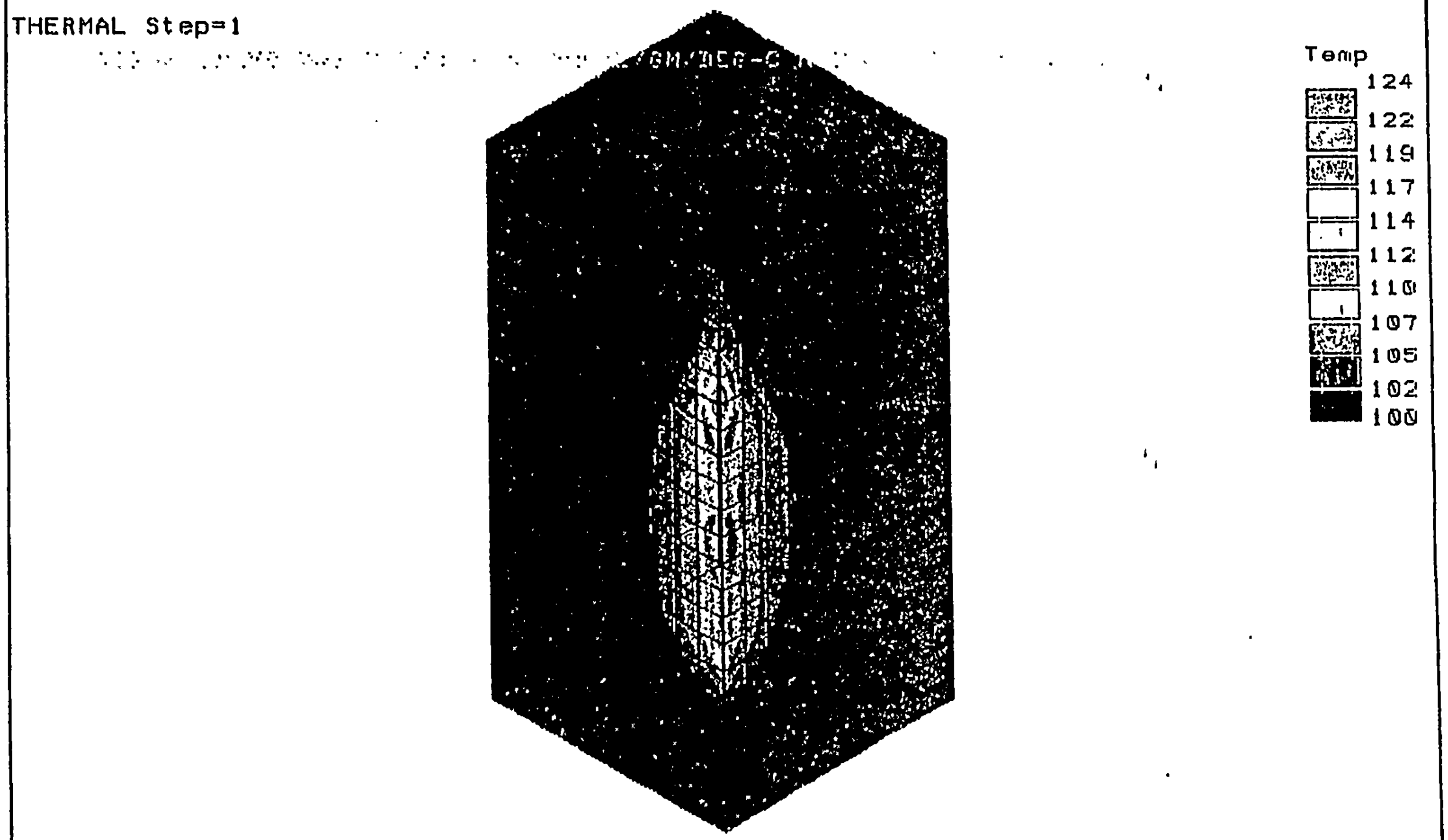
The following charts are the 3-D color (4-D) output plots from the COSMOS FEA thermal modeling program. *The model asssumes homogenous soil and constant heating.*

> Note: The origin of the coordinate system is at the center of the block. The heating applicators are positioned vertically. The z direction is vertical.

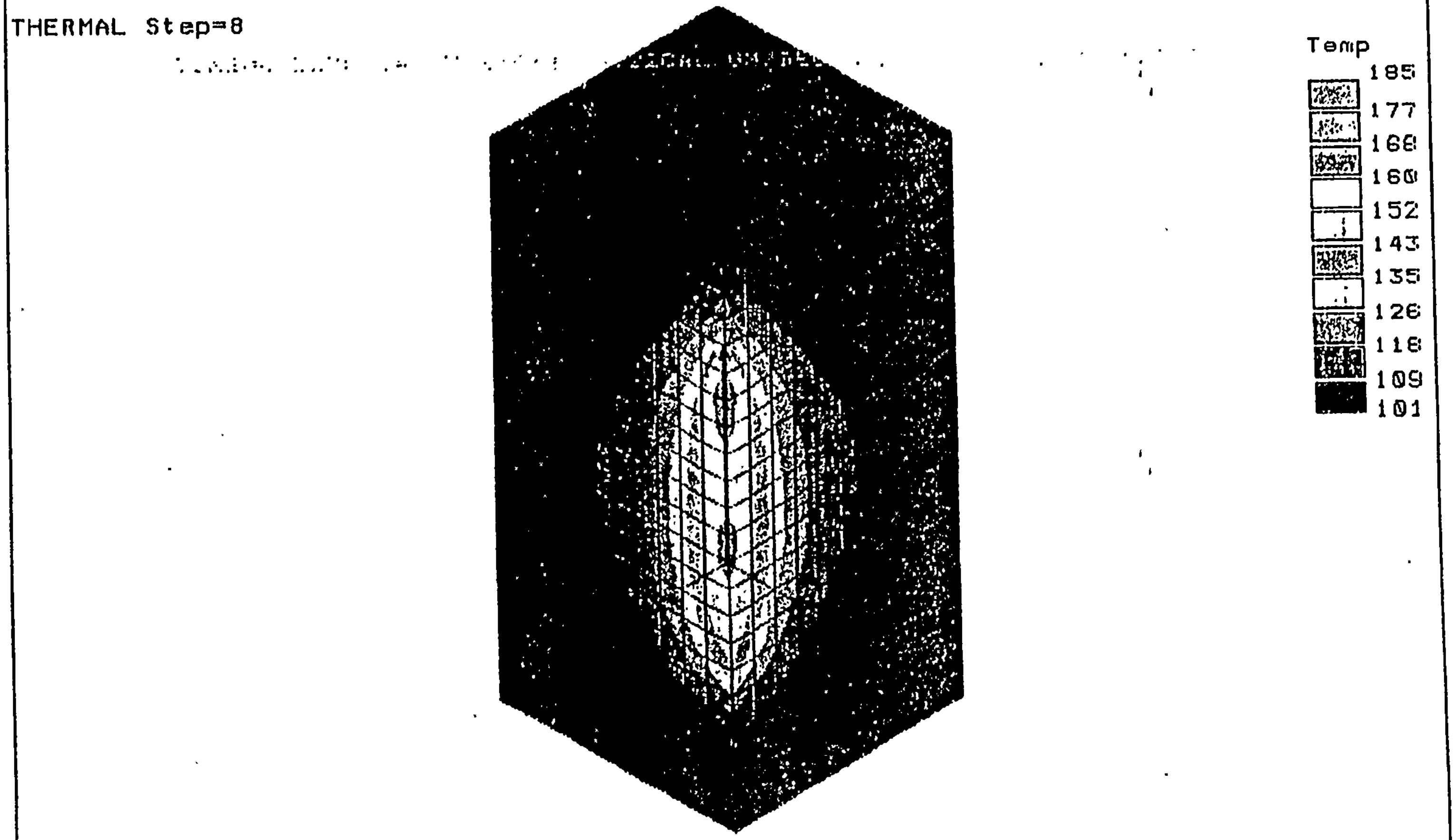
Designation	**Description**
20 kW average power level	
SGL.G01	Single Applicator Temperature vs. Time - 5' radially away from feed
SGL.G02	Single Applicator Temperature Profile - After 0.5 days of RF heating
SGL.G03	Single Applicator Temperature Profile - After 4 days of RF heating
SGL.G04	Single Applicator Temperature Profile - After 8 days of RF heating
SGL.G05	Single Applicator Temperature Profile - After 15 days of RF heating
SGL.G06	Single Applicator Temperature Profile - After 21 days of RF heating
SGL.G07	Single Applicator Temperature Profile - After 27 days of RF heating
SGL.G08	Single Applicator Temperature Profile - After 30 days of RF heating
10 kW average power to each applicator with a combined power of 20 kW	
1/4 volume removed view	
DBL.G01	Dual Applicators Temperature vs. Time - 5' radially away from feed
DBL.G02	Dual applicators Temperature Profile - After 0.5 days of RF heating
DBL.G03	Dual Applicators Temperature Profile - After 6 days of RF heating
DBL.G04	Dual Applicators Temperature Profile - After 11 days of RF heating
DBL.G05	Dual Applicators Temperature Profile - After 17 days of RF heating
DBL.G06	Dual Applicators Temperature Profile - After 23 days of RF heating
DBL.G07	Dual Applicators Temperature Profile - After 29 days of RF heating
DBL.G08	Dual Applicators Temperature Profile - After 30 days of RF heating
1/2 volume removed view (side pattern profile)	
DBL.G09	Dual applicators Temperature Profile - After 0.5 days of RF heating
DBL.G10	Dual Applicators Temperature Profile - After 6 days of RF heating
DBL.G11	Dual Applicators Temperature Profile - After 11 days of RF heating
DBL.G12	Dual Applicators Temperature Profile - After 17 days of RF heating
DBL.G13	Dual Applicators Temperature Profile - After 23 days of RF heating
DBL.G14	Dual Applicators Temperature Profile - After 29 days of RF heating
DBL.G15	Dual Applicators Temperature Profile - After 30 days of RF heating



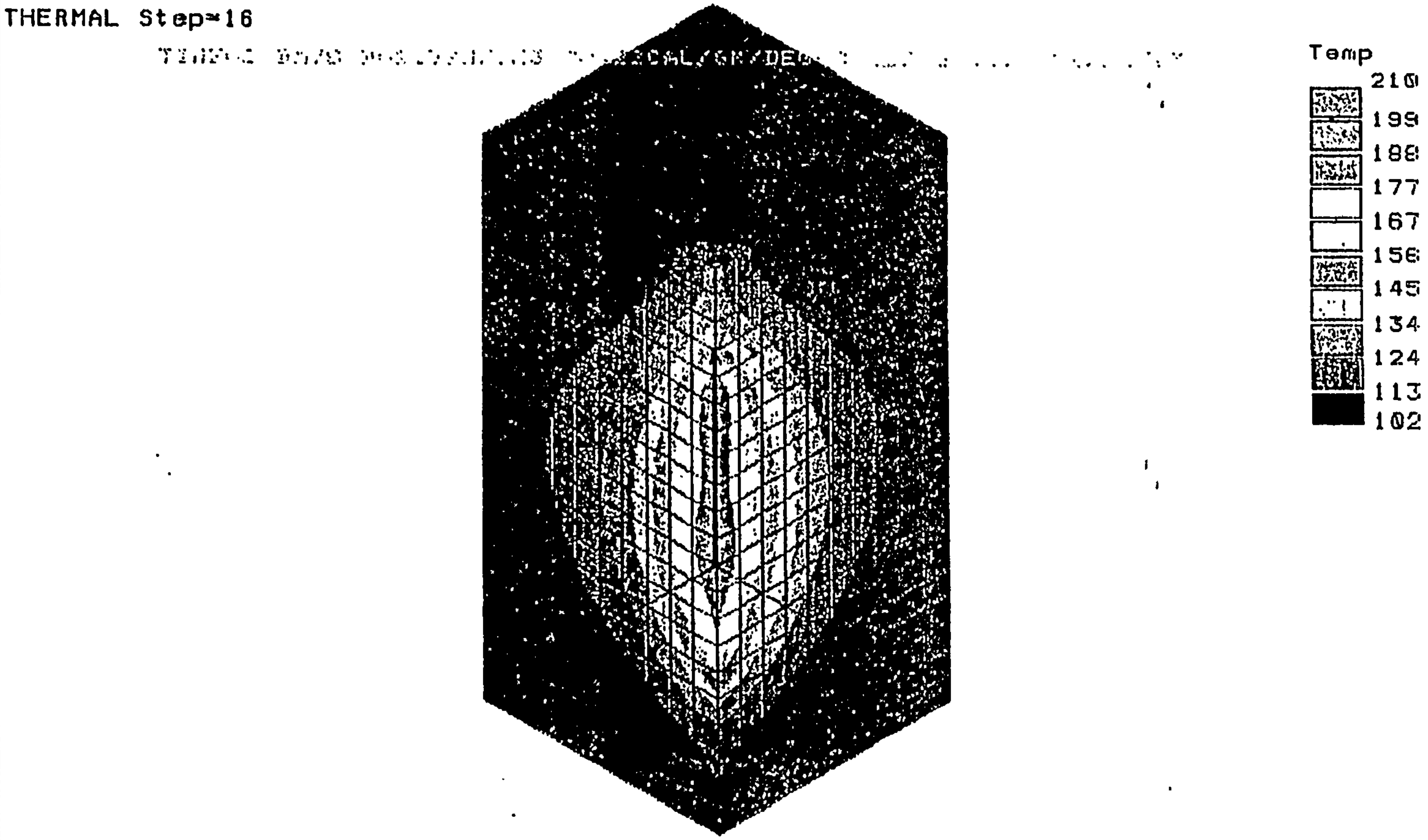
SGL.G01 **Single Applicator** Temperature vs. Time - 5' radially away from feed



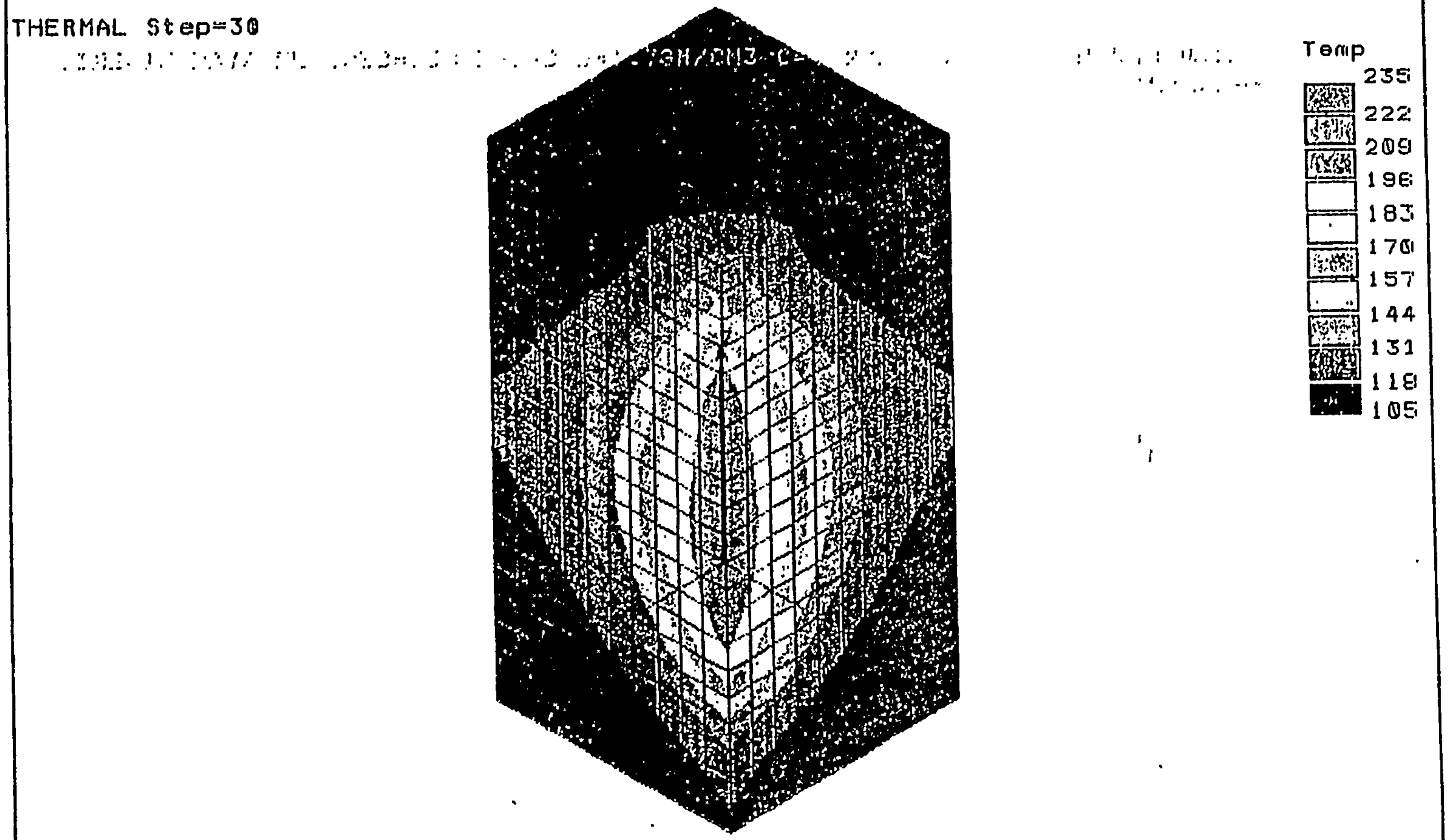
SGL.G02 **Single Applicator** Temperature Profile - After 0.5 days of RF heating



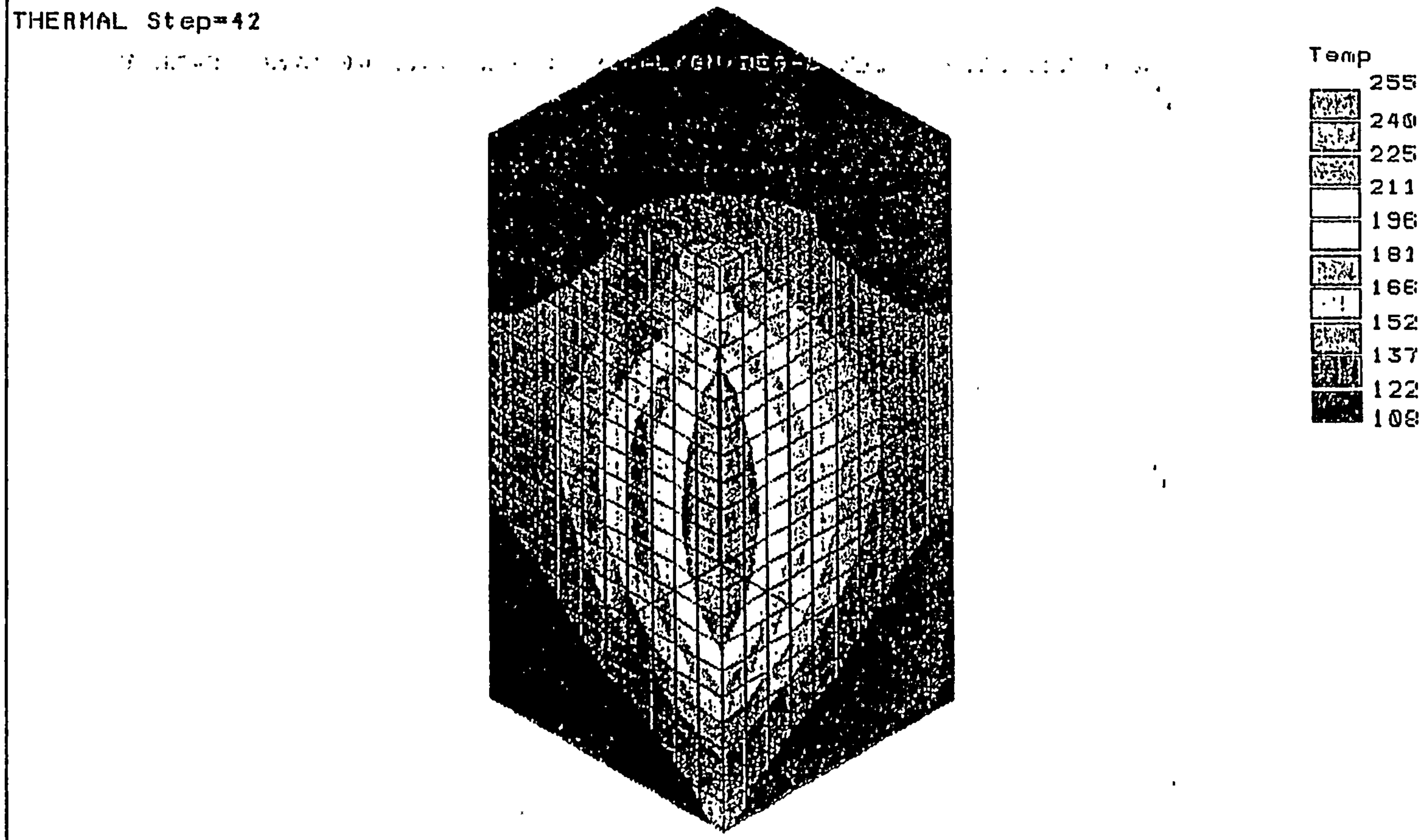
SGL.G03 **Single Applicator** Temperature Profile - After 4 days of RF heating



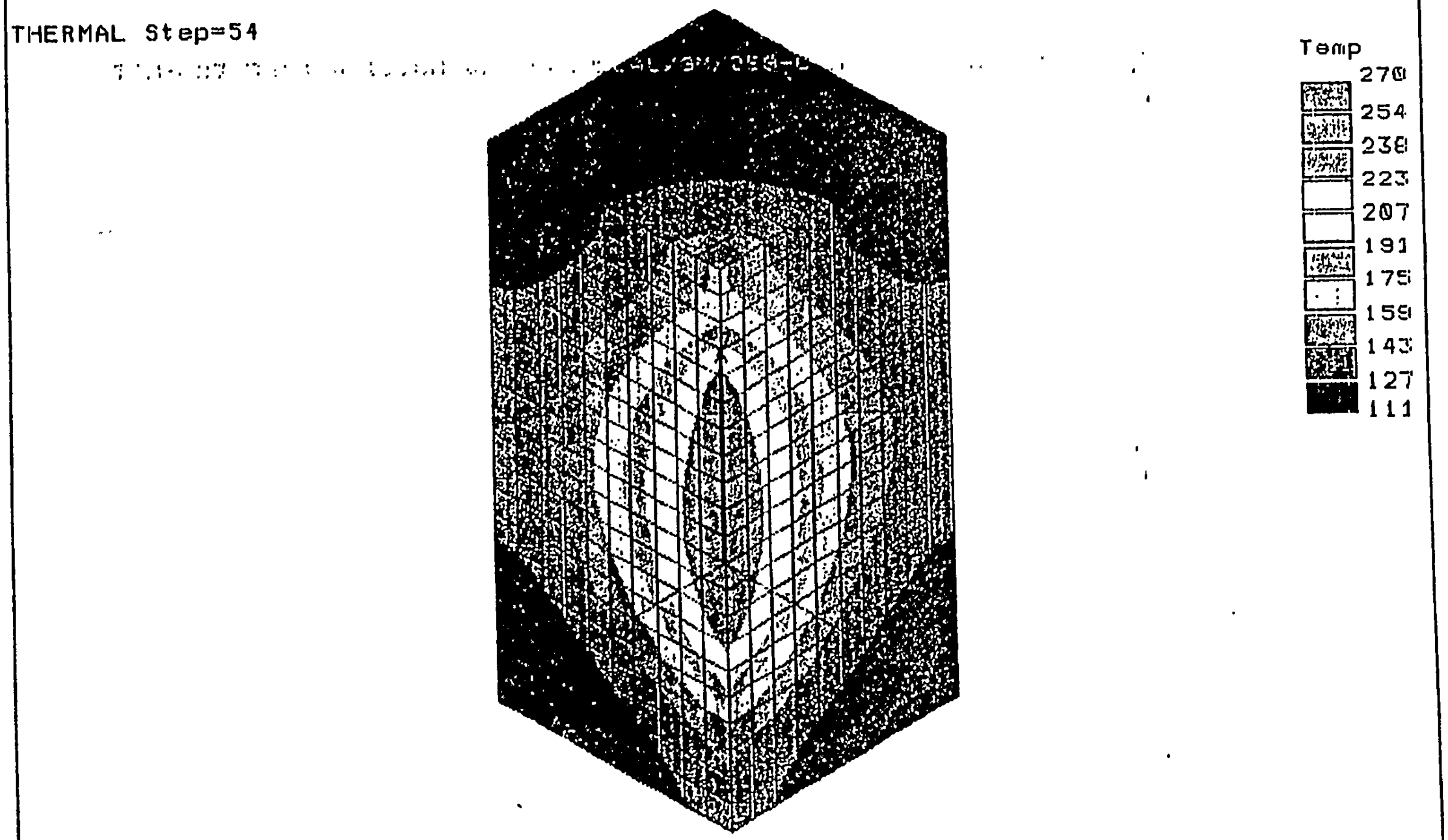
SGL.G04 **Single Applicator** Temperature Profile - After 8 days of RF heating



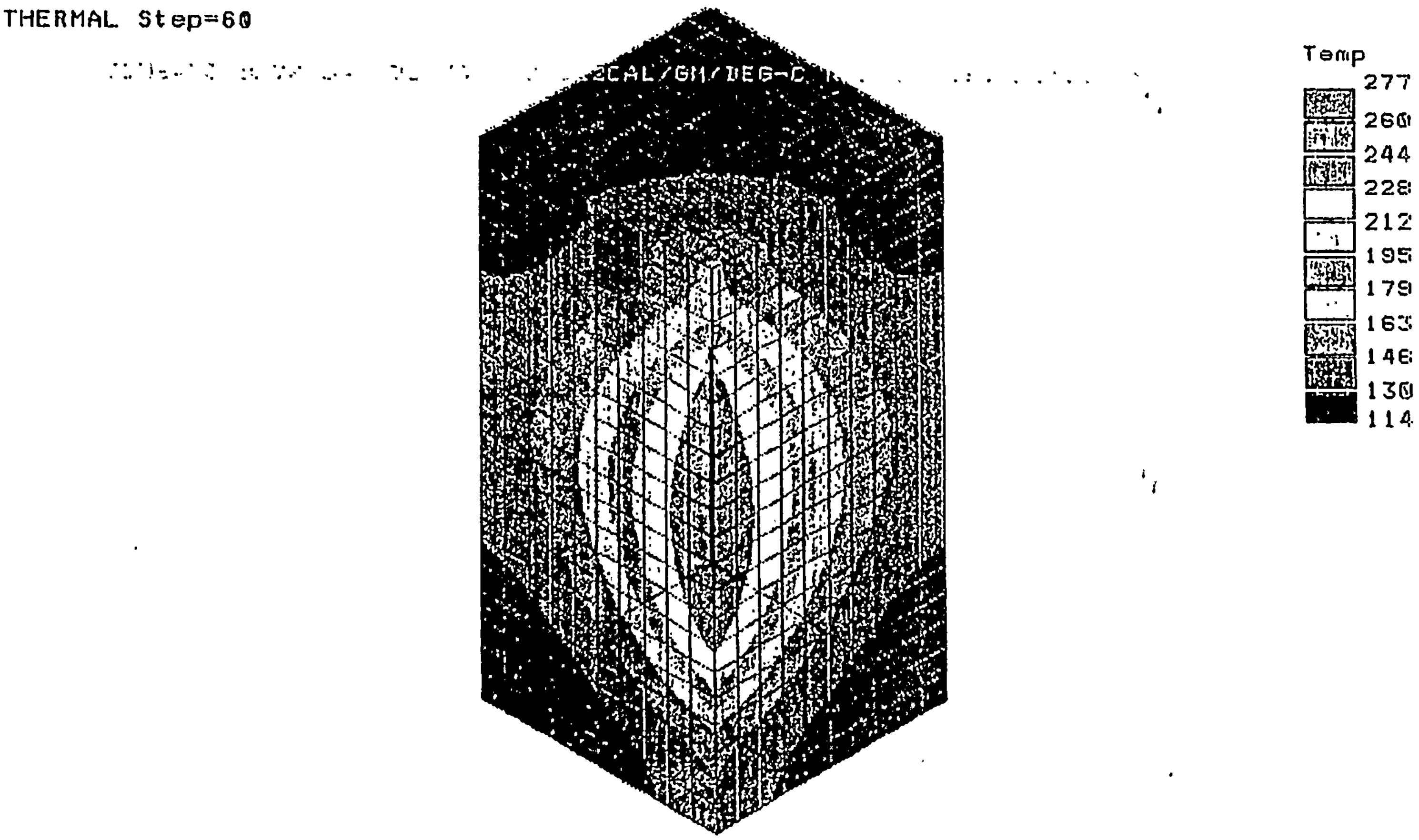
SGL.G05 **Single Applicator** Temperature Profile - After 15 days of RF heating



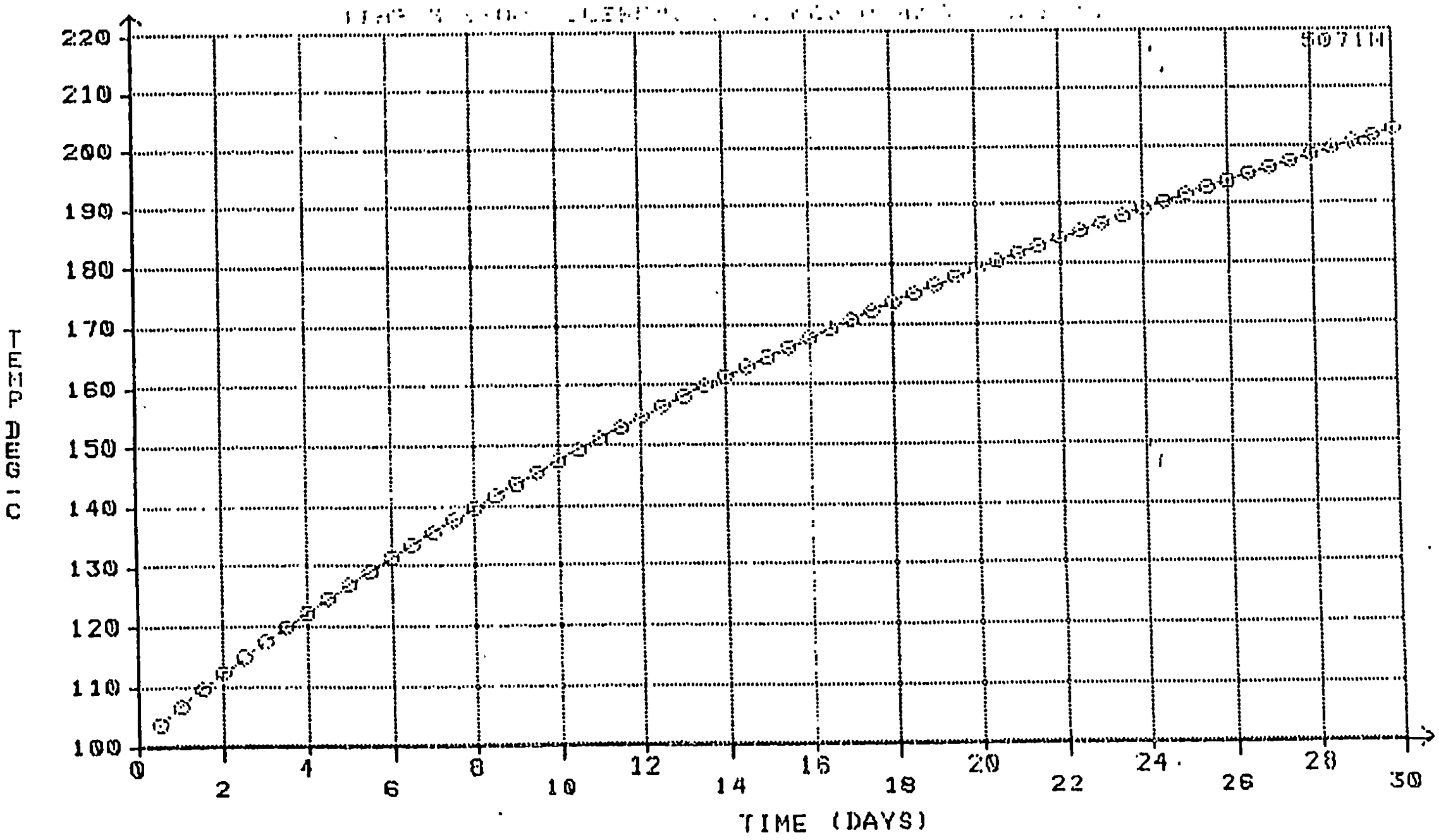
SGL.G06 **Single Applicator** Temperature Profile - After 21 days of RF heating



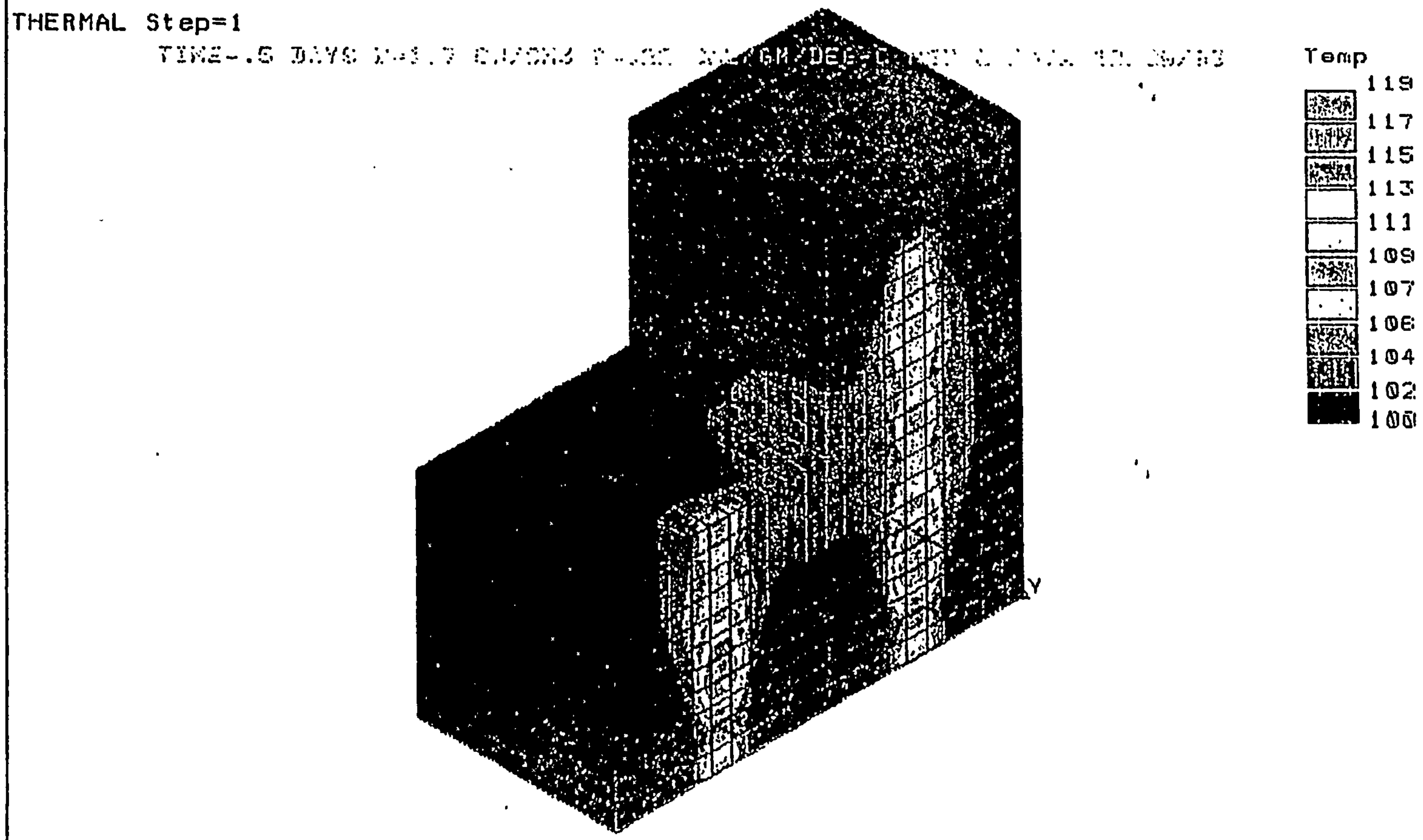
SGL.G07 **Single Applicator** Temperature Profile - After 27 days of RF heating



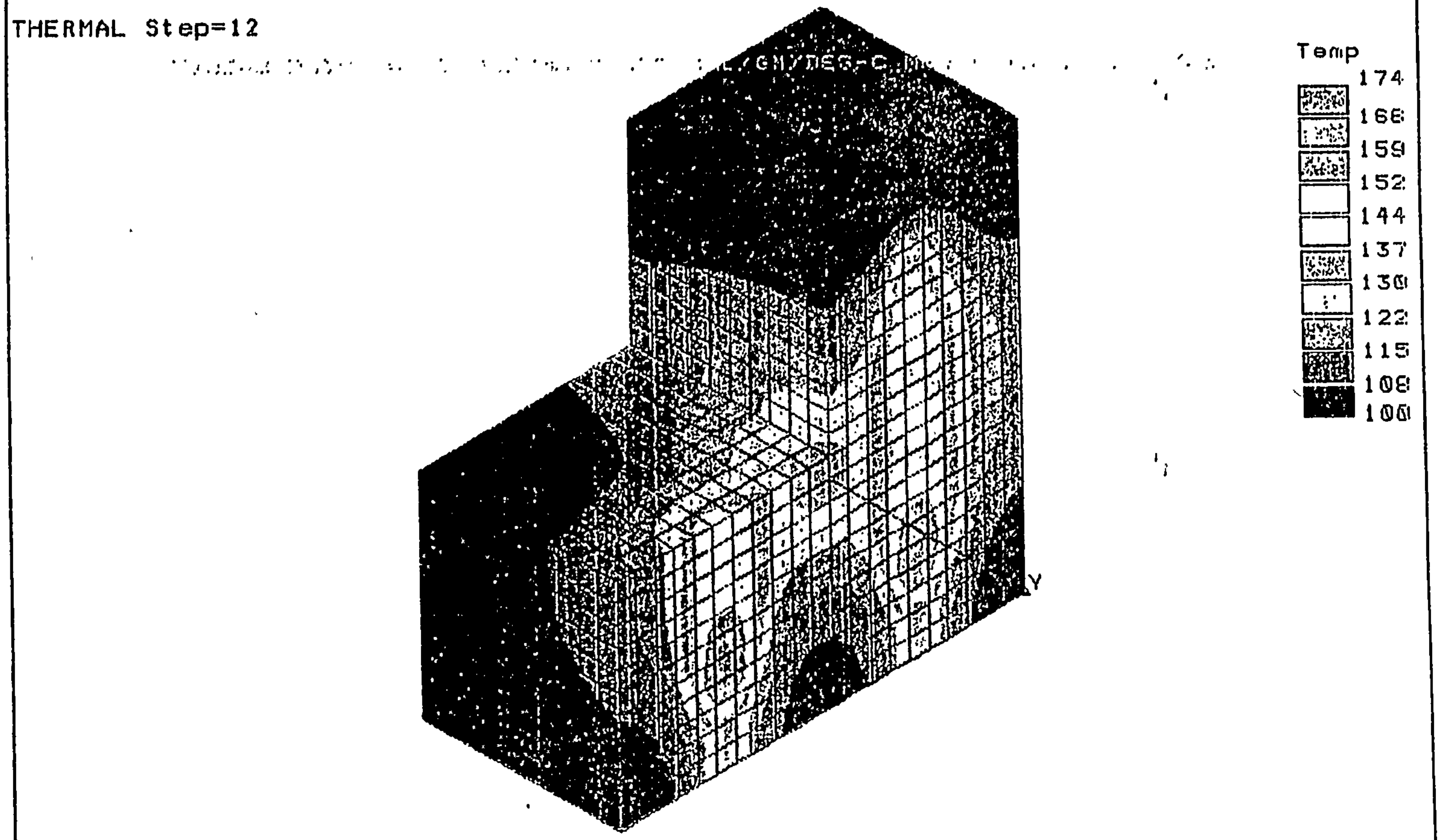
SGL.G08 **Single Applicator** Temperature Profile - After 30 days of RF heating



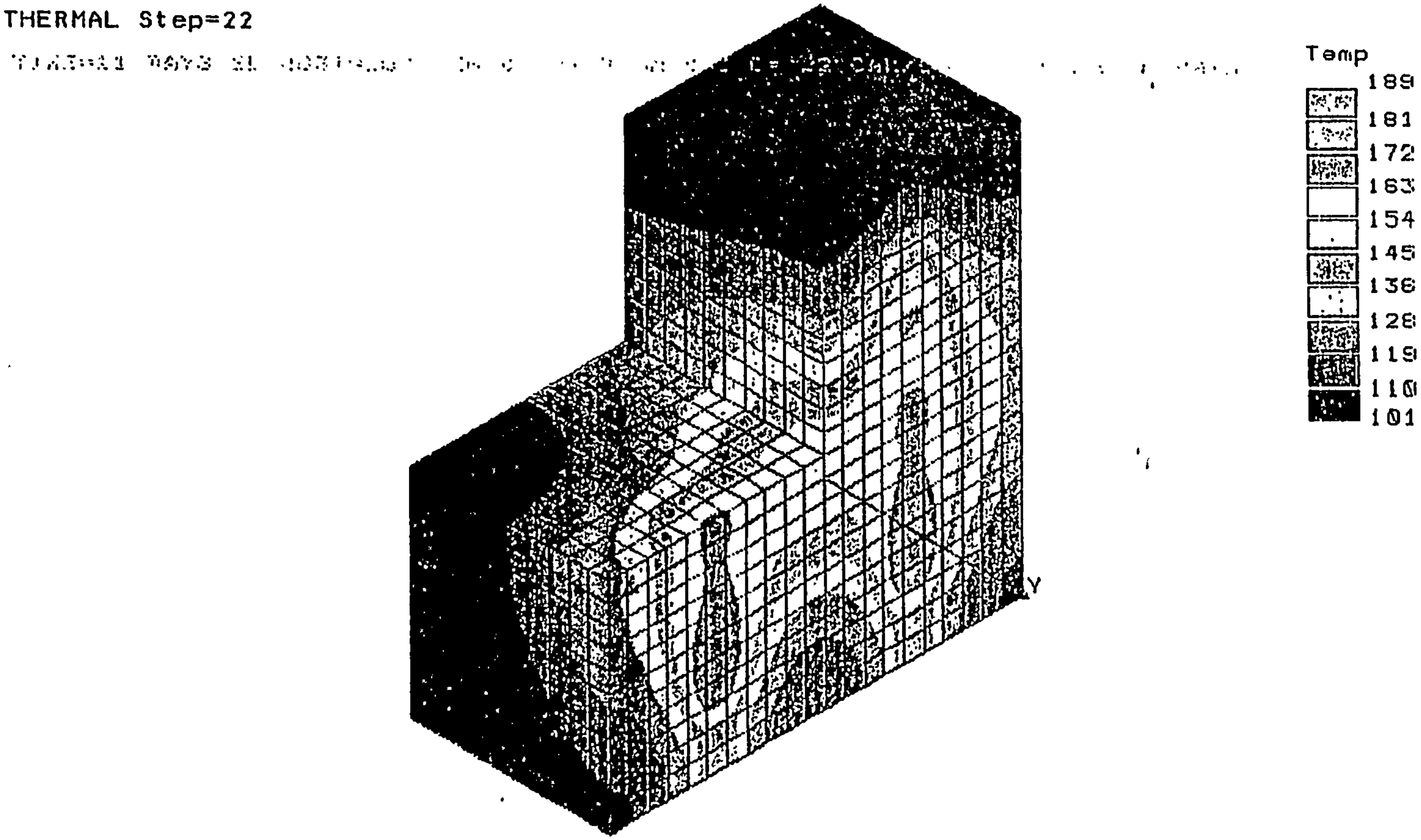
DBL.G01 **Dual Applicators** Temperature vs. Time - 5' radially away from feed



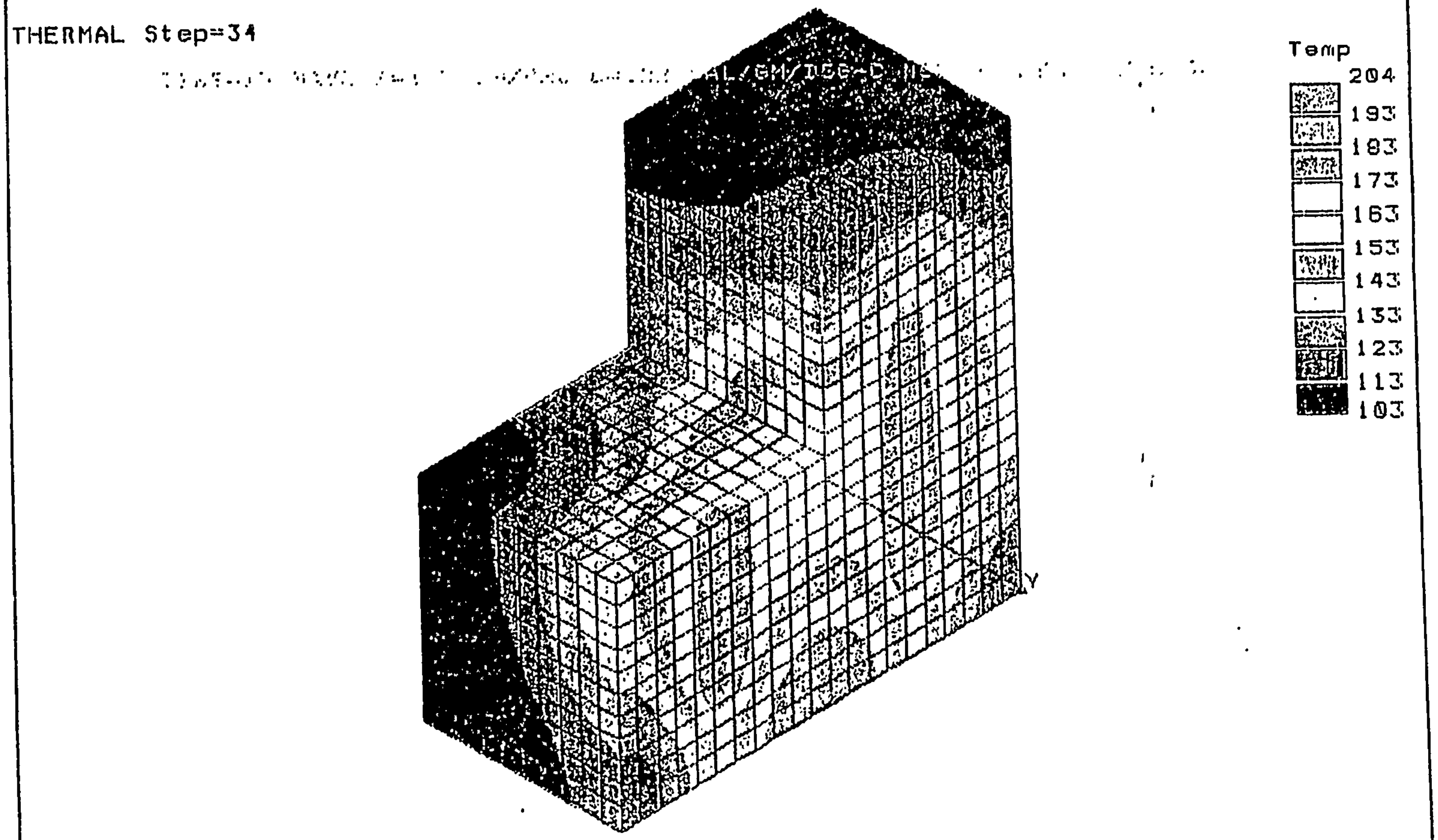
DBL.G02 **Dual applicators** Temperature Profile - After 0.5 days of RF heating



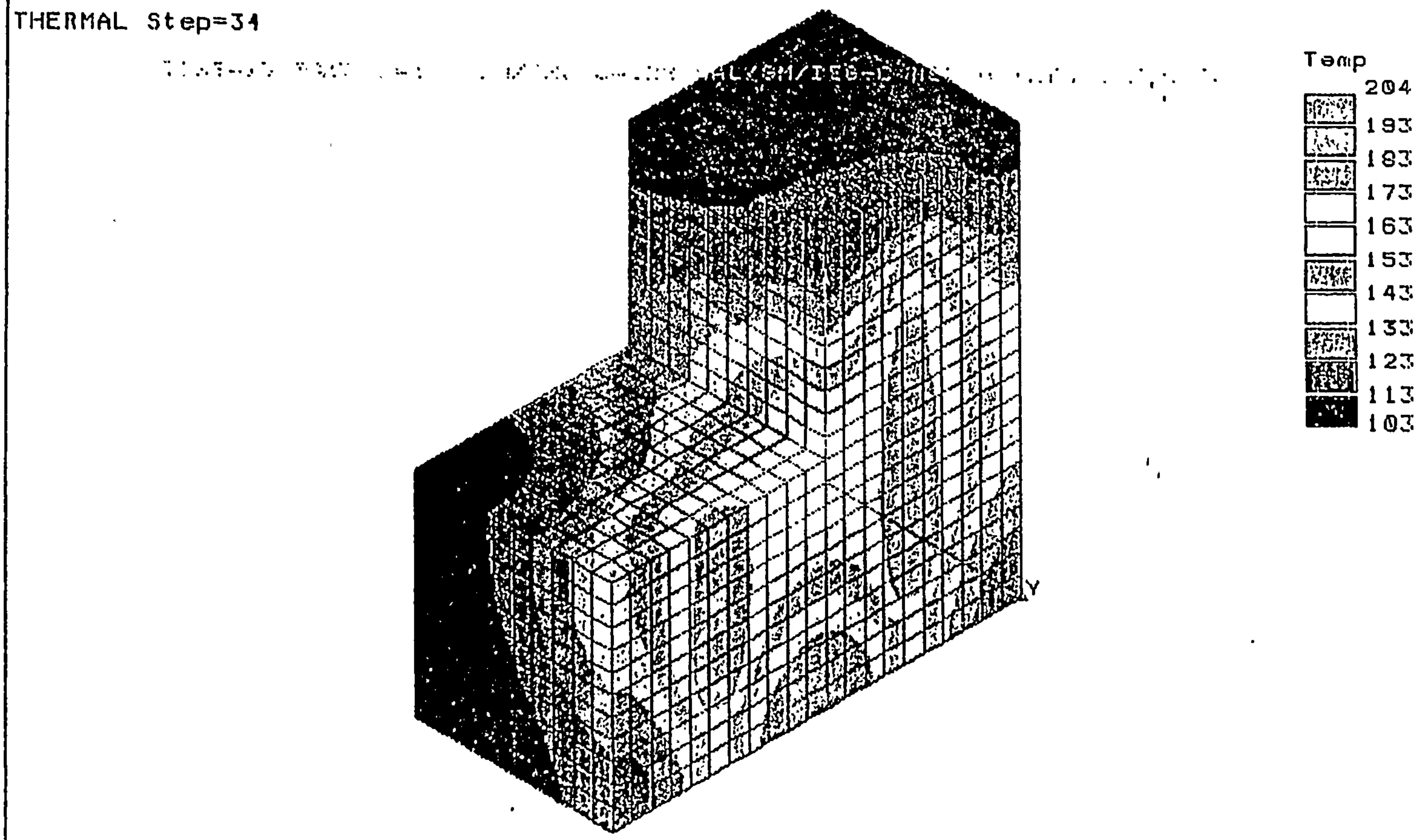
DBL.G03 **Dual Applicators** Temperature Profile - After 6 days of RF heating



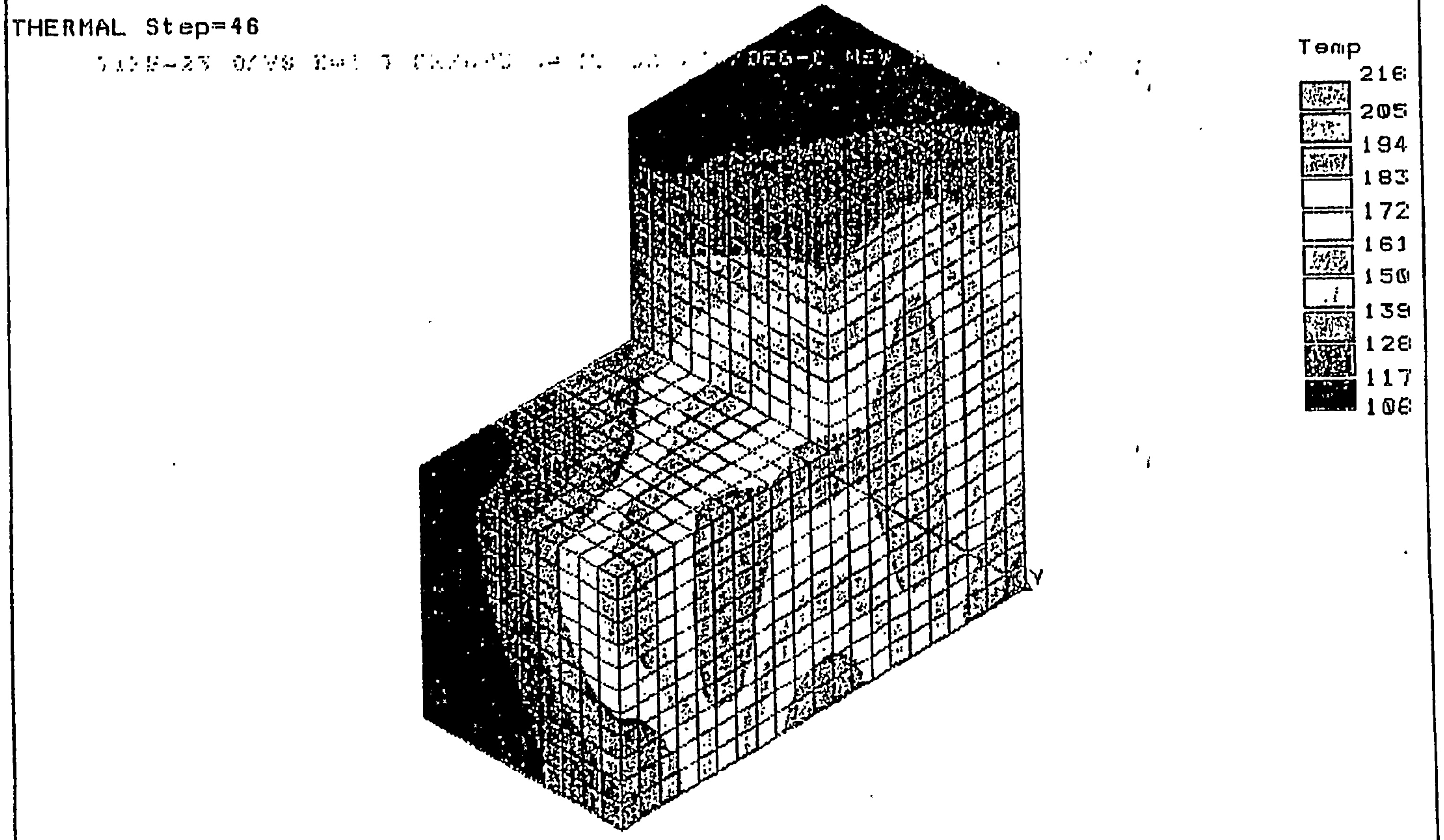
DBL.G04 **Dual Applicators** Temperature Profile - After 11 days of RF heating



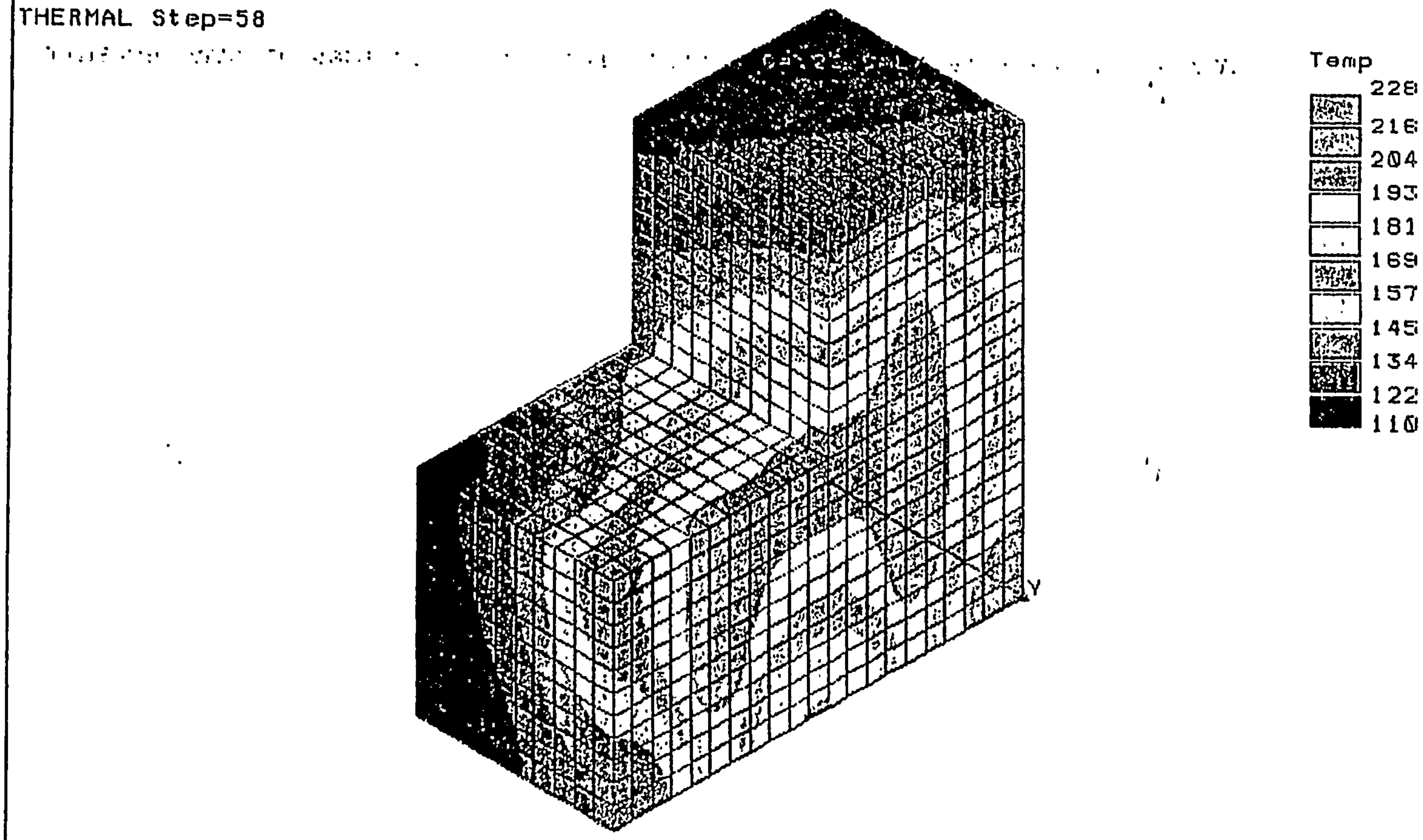
DBL.G05 **Dual Applicators** Temperature Profile - After 17 days of RF heating



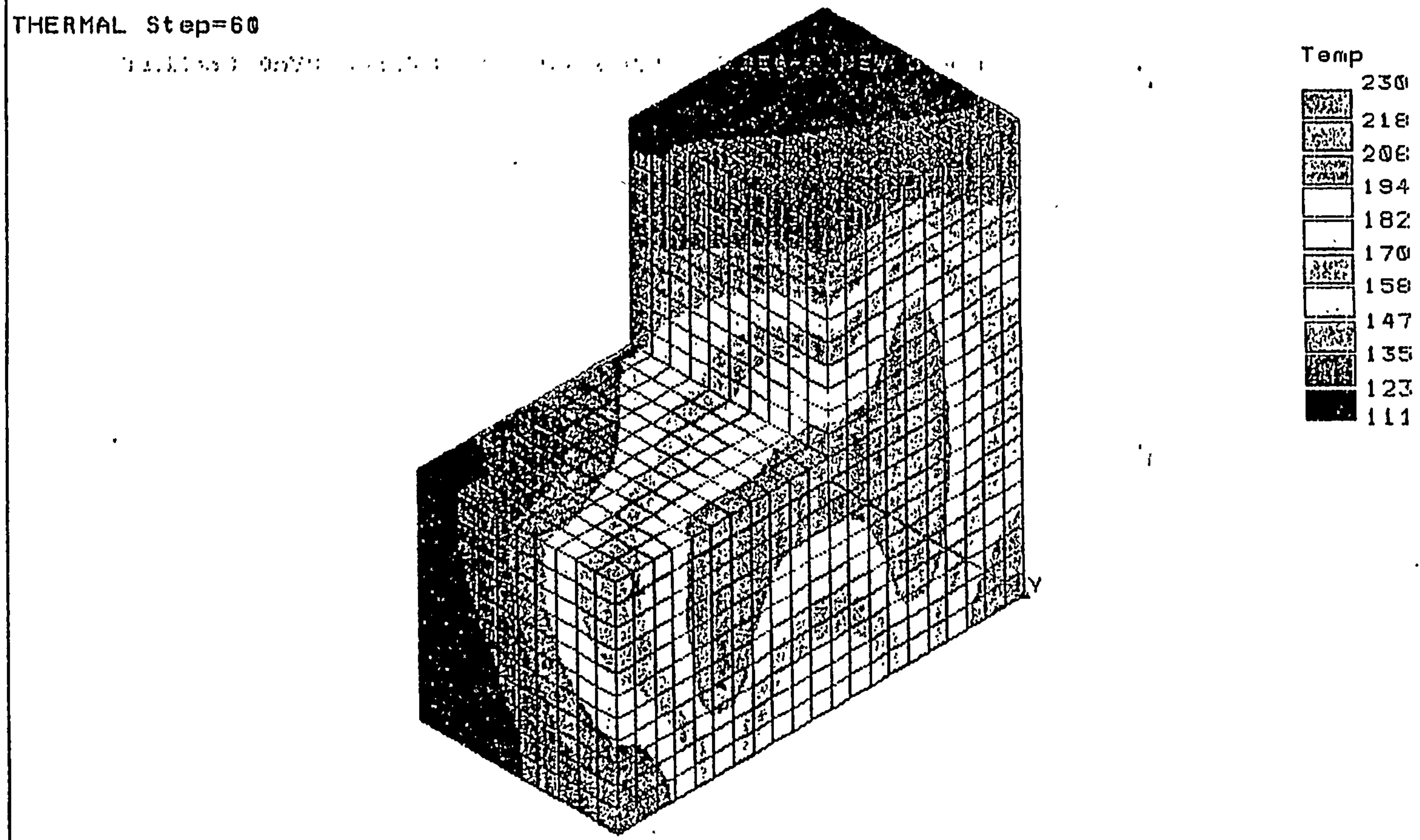
DBL.G05 **Dual Applicators** Temperature Profile - After 17 days of RF heating



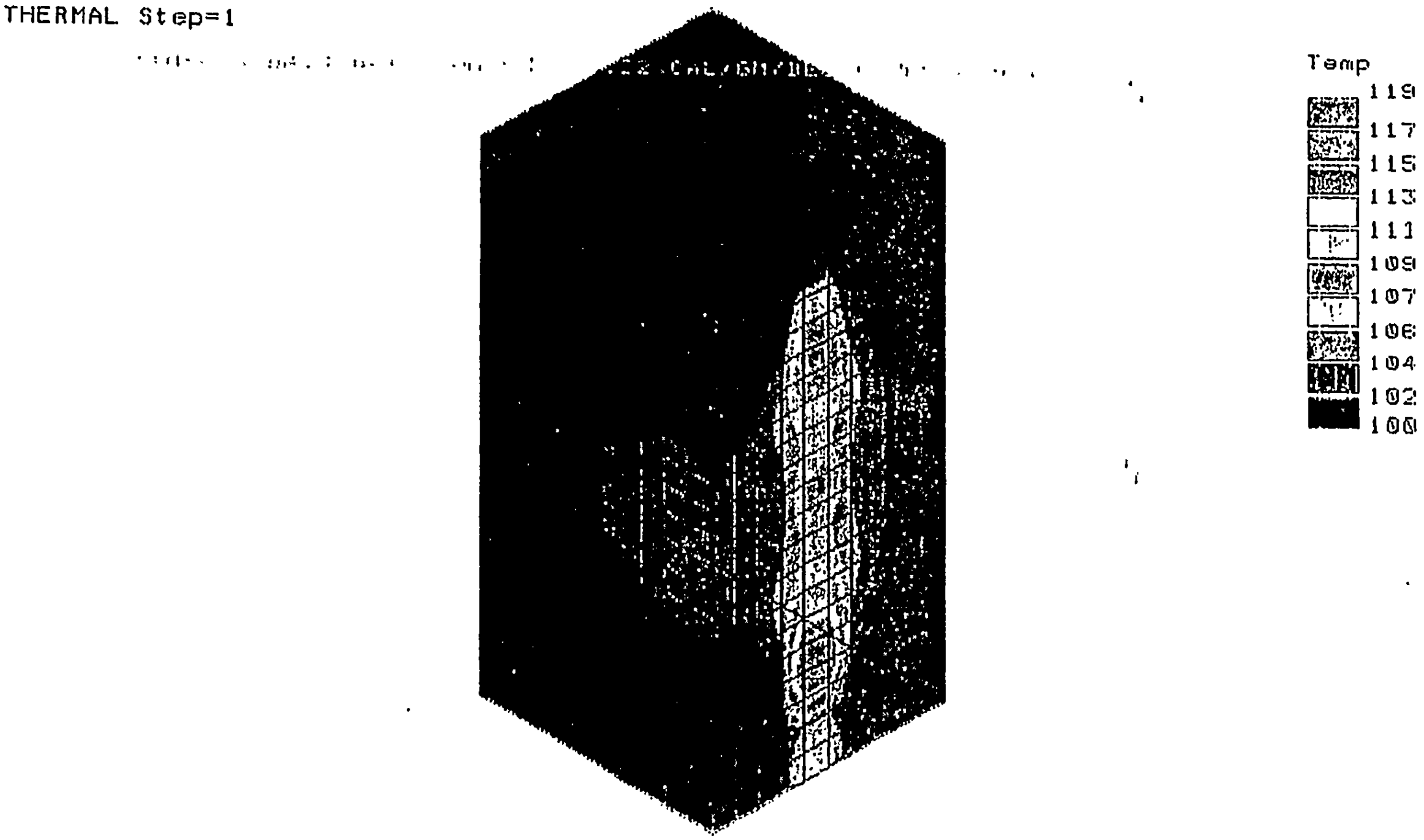
DBL.G06 **Dual Applicators** Temperature Profile - After 23 days of RF heating



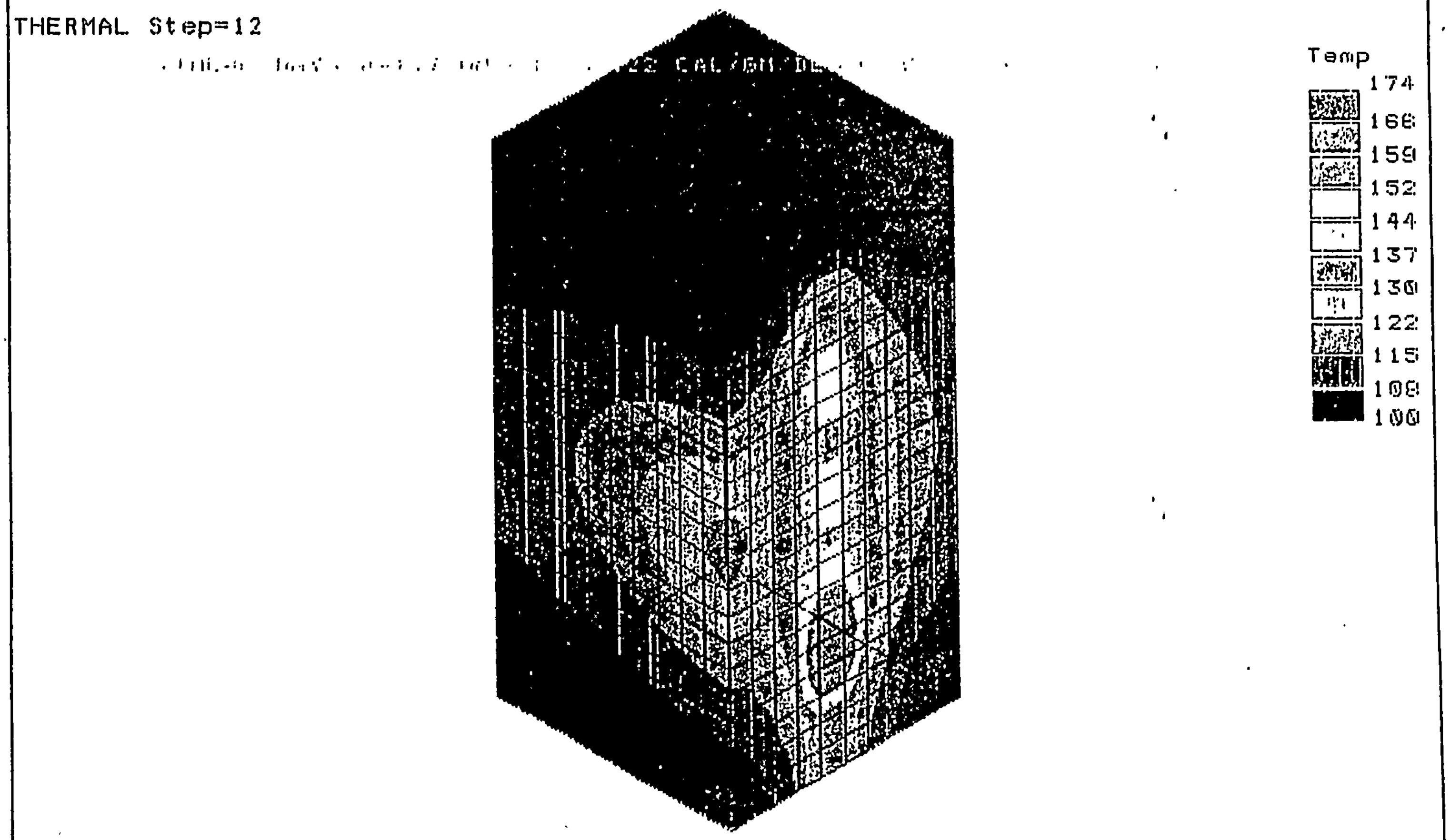
DBL.G07 **Dual Applicators** Temperature Profile - After 29 days of RF heating



DBL.G08 **Dual Applicators** Temperature Profile - After 30 days of RF heating

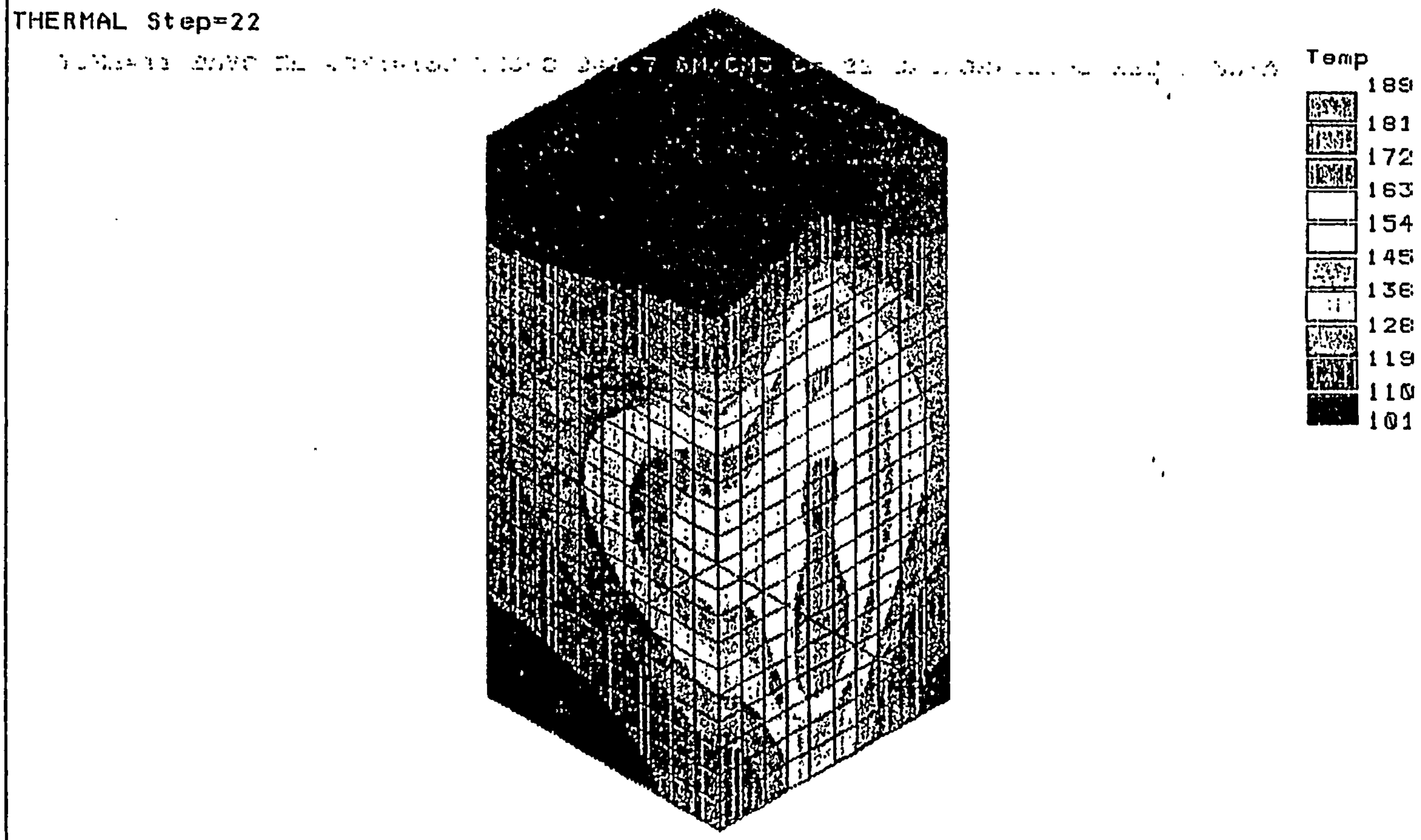


DBL.G09 **Dual applicators** Temperature Profile - After 0.5 days of RF heating

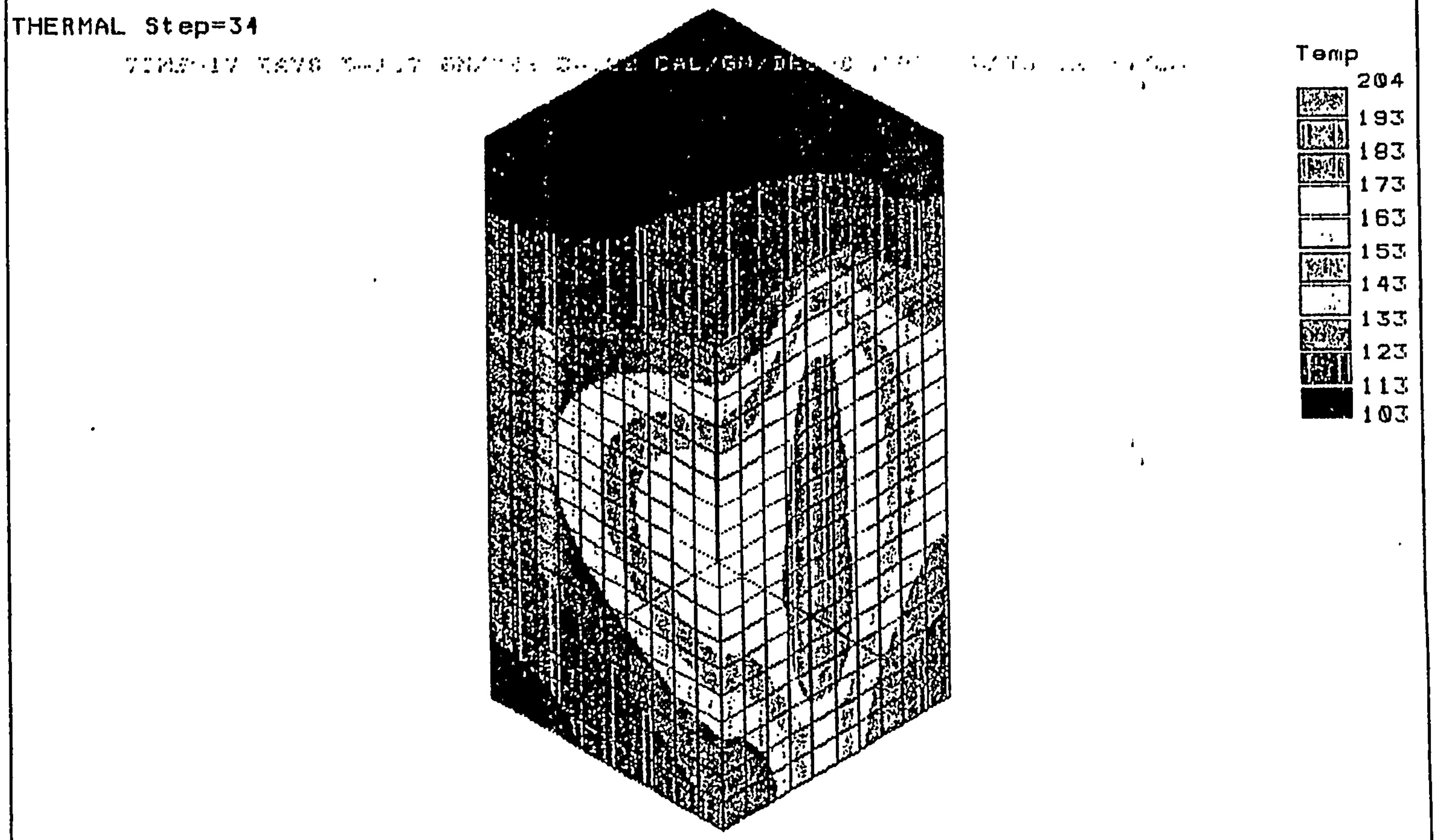


DBL.G10 **Dual Applicators** Temperature Profile - After 6 days of RF heating

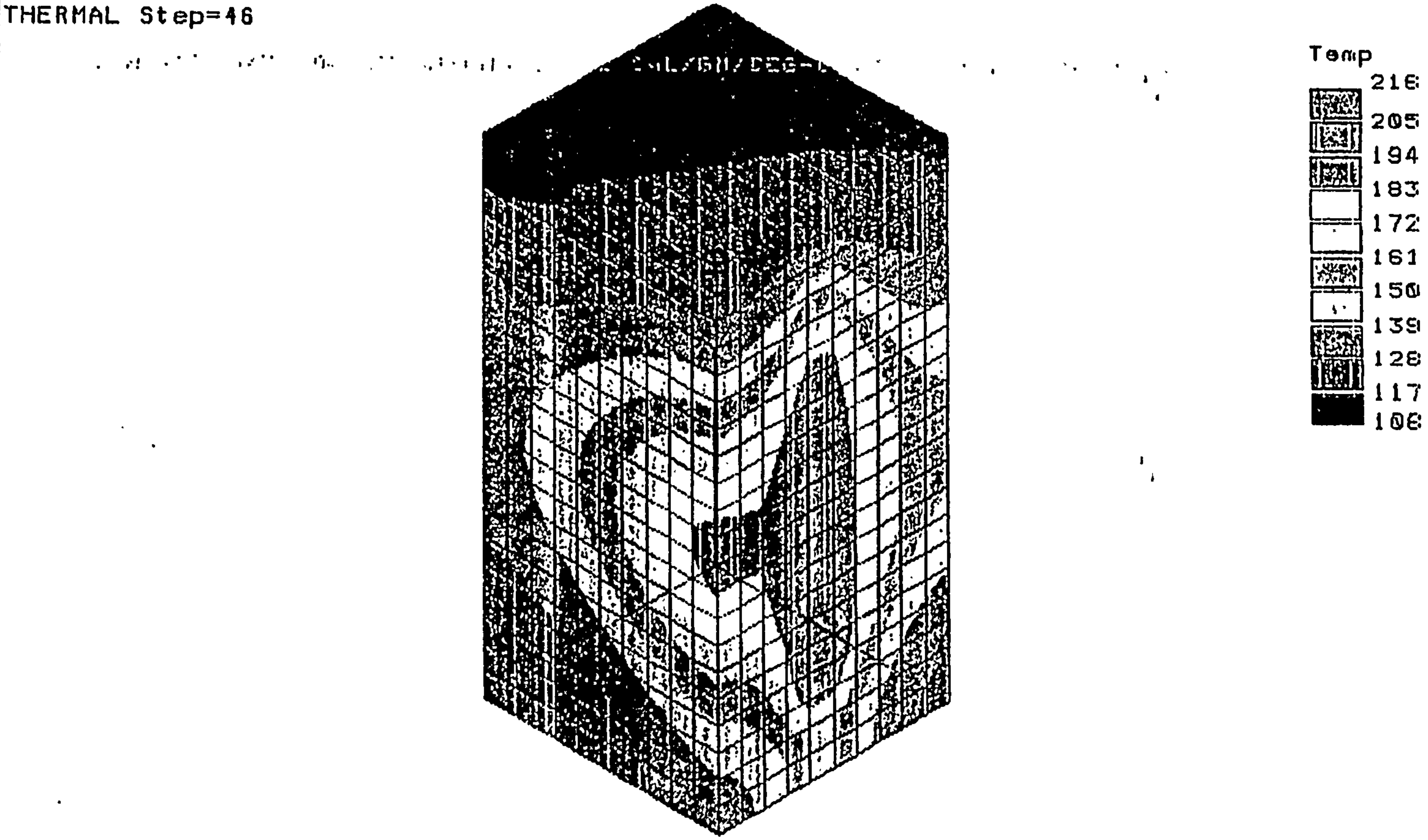
1 .G10



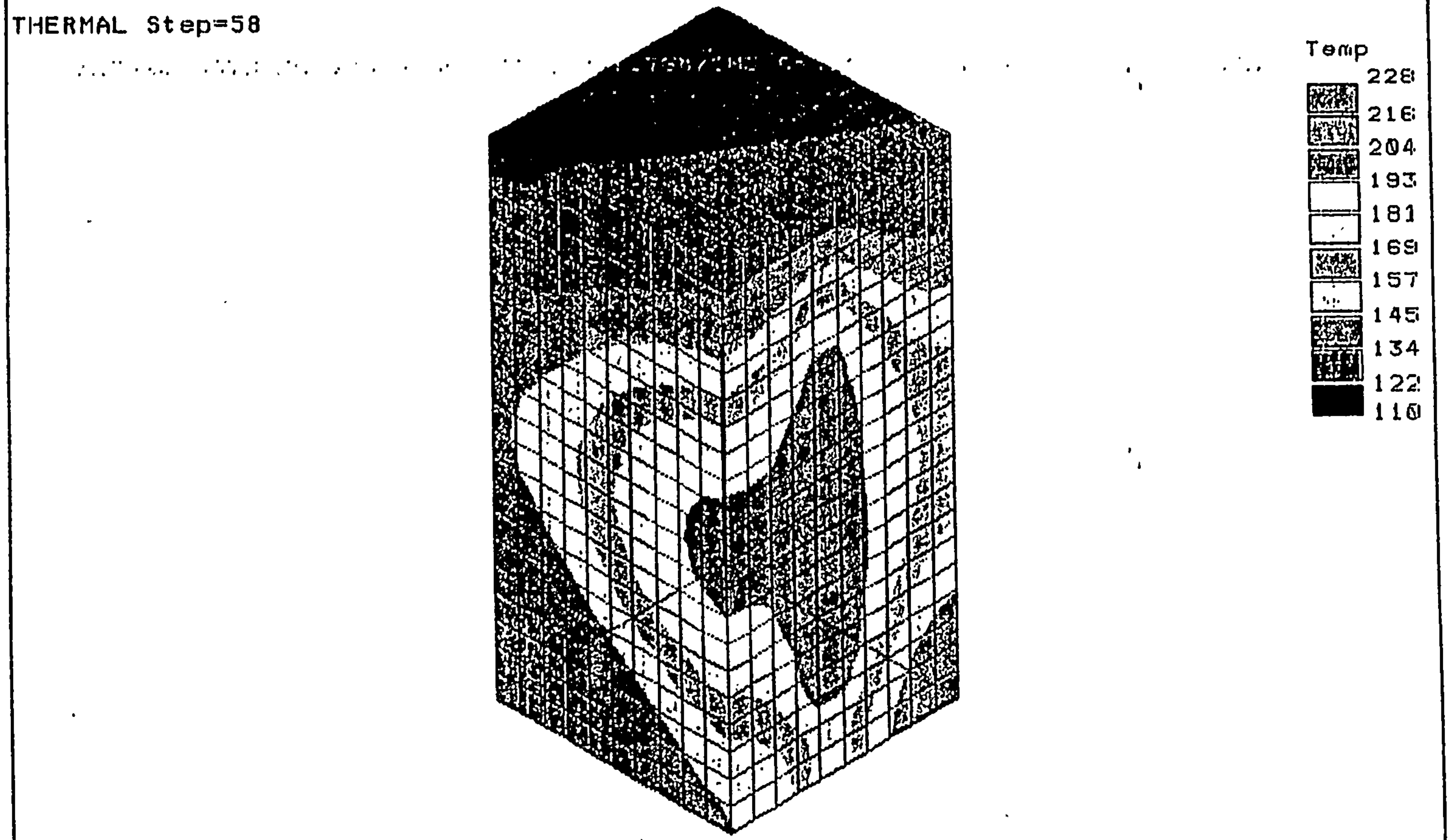
DBL.G11 **Dual Applicators** Temperature Profile - After 11 days of RF heating



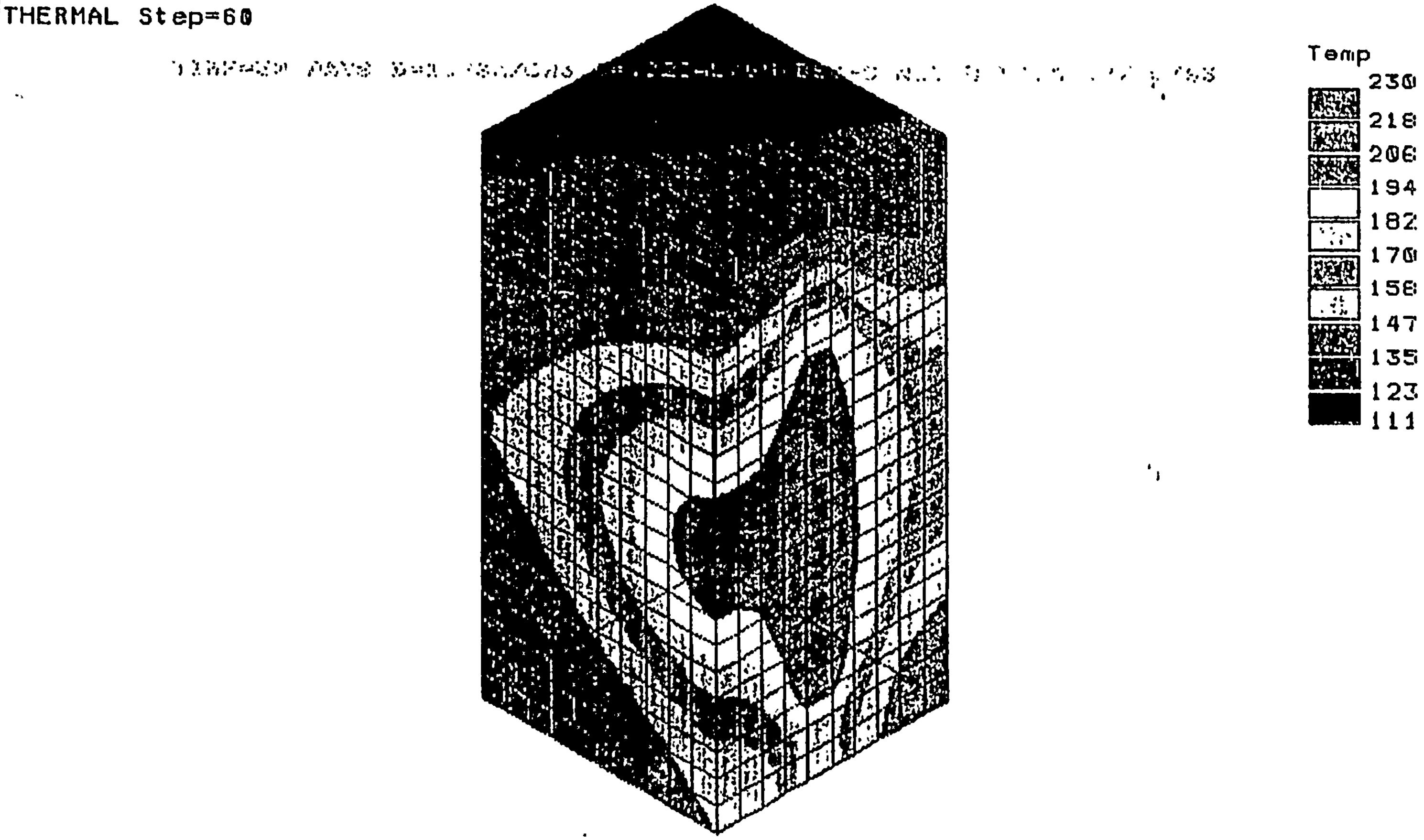
DBL.G12 **Dual Applicators** Temperature Profile - After 17 days of RF heating



DBL.G13 **Dual Applicators** Temperature Profile - After 23 days of RF heating



DBL.G14 **Dual Applicators** Temperature Profile - After 29 days of RF heating



DBL.G15 **Dual Applicators** Temperature Profile - After 30 days of RF heating

APPENDIX B.2.

HALLIBURTON NUS
Environmental Corporation

FIELD LOG OF BORING

SHEET: 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: A1
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: SST
DRILL RIG TYPE: Mobile B-53
DRILLING METHOD: Hollow Stem
DRILLERS NAME: John Talbot
TOTAL DEPTH (FT.) 28'
TIME STARTED 1630 DATE 1/11/94
TIME COMPLETED 1845 DATE 1/11/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING: Dry
BACKFILLED, TIME DATE
WEATHER CONDITIONS: Partly cloudy, mid 60°s, mod. windy
SURFACE ELEVATION
COMMENTS

Gravel @ sfc

Fill; clay, gravelly, dark brn, dry

#1 liner for analysis

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP	2	1.1	Good		KAA-A1-U0002 1645	0		
								1
								2
								3
								4
								5
								6
								7
								8
								9

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Holding

JOB NO. 3688

BORING NO. A1

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
								5	
								6	16'-20' Clay, silty, w/ gravel red - dk br,
3" SP	2.0	1.2	good	KRF-A1-41618 KRF-A1-41618D	1710	>1000		7	FILL. Moist 16'-18' < #2 liner for analysis #1 liner for duplicate
				KRF-A1-41820				8	
3" SP	2.0	1.1	good		1718	400		9	
								20	Moist
								1	
								2	
								3	
								4	24' Hit gravel
								5	
				KRF-A1-42728				6	
3" SP	0	0			~~1758~~	~~450~~		7	No recovery @ 26', or gravel blocking spoon
27'-28' 3" SP	1.1	[illegible]	fair		1758	450		8	
								9	100 blows for 1' recovery
								0	
								1	27'-28' gravel, silty, yellowish br ~~to tan~~
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. A2
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger 6¼" ID	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.) 27.2'	
TIME STARTED 1009	DATE 1/12/94
TIME COMPLETED 1225	DATE 1/12/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Overcast, upper 50s °F, NE wind - moderate	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	OVA ~~HNU~~ SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP	2.0	1.5	Good		KRF-A2-110002 1015	5		1 2
3" SP	2.0	1.5	Good		KRF-A2-110204 1022	0		3 4
3" SP	2.0	0.9	Good		KRF-A2-110406 1033	0		5 6
								7 8 9

COMMENTS

0'-0.5' Gravel fill

0.5'-2.0' Fill, Silt, clayey, w/ gravel, yellowish brn to med. brn, dry
#2 liner - regular

2'-4' Silt, clayey, plastic, wire, w/ gravel, FILL, #2 liner - regular

4'-6' Clay, silty, w/ gravel, copper wire, metal, wood, med. brn, moist.
#2 liner - regular

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. A2

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	OVA ~~HNU~~/SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP	2.0	2.0	Good	KRF-A2-U10	KRF-A2-U1012 1045	360		11 12
3" SP	2.0	2.0	Good		KRF-A2-U1214 1058	80		13 14
								15 16
3" SP	2.0	1.8	Good	KRF-A2-U1618D	KRF-A2-U1618 1107	300		17 18
								19 20
3" SP	2.0	1.6	Good		KRF-A2-U2022 1123	420		21 22
								23 24 25 26
3" SP	1.2	1.2	Good		KRF-A2-U2628 1151	>1000		27 28
								9 0 1 2 3 4 5 6 7 8 9 0

10'-12' Clay, dark brn, w/ minor gravel, FILL.
#2 liner - regular, #3 liner - duplicate

12'-14' Same as 10'-12'
#2 liner - regular

16'-18' Clay, silty, sandy, w/ minor gravel,
dark brn, FILL?, wet, #2 liner - regular
#3 liner - duplicate

20'-21.5' Same as 16'-18', moist, sampled - #2 liner
21.5'-22' Gravel, silty, some clay, yellowish
brn to tan, moist

26'-27½' Gravel, silty, some clay, chert,
yellowish brn to tan, moist

200 blows w/ 140 lb hammer for 1.2' driven
#2 liner - regular

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. E1
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.) 24.6	
TIME STARTED 0804	DATE 1/14/94
TIME COMPLETED 1100	DATE 1/14/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING Dry	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Fair, upper 30's F, slight breeze	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~OVA~~ ~~HNU~~ SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP	2.0	2.0	Good		KRF-E1-U0002	HNU 1100?		1
						0816		2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

0'-0.4' Gravel at sfc

0.4'-2.0' Silt, clayey, w/ gravel, red brn to blk brn, Fe stained, dry

#2 liner regular

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Plating
JOB NO. 3688
BORING NO. E1

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP	2.0	1.2	Good		KRF-E1-U10[illegible] 0830			11
								12
								13
								14
								15
								16
3" SP	2.0	1.7	Good		KRF-E1-U1618 KRF-E1-U1618D 0846	160		17
								18
								19
								20
								1
								2
								3
								4
3" SP	0.6	0.6	Fair		KRF-E1-U2425 0934			5
								6
								7
								8
								9
								0
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

10'-12' Clay, silty, w/ gravel, dk brn, moist.
#2 liner - regular

16'-18' Gravel, clayey, yellowish brn to tan. Moist w/ fuel odor, what appears to be free product?
#2 liner regular
#1 liner duplicate
#3 liner material had slipped out partially therefore used #1 liner for dup.

24'-24.6' Gravel, silty, sl. clayey, yellowish brn to tan, dry

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. E2
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger 4¼"	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.) 28.0	
TIME STARTED 1228	DATE 1/18/94
TIME COMPLETED 1402	DATE 1/18/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP	2.0	1.0	Fair	KRF-E2-U0002	1233	8		1
								2
								3
								4
								5
								6
								7
								8
								9
								10'

COMMENTS

0'-0.3' Gravel, silty, light brn
0.3'-2.0' Silt, clayey, w/ gravel,
2" chunk of asphalt in shoe, dk brn,
dry, FILL
#1 liner - regular

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating	BORING NO. E2
JOB NO. 3688	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
3" SP	2.0	1.3		KRF-E2-U1012	1303	84		11	10'-12' Clay, sl. silty, w/ gravel, moist,
								12	med. brn to dk brn, FILL
								13	
								14	#2 liner - regular
								15	
								16	
								17	
								18	18' Driller reports gravel
								19	
								20	
								21	
								22	
								23	
								24	
								25	
								26	26'-28' Gravel, clayey
3" SP	2.0	1.8		KAF-E2-U2628	1337	220		27	
								28	
								9	#2 liner - regular
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating

BORING NO. E3

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: SST

DRILL RIG TYPE: Mobile B-53

DRILLING METHOD: Hollow Stem Auger 4¼" ID

DRILLERS NAME: John Talbot

TOTAL DEPTH (FT.) 29.0

TIME STARTED 1542 DATE 1/17/94

TIME COMPLETED 1754 DATE 1/17/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING Wet

BACKFILLED, TIME DATE

WEATHER CONDITIONS Partly Cloudy, mild 60°F, strong NE wind

SURFACE ELEVATION

COMMENTS Gravel at sfc.

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E3

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	14'-16' Clay, sandy, silty, w/ gravel,
3" SP	2.0	1.3	Good	KRF-E3-U1416	1631	600		5	moist, FILL
								6	#2 liner - regular
3" SP	2.0	1.8	Good	KRF-E3-U1618	1644	38		7	16'-18' same as 14'-16' w/ wood fragments
								8	
								9	#2 liner - regular
								20	
3" SP	2.0	1.2	Good	KRF-E3-U2022	1657	>1000		1	20'-22' Clay, sandy, w/ gravel med.
								22	brn to dk brn, moist, soft,
								3	solvent odor, FILL
								4	#2 liner - regular
								5	24' Gravel
								6	
								7	
								8	
3" SP	0.9	0.9	Good	KRF-E3-U2829	1734	480		9	28'-29' Gravel
								30	
								1	
								2	
								3	200 blows for 0.9' drive
								4	#1 liner - regular
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. E4
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger 4¼" ID	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.) 26'	
TIME STARTED 1006	DATE 1/17/94
TIME COMPLETED 1208	DATE 1/17/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Partly Cloudy, lo 50°s F, strong 15-20mph N wind	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM) OVA	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
3" SP	2.0	0.3	Poor		1033	0		7
3" SP	2.0				1033	0		8
		2.0	Good	KRF-E4U6709	1055	32		9

COMMENTS

Gravel at sfc

3' Large gravel or concrete

6-7' On hard obstruction, cannot drive split spoon, use wedge and downhole hammer to break through obstruction, no sample due to poor recovery

7-9' clay, w/ sand, gravel, med. brn, slight hydrocarbon odor

#2 [illegible]

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E4

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP	2.0	1.8	Good	KRF-E4-U911	1104	34		1
								2
								3
								4
								5
								6
								7
								8
								9
								20
								1
								2
								3
								24
3" SP	2.0	1.6	Good	KRF-E4-U2426	1130	600		5
								6
								7
								8
								9
								0
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

9'-11' clay, sandy, silty, w/gravel, dk brn, moist at bottom, FILL

#2 liner - regular

24' Gravel

24'-26' Gravel, clayey, yellowish brn ~~stns~~ ~~stns~~, dry, solvent/fuel odor.

#2 liner - regular

NOTES:

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FIELD LOG OF BORING

SHEET: 1 OF 2

PLAN

PROJECT: RF Heating	BORING NO.: E5
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger 4¼"	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.) 22	
TIME STARTED 1355	DATE 1/17/94
TIME COMPLETED 1523	DATE 1/17/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS: Partly Cloudy, upper 50's F, strong NE wind	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
3" SP	2.0	1.7	Good		1404	4		5
								6
3" SP	2.0	1.2	Good		1408	14		7
								8
								9

COMMENTS

4'-6' Clay, sandy, silty, w/gravel, med. brn to dk brn, dry, filter fabric, wire
FILL.

#2 liner - regular

6'-8' Same as 4'-6'

#2 liner - regular

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E5

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNU/SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP	2.0	2.0	Good		1418	240		11
3" SP	2.0	2.0	Good		1426	24		13
3" SP	2.0	1.6	Good		1441	160		19
3" SP	2.0	1.8	Good		1454	80		21

10'-12' Clay, silty, some sand, w/ gravel, dk brn, moist, FILL #2 lin

12'-14' Same as 10'-12'
#2 liner - regular

18'-20' Clay, sandy, silty, w/gravel, dk brn, moist to wet in spots, solvent odor, FILL
#2 liner - regular

20'-22' Clay, sandy, silty, w/ gravel dk brn, moist to wet in spots, solvent odor, FILL
#2 liner - regular

NOTES:

HALLIBURTON NUS

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT:

BORING NO. E6

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: SST

DRILL RIG TYPE: Mobile B53

DRILLING METHOD: Hollow Stem Auger

DRILLERS NAME: John Tallon

TOTAL DEPTH (FT.) 22

TIME STARTED 1350 DATE 1/14/94

TIME COMPLETED 1443 DATE 1/14/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING: Dry

BACKFILLED, TIME DATE

WEATHER CONDITIONS: Fair, upper 60°F, mod. SW wind

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								0–1	Gravel
								2	
								3	
								4	
								5	
								6	
								7	
3" SP	2.0	1.9	Good	KRF-E6-U0810	1358	2		8–10	Clay, silty, sdy, w/ gravel, dk brn, moist, FILL #2 liner - regular

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Keating

JOB NO. 3688

BORING NO. E6

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNUSCAN~~ OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								11
								12
								13
								14
								15
								16
3" SP	2.0	1.6	Good	KRF-E6-U16180 KRF-E6-U1618	1410	180		17
								18
								19
								20
3" SP	2.0	1.6	Good	KRF-E6-U2022	1420	>1000		21
								22
								3
								4
								5
								6
								7
								8
								9
								0
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

16'-18' Clay, silty, w/ some gravel, wood frags., moist, fuel odor, moist, FILL
#2 liner - reg
#3 liner - dup.

20'-22' Clay, silty, w/ some large 3" diam chert clasts, moist, fuel odor, FILL
#2 liner - regular

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: E7
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: SST
DRILL RIG TYPE: Mobile B-53
DRILLING METHOD: Hollow Stem Auger
DRILLERS NAME: John Talbot
TOTAL DEPTH (FT.) 14
TIME STARTED 1600
DATE 1/13/94
TIME COMPLETED 1645
DATE 1/13/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING: Dry
BACKFILLED, TIME
DATE
WEATHER CONDITIONS: Partly Cloudy, upper 60°s, NE wind
SURFACE ELEVATION
COMMENTS

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM) OVA	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	Gravel at sfc.
3" SP	2.0	1.6	Good		RRF-E7-00204	32 1604		2 3	2'-4' Clay, silty, w/gravel, light brn to red brn, moist
								4	#2 liner - regular
								5	
								6	
								7	
								8	
								9	
								10	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E7

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNUSCAN~~ OVM (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
3" SP	2.0	2.0	Good	KRF-E7-UD19	1619	70		3	12'-14' Clay, silty, w/ minor
								4	gravel, med brn to dk brn, moist
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. E8
JOB NO. 3688	LOGGED BY: GDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger 4¼"	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.) 28'	
TIME STARTED 0925	DATE 1/18/94
TIME COMPLETED 1051	DATE 1/18/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING Wet, water at ~25'	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Partly Cloudy, lo 40°F, strong NE wind, gusty	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM) OVA	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	
								2	
								3	
								4	
								5	
								6	6'-8' Clay, silty, w/gravel, dk brn, sl. moist, FILL
3" SP	2.0	1.6	Good	KRF-E8-U0608		2 0935		7	
								8	
								9	#2 liner - regular
								10	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT	RF Heating
JOB NO.	3688
BORING NO.	E8

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	18 Driller reports gravel
								9	
								20	
								1	
								22	
								23	
								24	
3" SP	1.2	1.2	Good	KRF-E8-2426 1007		900		25	24.0'-25.2' Gravel, clayey; yellowish brn,
								26	Wet at bottom; 200 blows for 1.2'
3" SP	2.0	1.8	Good	KRF-E8-2628 1027		280		27	#2 liner - regular
								28	26'-28' Same as 24'-25.2'; wet,
								9	#2 liner, solvent odor
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. F1
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger 4 1/4" ID	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.): 23'	
TIME STARTED 0814	DATE 1/15/94
TIME COMPLETED 0937	DATE 1/15/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING Wet	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Partly cloudy, upper 30°sF, slight NW wind	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM) OVA	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
3" SP	1.5	0.7	Good	KRF-F1-010406 0822		4		4
								5
								6
								7
								8
								9
								10

COMMENTS

4-5.5' Clay, silty, w/ gravel, wood frags, dk brn, moist, FILL

#1 liner - regular

75 blows for 1.5' driven, driller reports no sand

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. F1

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
3" SP	2.0	0.8	Good		KRF-F1-U1012	74' 0829		11	10'-12' Clay, silty, sandy, w/ minor
								12	gravel, dk brn, moist, soft, FILL
								13	#1 liner - regular
								14	
								15	
								16	
								17	
								18	18'-20' Gravel, clayey, dk brn,
3" SP	2.0	1.9	Good		KRF-F1-U1820 0853	>1000ppm		19	wet w/ free product ~19'-20', FILL?
								20	Fuel odor from sample
								21	
								22	#2 liner - regular
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Testing
BORING NO. F2
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: SST
DRILL RIG TYPE: Mobile B-53
DRILLING METHOD: Hollow Stem Auger 4¼" ID
DRILLERS NAME: John Talbot
TOTAL DEPTH (FT.) 27.5
TIME STARTED 0958
DATE 1/15/94
TIME COMPLETED 1110
DATE 1/15/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING
BACKFILLED, TIME
DATE
WEATHER CONDITIONS Partly Cloudy, lo 60's F, light east wind
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
									Gravel
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. F2

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO	FIXED LAB. SAMPLE NO	HNU SCAN (PPM) OVA	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	14'-16' Clay, slightly silty, w/
3" SP	2.0	1.6	Good	KRF-F2-U1416	1011	.240		15	gravel, moist, dk brn, slight fuel
								16	odor, soft, FILL
								17	#2 liner - regular
								18	
								19	
								20	
								21	
								22	
								23	
								24	24' Gravel
								25	
								26	26'-27.5' Gravel, clayey, yellowish
3" SP	1.5	1.5	Good	KRF-F2-U2628	1038	800		27	brn; moist, outside wet from above
								28	strong fuel / solvent odor
								9	# 2 liner - regular
								0	210 blows for 1.5' drive
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: F3
JOB NO.: 3688
LOGGED BY: BDH
PROJ. MGR.: CFB
EDITED BY:
DRILLING COMPANY: SST
DRILL RIG TYPE: Mobile B-53
DRILLING METHOD: Hollow Stem Auger 4¼" ID
DRILLERS NAME: John Talbot
TOTAL DEPTH (FT.): 23
TIME STARTED: 12 15
DATE: 1/15/94
TIME COMPLETED: 1306
DATE: 1/15/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING: Dry
BACKFILLED, TIME:
DATE:
WEATHER CONDITIONS: Partly Cloudy, upper 60°F, moderate east wind
SURFACE ELEVATION:

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								0-1	Gravel
								1	
								2	
								3	
3" SP	2.0	1.5	Good	KRF-F3 010406 1221		0		4-6	4-6' Clay, slightly silty, w/ gravel, concrete frags dry to sl. moist, FILL
								6	#2 liner - regular
								7	
								8	
								9	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT	
JOB NO. 3688	BORING NO. F3

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNU/SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
3" SP	20	1.5	Good	KRF-F3-410		80! 1228		11	10'-12' Clay, slightly silty, w/ gravel
								12	dk brn, moist, FILL
								13	
								14	#2. liner regular
								15	
								16	
								17	
								18	
								19	
								20	
								21	
								22	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating	BORING NO.: F4
JOB NO.: 3688	LOGGED BY: BDH
PROJ. MGR.: CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem auger	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.): 29	
TIME STARTED: 1454	DATE: 1/14/94
TIME COMPLETED: 1646	DATE: 1/14/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING:	
BACKFILLED, TIME:	DATE:
WEATHER CONDITIONS: Fair, upper 50°sF, SW wind moderate	
SURFACE ELEVATION:	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
3" SP	2.0	1.3	Good	KRF-F4-U0002 1502 2				1
								2
								3
								4
								5
								6
								7
								8
								9

COMMENTS

0 - 0. Gravel

0. - 2' Clay, silty, w/ gravel, asphalt frags., med. brn to dk brn slightly moist, FILL

#2 liner - regular

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Venting

JOB NO. 3688

BORING NO. F4

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU SCAN~~ OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	12'-14'
3" SP	2.0	1.2	Good	KRF-F4-U1214 1516		38		13	Clay, sl. silty, w/gravel, dk brn,
								14	moist, FILL, some wood fragments
								15	
								16	
3" SP	2.0	0.6	Fair	KRF-F4-U1618 1528		44		17	16'-18'
								18	
								19	
								20	#1 liner - regular
								21	
								22	
								23	
								24	24' Gravel, clayey, yellowish brn
								25	
								26	
								27	
								28	28'-29' Gravel, clayey, yellowish brn
3" SP	1.2	1.2		KIRF-F4-U2829 1604		>1000		29	
								30	
								1	
								2	230 blows for 1.2' drive
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET: 1 OF 2

PLAN

PROJECT RF Hepting	BORING NO. F5
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger 4¼" ID	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.) 24.2	
TIME STARTED 0810	DATE 1/17/94
TIME COMPLETED 0950	DATE 1/17/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING Dry	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Partly cloudy, mid 40's F, strong N wind	
SURFACE ELEVATION	
COMMENTS Gravel at sfc.	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating
JOB NO. 3688
BORING NO. F5

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNU/SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								11
3" SP	2.0	0.8	Good		KRF-F5-U124. 0822	22		12 13 14
								15 16
3" SP	2.0	1.2	Good		KRF-F5-U1618 0837	>1000		16 17 18
3" SP	2.0	1.5	Good		KRF-F5-U1820 0850	550		18 19 20
								21 22
3" SP	1.2	1.2	Good		KRF-F5-U2324 0934	120		22 23 24
								5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

12'-14' Clay, silty, w/ gravel, dk brn, moist, soft, FILL
#1 liner - regular

16'-18' Clay, silty, w/ gravel, dk brn, moist, soft, slight fuel odor, FILL

#2 liner - regular

18'-20' Clay, silty, sandy, w/ gravel, dk brn, moist, slight fuel odor, soft, FILL
22' Hit gravel ↑ 3" block of wood /
#2 liner regular nail
22'-24' Gravel, 200 blows for 0.3' drive, no recovery, will drill down to 23' and try again

23'-24.2' Gravel, clayey, yellowish brn to tan, dry
200 blows for 1.2' drive
#2 liner - regular

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF ___

PLAN

PROJECT: RF Heating
BORING NO.: TD1 / TD2
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: SST
DRILL RIG TYPE: Mobile B-53
DRILLING METHOD: Hollow Stem Auger 4¼" ID
DRILLERS NAME: John Talbot
TOTAL DEPTH (FT.) 26
TIME STARTED 1435
DATE 1/13/94
TIME COMPLETED 1541
DATE 1/13/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING
BACKFILLED, TIME
DATE
WEATHER CONDITIONS: Partly Cloudy, upper 60°F, mod. NE wind
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10'

COMMENTS

Gravel at sfc.

Clay, silty, w/ gravel, rubber, wire, wood, FILL, moist.

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. TD1 / TD2

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB SAMPLE NO	FIXED LAB SAMPLE NO	HNU/SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								20	
								1	
								2	
								3	
								4	24' Gravel
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. TD3
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger 4"	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.) 26.0	
TIME STARTED 0953	DATE 1/13/94
TIME COMPLETED 1135	DATE 1/13/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Partly Cloudy, mid 50's, mod. NE wind	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
3" SP	2.0	0.7	Good		KRF-TD3-011406 1200	42		4–6
								7
								8
								9
								10

COMMENTS

0'-1' Gravel at sfc.

1'- Clay, silty; med. to dk brn w/ gravel, moist; # 1 liner - regular

4'-6' Clay, silty, med to dk brn, w/ gravel, moist.

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. TD3

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO	FIXED LAB. SAMPLE NO	~~HNU SCAN~~ OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
3" SP	2.0	1.8	Good		KRF-TD3-U1416 1024	50		5	14-16' Clay, silty, w/gravel, wood,
								6	brick, cinder frags., med. brn to
								7	dk brn, moist, FILL
								8	#2 liner - regular
								9	
								0	
								1	
								2	
								3	
								4	24-26' Gravel, clayey, yellowish
3" SP	2.0	1.8	Good	KRF-TD3-U2426D	KRF-TD3-U2426 1049	>1000		5	to tan, wet
								6	
								7	#2 liner - regular
								8	#3 liner - duplicate
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 1

PLAN

PROJECT: RF Heating
BORING NO.: TD4
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: SST
DRILL RIG TYPE: Mobile B-53
DRILLING METHOD: Hollow Stem Auger 4¼" ID
DRILLERS NAME: John Talbot
TOTAL DEPTH (FT.) 15
TIME STARTED 1345 DATE 1/13/94
TIME COMPLETED 1425 DATE 1/13/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING: Dry
BACKFILLED, TIME DATE
WEATHER CONDITIONS: Partly Cloudy, mid 60°F, NE wind
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
									gravel at sfc.
								1	
								2	
								3	
								4	
								5	
								6	Hard drilling at 6' and 8'
								7	
								8	
								9	
								10	

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: TD5
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: SST
DRILL RIG TYPE: Mobile B-53
DRILLING METHOD: Hollow Stem Auger, 4¼"
DRILLERS NAME: John Talbot
TOTAL DEPTH (FT.) 24.8
TIME STARTED 0941 DATE 1/19/94
TIME COMPLETED 1058 DATE 1/19/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING: Wet
BACKFILLED, TIME: DATE:
WEATHER CONDITIONS: Partly Cloudy, lo 30°F, NE wind
SURFACE ELEVATION:

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM) OVA	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	
								2	
								3	
3" SP	2.0	1.0	Fair	KRF-TD5-40406 0946		2		4	4-6' Clay, silty; dk brn, w/ gravel, slightly moist
								5	
								6	# 1 liner - - [illegible]
								7	
								8	
								9	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT KRF Heating

JOB NO. 3688

BORING NO. TD5

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	14'-16' clay, silty, w/ gravel, dk
3" SP	2.0	1.0	Good	KRF-TD5-U1416	0956	360		5	brn, moist, solvent odor, FILL
								6	
								7	
								8	#1 liner - regular
								9	16' Driller reports gravel
								20	
								1	
								2	
								3	
								4	24'-24.8' Gravel, clayey, yellowish
3" SP	0.8	0.8	Good	KRF-TD5-U2425	1028	>1000		5	brn, moist to wet, solvent odor.
								6	
								7	#1 liner - regular
								8	270 blows for 0.8' drive
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. TD6
JOB NO. 3688	LOGGED BY: DDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger 4¼"	
DRILLERS NAME: John Talbot	
TOTAL DEPTH (FT.) 26.5	
TIME STARTED 1418	DATE 1/18/94
TIME COMPLETED 1543	DATE 1/18/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Partly Cloudy, mid 40°s F, strong NE win gusty	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	
								2	
								3	
3" SP	2.0	1.0	Fair	KRF-TD6-010406 1428				4	
								5	
								6	#1 liner - regular
								7	
								8	
								9	
								10	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating
JOB NO. 3688
BORING NO. TD6

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO	FIXED LAB. SAMPLE NO	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
3" SP	2.0	0.7	poor	KRF-TD6-U1416	1438	20		15	Clay, silty, sandy, w/gravel, dk
								16	brn, sl moist
								17	#1 liner
								18	
								19	
								20	
								21	
								22	
								23	
								24	
3" SP	~~0.5~~ 1.5	0 1.9	good		1545	180		25	
				XRF-TD6-U2527				26	200 blows for 0.5', no recovery
								7	drill on down ~~to~~ 25'
								8	25-26.5' gravel. layer
								9	#2 liner - regular
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

HALLIBURTON NUS
Environmental Corporation

FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. TD7 / TD8
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: SST	
DRILL RIG TYPE: Mobile B-53	
DRILLING METHOD: Hollow Stem Auger	
DRILLERS NAME: John Falbot	
TOTAL DEPTH (FT.) 25	
TIME STARTED 1410	DATE 1/12/94
TIME COMPLETED 1610	DATE 1/12/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING	
BACKFILLED, TIME	DATE
WEATHER CONDITIONS Overcast; upper 50's F, strong NE wind	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9

COMMENTS

0'-0.5' Gravel

0.5'-18 Fill, clay, silty,
w/ gravel med. brn to dk brn, moist

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. TD7 / TD8

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	18'-25' Gravel, silty, clayey,
								9	yellowish brn to tan
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

HALLIBURTON NUS
Environmental Corporation

FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating	BORING NO.: A1A
JOB NO. 36880	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger
DRILLERS NAME: Kama
TOTAL DEPTH (FT.) 27

TIME STARTED 1526	DATE 7/11/94
TIME COMPLETED 1716	DATE 7/11/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

BACKFILLED, TIME 1720	DATE 7/11/94

WEATHER CONDITIONS
Fair, hot, mid 90°F, light SE wind

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
	2.0	1.7	Good			22 @1543		1 2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

Silt, clayey, w/ some gravel,
light to med. brn
Very dry
#2 liner

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating	BORING NO.
JOB NO. 3688	A1A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
	2.0	0.7	Good		KRF-A1A-U1618	40 1610		17	16-18' Silt, clayey, w/ gravel, med. brn
								18	to dk brn, moist, #1 liner
	2.0	0.8	Good		KRF-A1A-U1820 @	90 @1616		19	18-20' silt, clayey, w/ gravel, med. to dk.
								20	brn, moist, #1 liner
								21	
								22	
								23	
								24	
								25	
								26	200 blows for 0.7' driven
	0.7	0.7	Good		KRF-A1A-U2627	480 @1647		27	Gravel, clayey, yellowish brn, wet,
								28	solvent odor, #1 liner
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. A2A
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: Jedi	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem auger	
DRILLERS NAME: Ramon	
TOTAL DEPTH (FT.) 27	
TIME STARTED 0655	DATE 7/13/94
TIME COMPLETED 0916	DATE 7/13/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING ~25'	
BACKFILLED, TIME 0926	DATE 7/13/94
WEATHER CONDITIONS Partly Cloudy, mid 70°s F, SE wind	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
	2.0	1.1	Good	KRF-A2A-U0002		34 @0706		1 2
	2.0	0.7	Good	KRF-A2A-U0204		12 @0712		3 4
	2.0	1.2	Good	KRF-A2A-U0406		@0725 300		5 6
								7 8 9 10

COMMENTS,
0.0'-0.3'
Sand, gravel
0.3' - 2.0' Silt, clayey, w/gravel, brick fragment in shoe, med. brn, dry to very sl moist at bottom, #1 liner
Silt, clayey, w/ gravel, med brn, sl. moist, #1 liner

4-6' 1st run recovered 0.3' not enough for sample, pushed spoon again
Silt, sl. clayey, w/ gravel, brick fragments, very dried out, powdery, sample slightly warm, #1 liner; yellowish brn to light brn.

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. A2A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNUSCAN~~ OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
	2.0	1.7	Good	KRF-A2A-[illegible]		38 @0735		11 12
	2.0	1.7	Good	KRF-A2A-U1214		40 @0748		13 14
								15 16
	2.0	1.3	Good	KRF-A2A-U1618		74 @0803		17 18
								19 20
	2.0	1.7	Good	KRF-A2A-U2022		180 @0812		21 22
						~~40~~ ~~@0841~~		23 24 25 26
	0.5	0.5	Good	KRF-A2A-U2627		40 @0841		27
								28 9 0 1 2 3 4 5 6 7 8 9 0

10'-12'

Silt, sl. clayey, w/ gravel, light brn, very dry, powdery, #2 liner, sample slightly warm

12'-14' Silt, sl. clayey, w/ gravel, light brn, very dry, powdery, #2 liner

16'-18' Silt, clayey, w/ some sand, w/ minor gravel, moist to wet at bottom, solvent odor, sample slightly warm, #2 liner, dk brn.

20'-22' Silt, clayey, sandy, w/ minor gravel, dk brn, moist, solvent odor, #2 liner

23.5' gravel - driller reports

26' - 200 blows for 0.5' driven

26'-27' Gravey, clayey, yellowish brn, moist to wet, solvent odor, #1 liner

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Hepting
BORING NO.: EIA
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Augers
DRILLERS NAME: Ramon
TOTAL DEPTH (FT.) 24.7
TIME STARTED 0647 DATE 7/9/94
TIME COMPLETED 0838 DATE 7/9/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING: moist @ 25'
BACKFILLED, TIME 0900 DATE 7/9/94
WEATHER CONDITIONS: Partly Cloudy, mid 70's F, little wind
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
	2.0	1.3	Good		RRF-EIA-40002 @ 0708	16		1
								2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

0.0'-0.2' Orange brn sd (fill), gravel at sfc. fill.
0.2'-2.0' Silt, clayey, w/ gravel, med. to dk brn, sl. moist
#2 liner

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. EIA

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
									10'-12'
	2.0	0.6	Poor		KRF-EIA-U1012	0		11	Silt, clayey, w/ gravel, some asphalt
					@0726			12	sl. moist, light to med. brn
								13	#1 liner
								14	
								15	
								16	16'-18'
	2.0	1.2	Good		KRF-EIA-U1618	120		17	Silt, clayey, w/ gravel, med. brn to
								18	dk brn moist to wet in spots, solvent od
					@0750			19	#2 liner
								20	Gravel at 18'
								21	
								22	
								23	
								24	24'-24.7' Gravel, clayey, yellowish brn,
	0.7	0.7			KRF-EIA-U2425	700		25	moist, strong solvent odor
								26	
					@0827			7	#1 liner
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. E2A
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: Jedi	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem Auger	
DRILLERS NAME: Ramon	
TOTAL DEPTH (FT.) 26.6	
TIME STARTED 0917	DATE 7/9/94
TIME COMPLETED 1025	DATE 7/9/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING ~25'	
BACKFILLED, TIME 1041	DATE 7/9/94
WEATHER CONDITIONS Partly Cloudy, hot, upper 80°F, light SE wind	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
	2.0	1.2	Good		KRF-E2A-U002 @0926	2		1
								2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

0.0'-0.2' orange brn sand (fill)
and gravel, dry
0.2'-2.0' Silt, clayey, w/gravel,
med. brn
#1 liner

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E2A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
	2.0	1.1	Good		KRF=E2A-111012 @0938	5		11	10'-12' Silt, clay, w/ gravel, med.
								12	to dk br, sl. moist
								13	#1 liner
								14	
								15	
								16	
								17	
								18	
								19	
								20	
								21	
								22	
								23	
								24	
								25	Gravel at 25'
								26	
	2.0	0.6	Fair		KRF-E2A-112628 @1013	260		27	26'-26.6' Gravel, clayey, yellowish
								28	brown, wet at lower 0.2', strong solvent od.
								9	#1 liner
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: E3A
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger
DRILLERS NAME: Ramon
TOTAL DEPTH (FT.) 28.7
TIME STARTED 1058
DATE 7/8/94
TIME COMPLETED 1337
DATE 7/8/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING ~25'
BACKFILLED, TIME 1354
DATE 7/8/94
WEATHER CONDITIONS
Partly Cloudy, lo 90°s F, SE wind
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT: RF Heating

JOB NO. 3688

BORING NO. E3A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								11
								12
								13
								14
	2.0	1.6	Good	KRF-E3A-U1416	KRF-E3A-U1416D @1131	8		15
								16
	2.0	1.6	Good	KRF-E3A-U1618 KRF-E3A-U1618D		1142 @ 220		17
								18
								19
								20
	2.0	1.7	Good		KRF-E3A-U2022 @	260		21
						1150		22
								23
								24
								25
								26
								27
								28
	0.7	0.7	Good		KRA-E3A-U2830	190		29
						1239		30
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

14'-16'
Silt, clay, some gravel, med. to dk brn, sl. moist
#1 liner - duplicate
#2 liner - regular
16'-18' Silt, clay, sandy, w/ some gravel, med. brn to dk brn, moist
strong solvent odor
#1 liner duplicate
#2 liner regular
19' Gravel
20'-22' Clay, sandy, silty, minor gravel, med. to dk brn, moist, strong solvent odor
#2 liner - regular
28'-29.7 Gravel, clayey, yellowish brn wet, strong solvent odor, #1 liner

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: E4A
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger
DRILLERS NAME: Ramon
TOTAL DEPTH (FT.) 26
TIME STARTED 0732 DATE 7/12/94
TIME COMPLETED 0923 DATE 7/12/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING ~25'
BACKFILLED, TIME 0940 DATE 7/12/94
WEATHER CONDITIONS: Partly cloudy, mid 70's F, SE wind
SURFACE ELEVATION
COMMENTS

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	OVA ~~HNU~~ SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
				HRF-BF-40608	HRF-E4A-40609			6
	2.0	0.8	Good			0 @0757		7
					40911			8
	2.0	0.7	Fair		HRF-E4A	22 @0824		9
								10

6-8'
Silt, clayey, w/ gravel, dried out to sl. moist, red. br.

Took 8-10' sample, but driller dropped it into decon bucket, will resample @ 9-11'
9-11' Silt, clayey, w/ gravel, moi

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E4A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU/~~SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								11
								12
					TRF-BS2-41416			13
								14
	2.0	1.6	Good			120		15
						@0840		16
								17
								18
					TRF-BS3-42022			19
								20
	2.0	1.7	Good			>1000		21
						@0848		22
								23
					TRF-E4A-42426			24
	2.0	1.9	Good			60		25
						@0910		26
								7
								8
								9
								0
								1
								2
								3
								4
								5
								6
								7
								8
								9
								0

sand, red brn, sl moist, #1 liner
Sand has appearance of being
backfill from other boreholes, possible
that we have drilled into other boring,
1st sample was good though (6'-8')

14'-16' Clay, silty, w/ some gravel,
med. to dk brn., moist, sample was
warm, took biosample #2, w/ plastic

24'-26' 150 blows for 2.0' driven
24'-25.1' Bentonite seal from
another hole, augers have drifted
into other hole.
25.1'-26' Gravel, clayey, solvent
odor, wet, yellowish brn

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. E5A
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger
DRILLERS NAME: Ramon
TOTAL DEPTH (FT.) 22

TIME STARTED 1228	DATE 7/12/94
TIME COMPLETED 1357	DATE 7/12/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

BACKFILLED, TIME 1357	DATE 7/12/94

WEATHER CONDITIONS Partly Cloudy, lo 90°s F, strong SE wind
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
	0.6 2.0	0.6 0.9	Good		KRF-E5A-40406	10 @1244		4 5
	2.0	1.6	Good			140 @1257		6 7
								8 9 10

COMMENTS

4'-6' 1st run recovered 0.6', recovered concrete ~ 4" in spoon, ~~went~~ back in boring to get 4'-6' interval
Silt, clayey, w/ gravel, #1 liner

6'-8' Silt, clayey, w/ gravel, light brn, very dried out, powdery
#2 liner

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Hesting

JOB NO. 3688

BORING NO. E5A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNUSCAN~~ OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
	2.0	1.4	Good		KRF-E5A-U1[illegible]	140 @ 1307		11 12
	2.0	0.7	Good		KRF-E5A-U1214	0 @ 1320		13 14
								15 16 17 18
	2.0	1.6	Good		KRF-E5A-U1820	240 @ 1331		19 20
	2.0	1.5	Good		KRF-E5A-U2022	>1000 @ 1342		21 22
								3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

10'-12'
Silt, clayey, w/ gravel, light brn, very dry, powdery, #2 liner
12'-14' Silt, clayey, minor gravel, very dry, powdery
#4 liner

18'-20' Silt, clayey, minor gravel, sandy, med. to dk brn, moist
#2 liner
20'-22' Silt, clayey, sandy, minor gravel, dk brn, moist
#2 liner

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	**BORING NO.** E6A
JOB NO. 3688	**LOGGED BY:** BDH
PROJ. MGR. CFB	**EDITED BY:**

DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Augers
DRILLERS NAME: Ramon
TOTAL DEPTH (FT.) 23

TIME STARTED 0737	**DATE** 7/7/94
TIME COMPLETED 0940	**DATE** 7/7/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING Dry

BACKFILLED, TIME 0948	**DATE** 7/7/94

WEATHER CONDITIONS Partly Cloudy, mid 70°s F, SE wind, moderate

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
SP	2.0	1.9	Good		ARF-E6A-40810 @0800	12		9	Silt, clayey, w/ some gravel, med. to dk brn, sl. moist #1 liner, #2 liner for particle analysis
								10	

FIELD LOG OF BORING (CONT'D.)

SHEET ___ OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E6A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNUSCAN~~ OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
								5	
								16	
	2.0	1.2	Good		KRF-E6A-41618 @ 0818	60		7	Silt, clayey, w/ gravel, red. to
								18	dk brn, sl. moist, up to 60 ppm
								9	max., ~20 ppm sustained.
								20	#1 liner , #2 liner for particle anal.
	2.0	0.4	Poor		KRF-E6A-42021 0845			21	Silt, clayey, w/ gravel, red. to
								22	dk. brn, moist, solvent odor
	1.0	0.2	Poor					3	#1 liner
								4	
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: E7A
JOB NO. 3688
LOGGED BY: BDH
PROJ. MGR. CFB
EDITED BY:
DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Augers
DRILLERS NAME: Ramon
TOTAL DEPTH (FT.) 14
TIME STARTED 1000
DATE 7/7/94
TIME COMPLETED 1102
DATE 7/7/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING: Dry
BACKFILLED, TIME 1114
DATE 7/7/94
WEATHER CONDITIONS: Partly Cloudy, upper 80°F, SE wind
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
	2.0	1.7	Good		KRF-E7A-U0204 1014	3		3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

Silt, clayey, w/ some gravel up to 3" diam., red brn.
#2 liner
#1 liner duplicate
#3 liner particle analysis

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E7A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
					RRF-E7A-41214			12	
	2.0	1.4	Good			1050 62		13	Clay, silty, w/ some gravel, moist
								14	med. to dk brn
								5	#2 liner
								6	#1 liner - particle analysis
								7	#3 liner - particle analysis duplicate
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. E8A
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger
DRILLERS NAME: Ramon
TOTAL DEPTH (FT.) 27

TIME STARTED 1055	DATE 7/7/94
TIME COMPLETED 1450	DATE 7/7/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING ~25'

BACKFILLED, TIME 1506	DATE 7/7/94

WEATHER CONDITIONS Partly Cloudy, mid 90's F, SE wind, gusty
SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
	2.0	1.3	Good		KRF-E8A-410608 1314			7
								8
								9
								10

COMMENTS

Silt, clayey, some gravel, light to med brn., very dry

#2 liner
#1 liner particle analysis

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. E8A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNU/SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
								15	
								16	
								17	
								18	
								19	
								20	
								21	
								22	
								23	
	1.0	0.9	Good		KRF-E8A-42425	1358 ≥1000		24	100 blows for 1' driven in gravel
	1.0	0.8.	Good		KRF-E8A-0067	1430 ≥1000		25	Gravel, silty, clayey, yellowish br.,
	↓	↓	↓					26	wet, strong solvent odor, #1 liner
								7	26'-27'
								8	
								9	wet
								0	
								1	#1 liner
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating

BORING NO. F1A

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: Jedi

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger

DRILLERS NAME: Ramon

TOTAL DEPTH (FT.) 20

TIME STARTED 1058

DATE 7/9/94

TIME COMPLETED 1200

DATE 7/9/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING Dry

BACKFILLED, TIME 1209

DATE 7/9/94

WEATHER CONDITIONS Partly Cloudy, hot, upper 80's F, slight SE w

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
	2.0	0.6	Fair	KRF-F1A-U0406 @ 1111		0		5
								6
								7
								8
								9
								10

COMMENTS

Silt, sandy, w/ gravel, concrete, asphalt-like material, med. to dk brn, concrete at end of shoe blocking it.

#1 liner

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

BORING NO. F1A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU SCAN~~ OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
									10'-12'
	2.0	0.6	Fair		KRF-F1A-U1012	6 @1120		11	Silt, clayey, w/ gravel, light
								12	to red brn., extremely dry; powdery;
								13	#1 liner
								14	
								15	
								16	
								17	
								18	
	2.0	1.5	Good	KRF-E1A-U1820	KRF-F1A-U1820D @	460 1141		19	Clay, silty, w/ gravel, dk brn, moist
								20	solvent odor
								1	
								2	#1 liner duplicate
								3	#2 liner regular
								4	
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PROJECT: RF Heating

BORING NO.: F2A

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: Pdi

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger

DRILLERS NAME: Rason

TOTAL DEPTH (FT.) 27.4

TIME STARTED 0738 DATE 7/11/94

TIME COMPLETED 0915 DATE 7/11/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING ~25'

BACKFILLED, TIME 0920 DATE 7/11/94

WEATHER CONDITIONS Partly cloudy, mid 70°s F, slight SE wind

SURFACE ELEVATION

PLAN

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating	**BORING NO.** F2A
JOB NO. 3688	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
					KRF-F2A-U1416			14	
	2.0	0.7	Good			22		15	14-16' Silt, clayey, w/ some gravel,
								16	light brn, dried out portion, med.
						@0803		17	to drk brn, sl. moist portion.
								18	Top part of sample is very dried
								19	out, powdery appearance; lower half
								20	is sl. moist and very hard, more
								21	cohesive #1 liner
								22	(Chunk of hard soil in shoe (catcher)
								23	blocked better sample recovery
								24	Driller reports gravel at 17.5'
								25	Center bit is wet when pulled at
				KRF-F2A-U2627	KAF-F2A-2627D			26	26'
	1.0	1.4	Good			720		27	26-27' 150 blows for 1.0' driven
								28	Gravel, clayey, yellowish brn, wet,
						@0840		9	strong solvent odor
								0	#1 liner - duplicate
								1	#2 liner - regular
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. F3A
JOB NO. 3688	LOGGED BY: CFB
PROJ. MGR. CFB	EDITED BY:
DRILLING COMPANY: Jedi	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem Auger	
DRILLERS NAME: Ramon	
TOTAL DEPTH (FT.) 12	
TIME STARTED 1007	DATE 7/12/94
TIME COMPLETED 1037	DATE 7/12/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING Dry	
BACKFILLED, TIME 1041	DATE 7/12/94
WEATHER CONDITIONS Partly cloudy, upper 70°s F; SE wind	
SURFACE ELEVATION	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
	2.0	1.1	Good		KRF-F3A-UD406 @1019	4		5
								6
								7
								8
								9
								10

COMMENTS

4'-6' Silt, clayey, w/ gravel, med brn, dried out, hard; used #1 liner since 2nd liner had sloughed material from a #1 liner - regular

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating
JOB NO. 3688
BORING NO. F3A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	HNUSCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	10'-12'
	2.0	0.8	Tin		KBF-F3A-41012	100		11	Silt, slightly clayey, w/gravel, light
						@ 1034		12	brn, very dry, powdery.
								3	
								4	#1 lisa
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT RF Heating	BORING NO. F4A
JOB NO. 3688	LOGGED BY: BDH
PROJ. MGR. CFB	EDITED BY:

DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger
DRILLERS NAME: Ramon
TOTAL DEPTH (FT.) 29

TIME STARTED 1248	DATE 7/11/94
TIME COMPLETED 1450	DATE 7/11/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING ~25'

BACKFILLED, TIME 1500	DATE 7/11/94

WEATHER CONDITIONS
Fair, hot, lo 90's F, light SE wind

SURFACE ELEVATION

COMMENTS
Silt, clayey, w/ gravel, red brn to dk brn, dry to sl moist, w/ brick fragments, #2 liner

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
	2.0	1.2	Good		KRF-F4A-U0002	6 @1305		1
								2
								3
								4
								5
								6
								7
								8
								9
								10

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

BORING NO. F4A

JOB NO. 3688

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	OVA ~~HNU~~SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
	~~2.0~~	~~1.5~~	~~Good~~			~~18~~		11	
	2.0	1.5	Good		HRF-F4A-41214	@1333 18		12	12'-14' Silt, clayey, w/ some gravel,
								13	med. to dk brn, moist
								14	
								15	#1 liner - duplicate
								16	#2 liner - regular
	2.0	1.2	Good		HRF-F4A-41618	220 @1348		17	16'-18' Silt, clayey, w/ some gravel,
								18	med. to dk brn, moist, solvent odor,
								19	#2 liner
								20	
								21	
								22	Driller reports gravel at 21'
								23	
								24	
								25	
								26	
								27	
								28	28'-29'
	1.0	1.0	Good		HRF-F4A-42829	100 @1432		29	200 blows for 1.0' driven
								30	Gravel, silty, yellowish brn,
								1	wet, solvent odor, #1 liner
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating

BORING NO.: F5A

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: Jedi

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow stem auger

DRILLERS NAME: Ramon

TOTAL DEPTH (FT.) 23.2

TIME STARTED 0942 DATE 7/11/94

TIME COMPLETED 1123 DATE 7/11/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING

BACKFILLED, TIME 1129 DATE 7/11/94

WEATHER CONDITIONS

Partly Cloudy, mid 80's F, light SE wind

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	HNU SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
								5
								6
								7
								8
								9
								10

COMMENTS

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT KF Heating

JOB NO. 3688

BORING NO. F5A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	12'-14' Silt, clayey, w/ gravel,
	2.0	0.2	Good			0		13	light br, very dry, powdery texture, more moist at bottom, hard
						@1017		14	
					KRF-F5A-U1618			15	
								16	16'-18' Silt, clayey, w/ gravel, med. br to dk br, moist, #2 liner
	2.0	1.1	Good			196		17	
						@1028		18	18'-20' Silt, clayey, w/ gravel, med.
	2.0	1.4	Good		KRF-F5A-U1820	500		19	to dk br, moist, wet in spots
								20	at bottom, solvent odor, #2 liner
						@1032		21	Driller reports gravel at 21.5'
								22	22'-23.2' Gravel, silty, clayey,
	1.2	1.1	Good		KRF-F5A-U2224	380		23	yellowish br, moist, solvent odor
						@1100		24	#2 liner
								5	200 blows for 1.2' driven
								6	
								7	
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating	BORING NO.: TD3A
JOB NO.: 3688	LOGGED BY: BDH
PROJ. MGR.: CFB	EDITED BY:
DRILLING COMPANY: Jedi	
DRILL RIG TYPE: Mobile B-61	
DRILLING METHOD: Hollow Stem Auger	
DRILLERS NAME: Ramon	
TOTAL DEPTH (FT.): 25	
TIME STARTED: 1420	DATE: 7/8/94
TIME COMPLETED: 1554	DATE: 7/8/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING: ~25'	
BACKFILLED, TIME: 1604	DATE: 7/8/94
WEATHER CONDITIONS: Partly Cloudy, upper 90°s F, moderate SE w	
SURFACE ELEVATION:	

	SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
									1
									2
									3
4-5		2.0	0.2	Poor			28		4
									5
5-7'		2.0	0.2				6		6
6.5-8.5		2.0	0.6	Poor	KRF-TD3A-00608	① 1450			7
									8
									9
									10

COMMENTS

4.0'-4.2' Silt, clayey w/ gravel, piece of concrete at end of sampler blocking sample recovery

Concrete still preventing good recovery, will go down 1' and try again.

6.5'-8.5' Silt, clayey, w/ gravel, med- to dk. brn, sl. moist
#1 liner

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Plating

JOB NO. 3688

BORING NO. TD3A

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								1	
								2	
								3	
								4	
	2.0	0.8	Good		KRF-TD3A-U1416	38		5	Silt, clayey, w/ some gravel, med to
						@1502		6	dk bn, moist
								7	#1 liner
								8	
								9	Gravel at ~18.5'
								20	
								21	
								22	
								23	
								24	
	1.0	0.5	Fair		KRF-TD3A-U2425	120		25	24'-25' Gravel, clayey, yellowish
						@1533		26	bn, wet, solvent odor
								7	#1 liner
								8	
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

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FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating

BORING NO.: TD5A

JOB NO. 3688

LOGGED BY: BDH

PROJ. MGR. CFB

EDITED BY:

DRILLING COMPANY: Jedi

DRILL RIG TYPE: Mobile B-61

DRILLING METHOD: Hollow Stem Auger

DRILLERS NAME: Ramon

TOTAL DEPTH (FT.) 28

TIME STARTED 0643 DATE 7/8/94

TIME COMPLETED 0812 DATE 7/8/94

GROUND-WATER CONDITION AT COMPLETION OF DRILLING: Dry

BACKFILLED, TIME 0822 DATE 7/8/94

WEATHER CONDITIONS: Partly Cloudy

SURFACE ELEVATION

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)
								1
								2
								3
								4
	2.0	1.1	Good		KRF-TD5A-U0406	4 0654		5
								6
								7
								8
								9
								10

COMMENTS

Silt, clayey, w/ some gravel med. to dk brn, sl. moist
#1 liner

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating	BORING NO. TD5A
JOB NO. 3688	

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU SCAN~~ OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
	2.0	1.1	Good		KRF-TD5A-U1416 @0710	>1000		15	Silt, clayey, w/ some gravel, med.
								16	to dk brn, sl. moist.
								17	#1 liner
								18	
								19	Gravel at 18.5'
								20	
								21	
								22	
								23	
								24	
	0.9	0.8	Good		KRF-TD5A-U2425 0745	300		25	100 blows for 0.9' driven
								26	gravel, clayey, yellowish brn,
								7	wet in spots, solvent odor
								8	#1 liner
								9	
								0	
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

NOTES:

HALLIBURTON NUS
Environmental Corporation

HALLIBURTON NUS
Environmental Corporation

FIELD LOG OF BORING

SHEET 1 OF 2

PLAN

PROJECT: RF Heating
BORING NO.: TD6A
JOB NO.: 3688
LOGGED BY: BDH
PROJ. MGR.: CFB
EDITED BY:
DRILLING COMPANY: Jedi
DRILL RIG TYPE: Mobile B-61
DRILLING METHOD: Hollow Stem Auger
DRILLERS NAME: Ramon
TOTAL DEPTH (FT.): 27
TIME STARTED: 0846
DATE: 7/8/94
TIME COMPLETED: 1012
DATE: 7/8/94
GROUND-WATER CONDITION AT COMPLETION OF DRILLING: 25'
BACKFILLED, TIME: 1030
DATE: 7/8/94
WEATHER CONDITIONS: Partly Cloudy, lo 80's F, SE wind
SURFACE ELEVATION:

SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LABORATORY SAMPLE NUMBER	FIXED LABORATORY SAMPLE NUMBER	~~HNU~~ OVA SCAN (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	COMMENTS
								1	
								2	
								3	
	2.0	0.9	Good		KRF-TD6A-40406 0332	3		4–6	Silt, clayey; w/ some gravel, yellowish br, red br, mottled, sl. moist, #1 liner
								7	
								8	
								9	
								10	

FIELD LOG OF BORING (CONT'D.)

SHEET 2 OF 2

PROJECT RF Heating

JOB NO. 3688

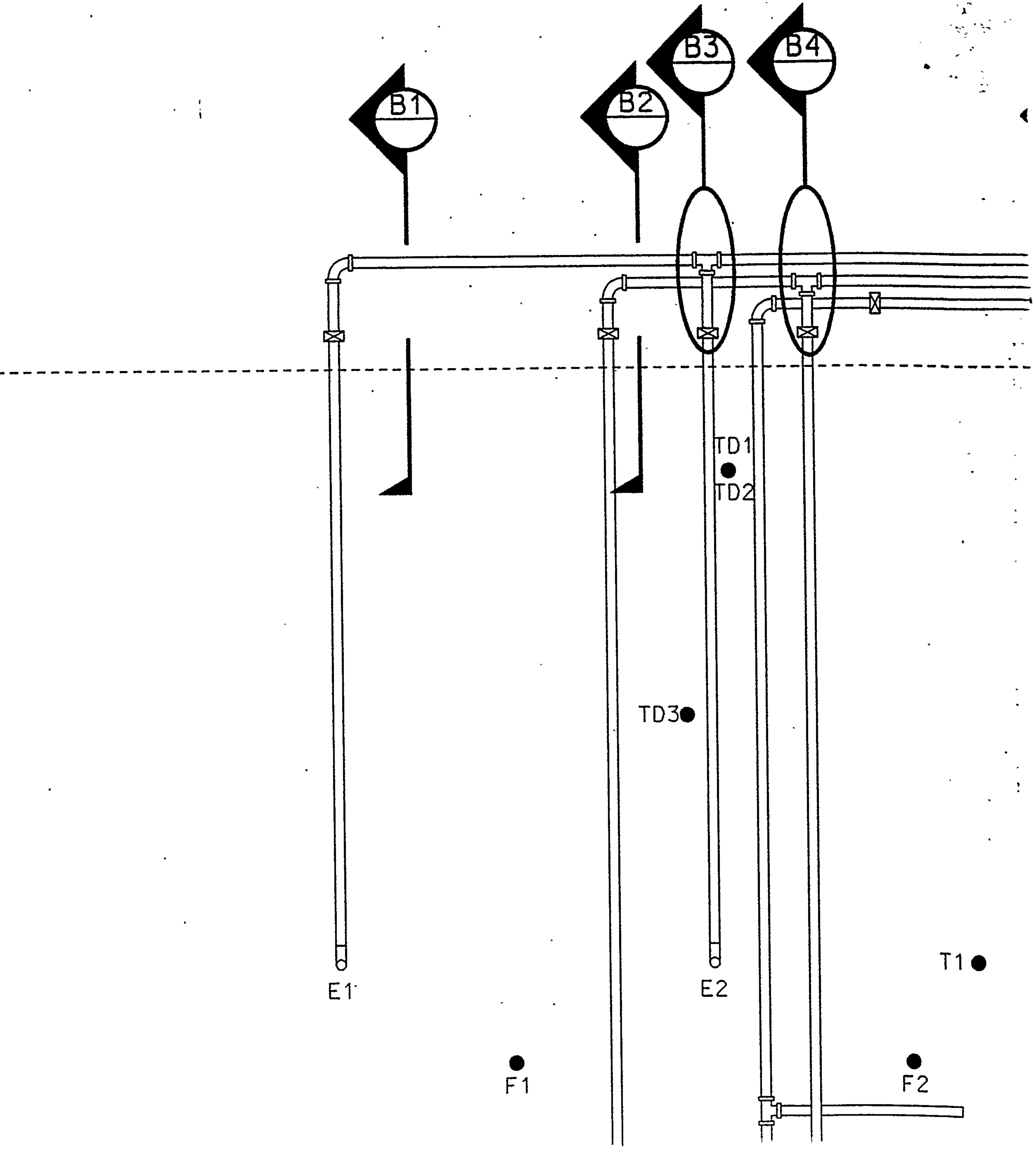
BORING NO. TD6A

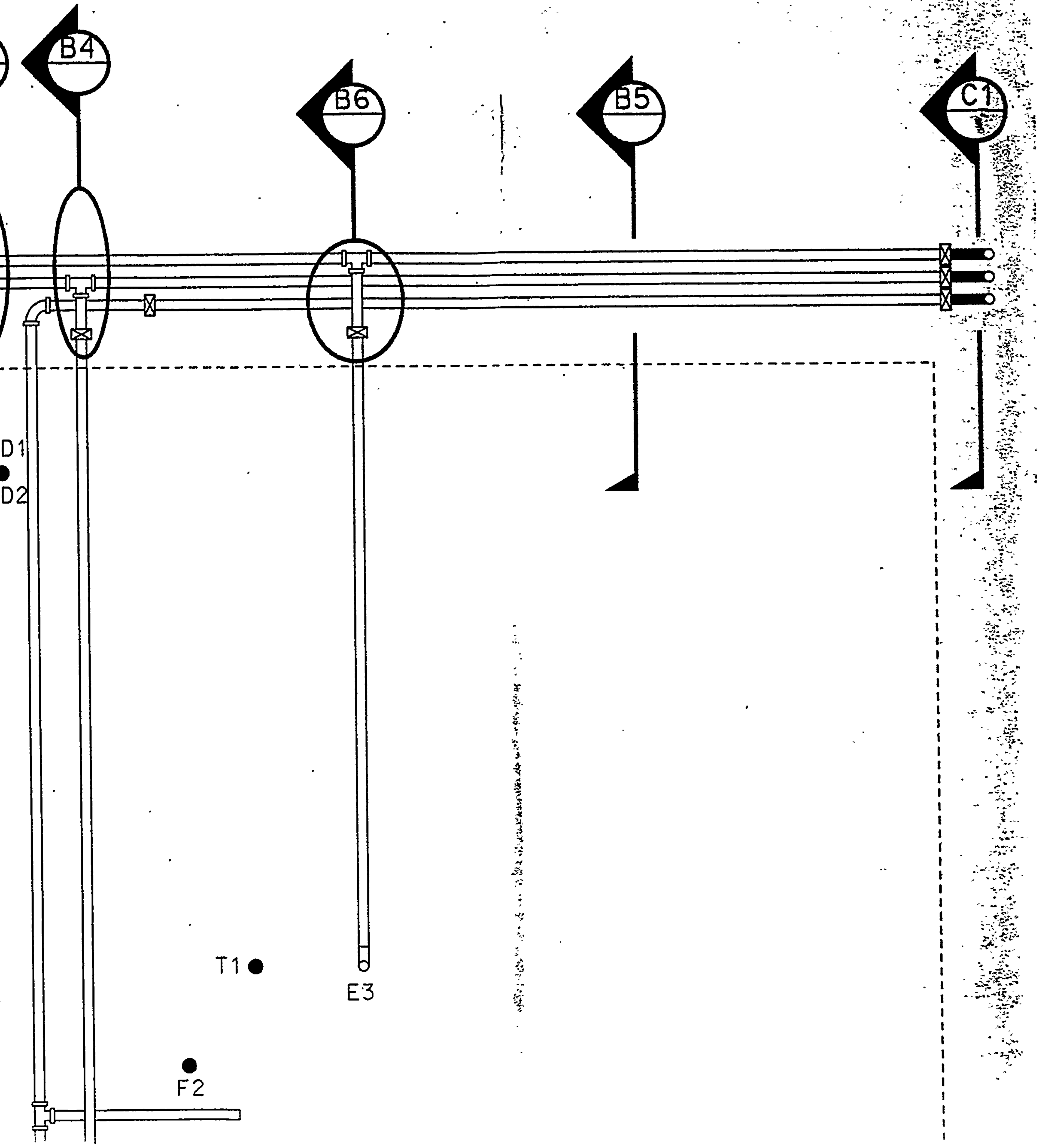
SAMPLER TYPE	FEET DRIVEN	FEET RECOVERED	SAMPLE CONDITION	FIELD LAB. SAMPLE NO.	FIXED LAB. SAMPLE NO.	~~HNU~~SCAN OVA (PPM)	LITHOLOGIC CODE	DEPTH (FEET)	
								11	
								12	
								13	
								14	
	2.0	1.1	Good		KRF-TD6A-U1416	54 0914		15	Clay, silty, w/ some gravel, sl.
								16	moist, med. to dk brn, #1 liner
								17	
								18	
								19	Gravel at 19'
								20	
								21	
								22	
								23	
								24	
								25	Water at ~25'
								26	
	1.0	0.9	Good		KRF-TD6A-U2627	250 0954		27	150 blows for 1' driven
								28	Gravel, clayey, yellowish brn, tan,
								9	wet, solvent smell
								0	#1 liner
								1	
								2	
								3	
								4	
								5	
								6	
								7	
								8	
								9	
								0	

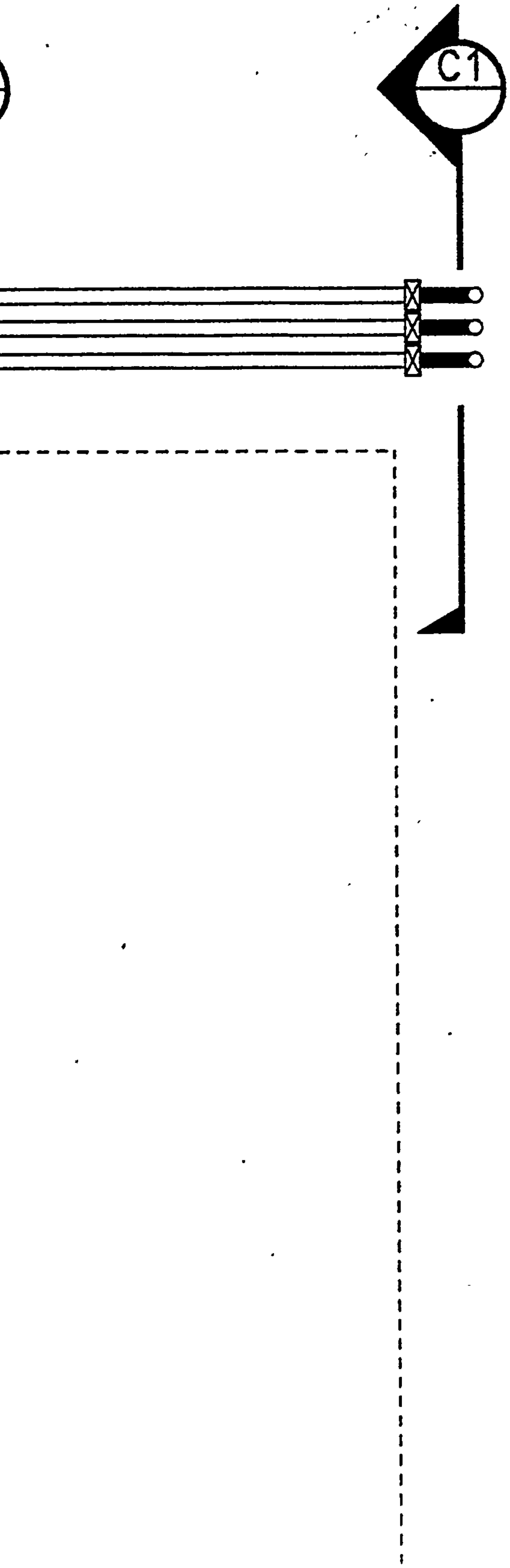
NOTES:

HALLIBURTON NUS
Environmental Corporation

APPENDIX B.3


B1
B2
B3
B4
TD1
TD2
TD3
E1
E2
T1
F1
F2


B4
B6
B5
C1
D1
D2
T1
E3
F2



LEGEN

●A A

○E E

●T T

●TD T

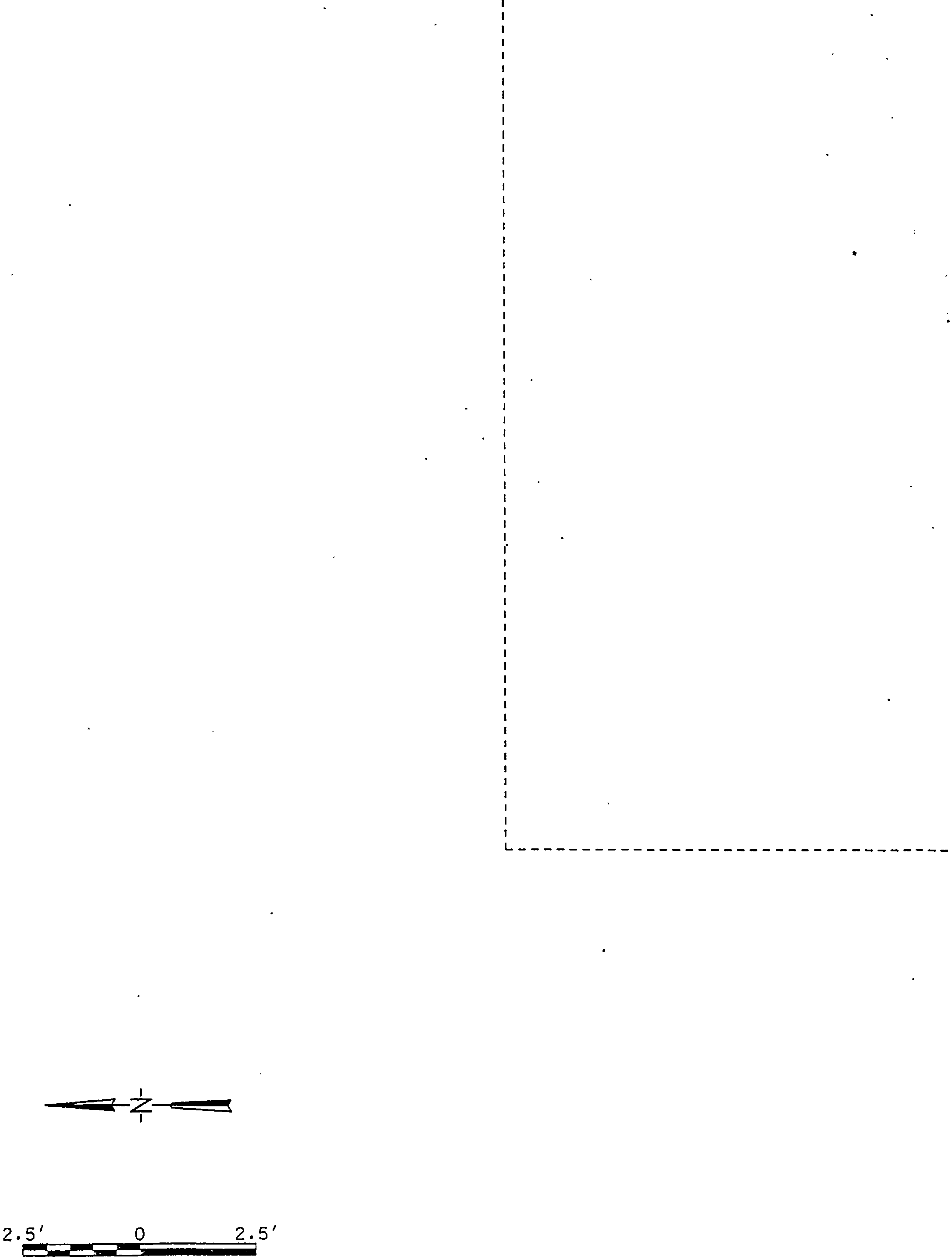
●F F

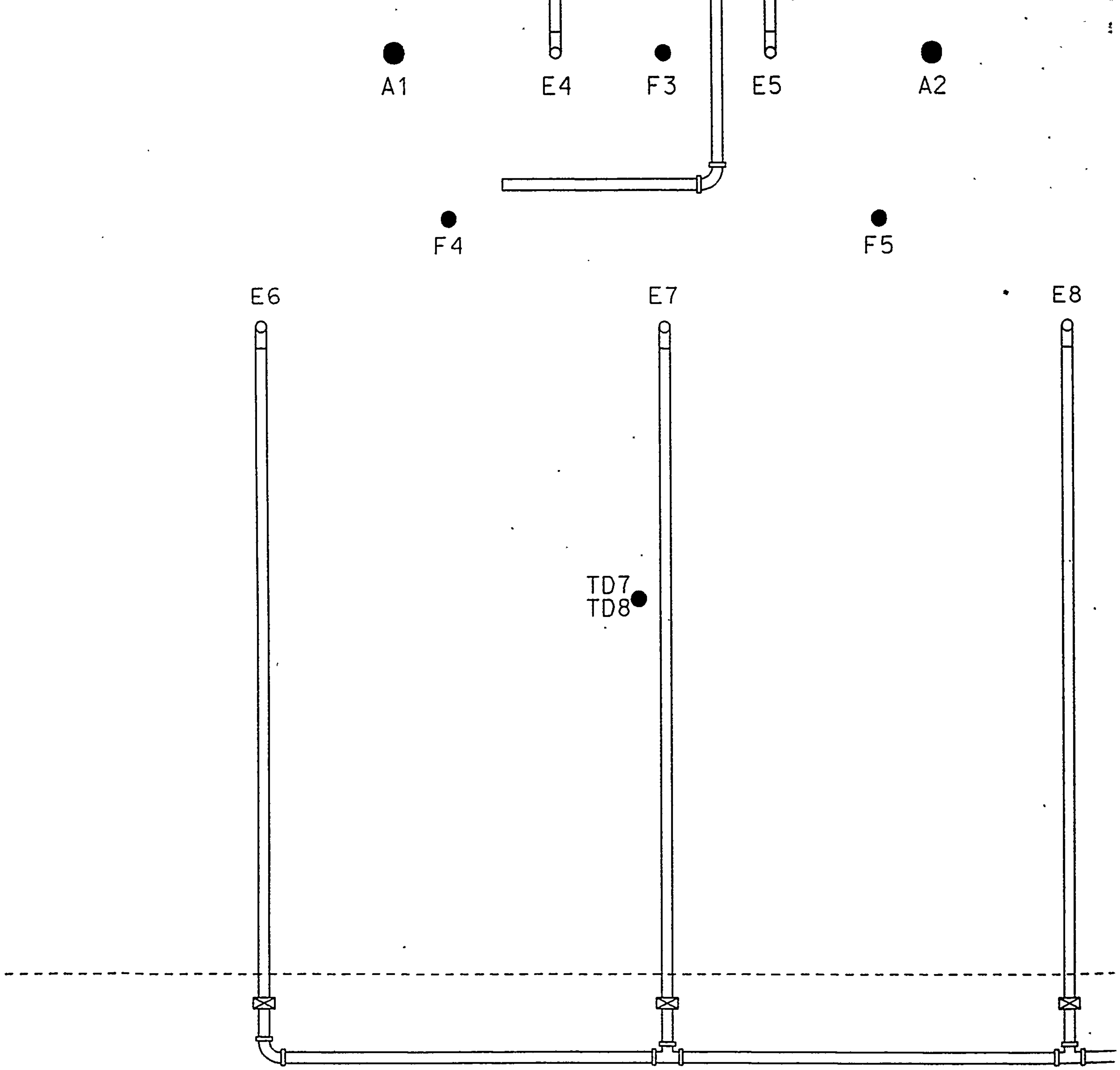
NOTE

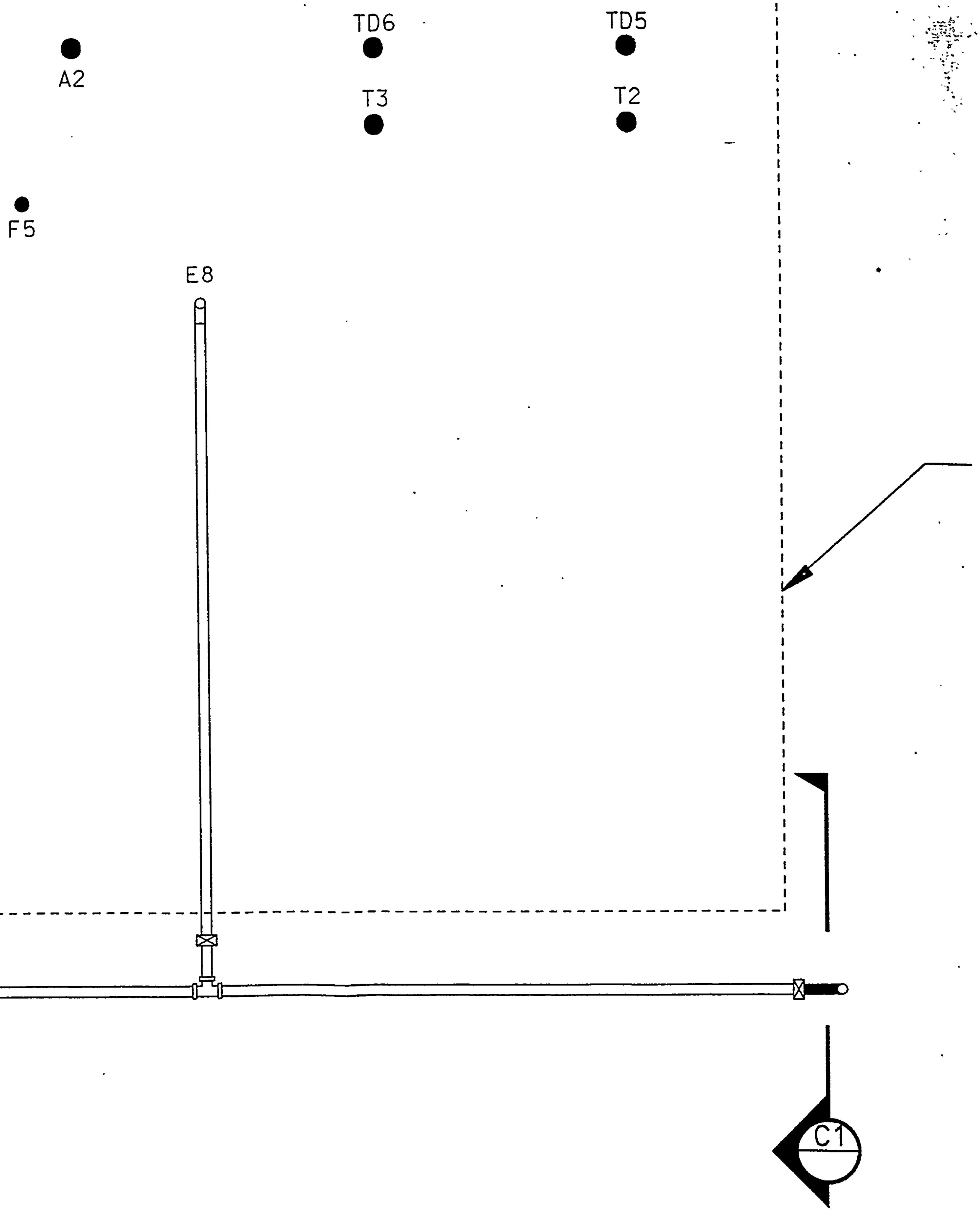
LEGEND

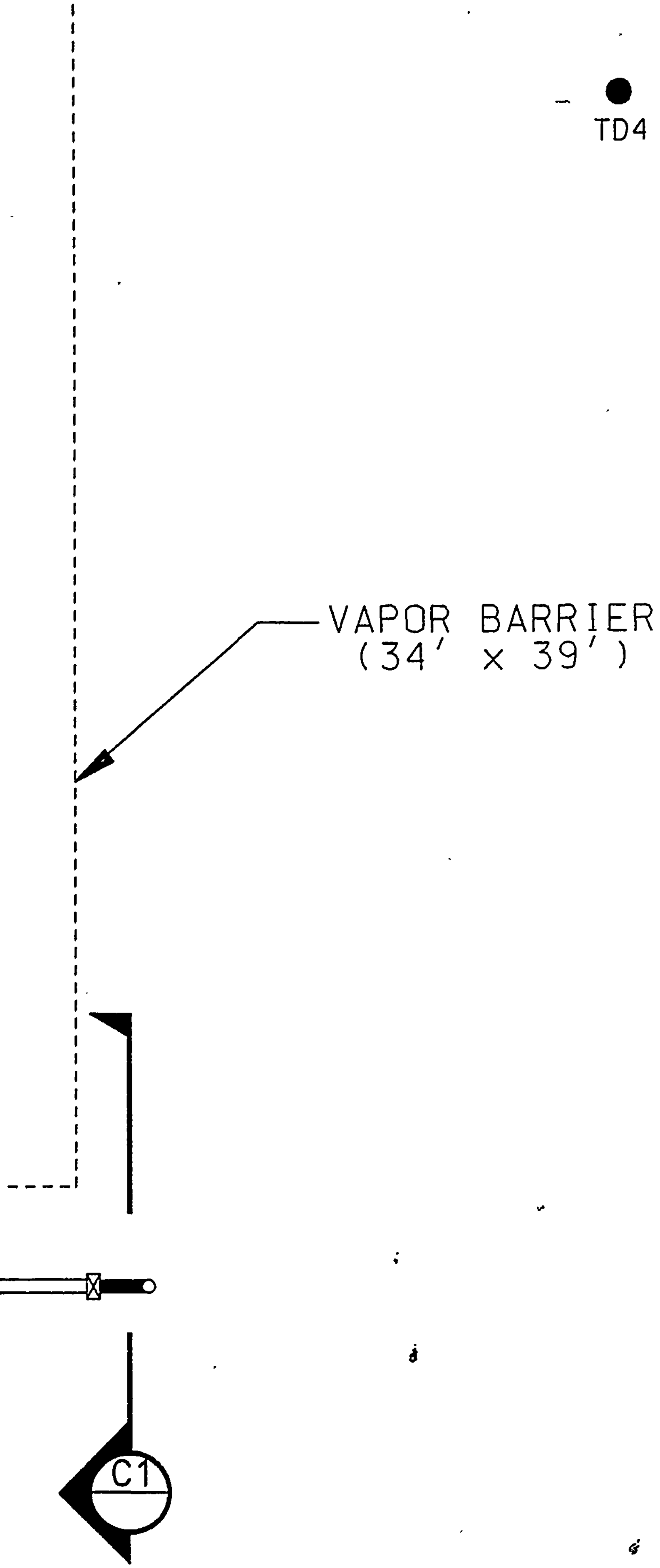
●$_{A}$	ANTENNA WELL
○$_{E}$	EXTRACTION WELL
●$_{T}$	THERMOCOUPLE WELL
●$_{TD}$	TRANSDUCER WELL
●$_{F}$	FIELD MEASUREMENT WELL

NOTE: TEFLON TUBES NOT SHOWN.


N
2.5'
0
2.5'


A1
E4
F3
E5
A2
F4
F5
E6
E7
E8
TD7
TD8

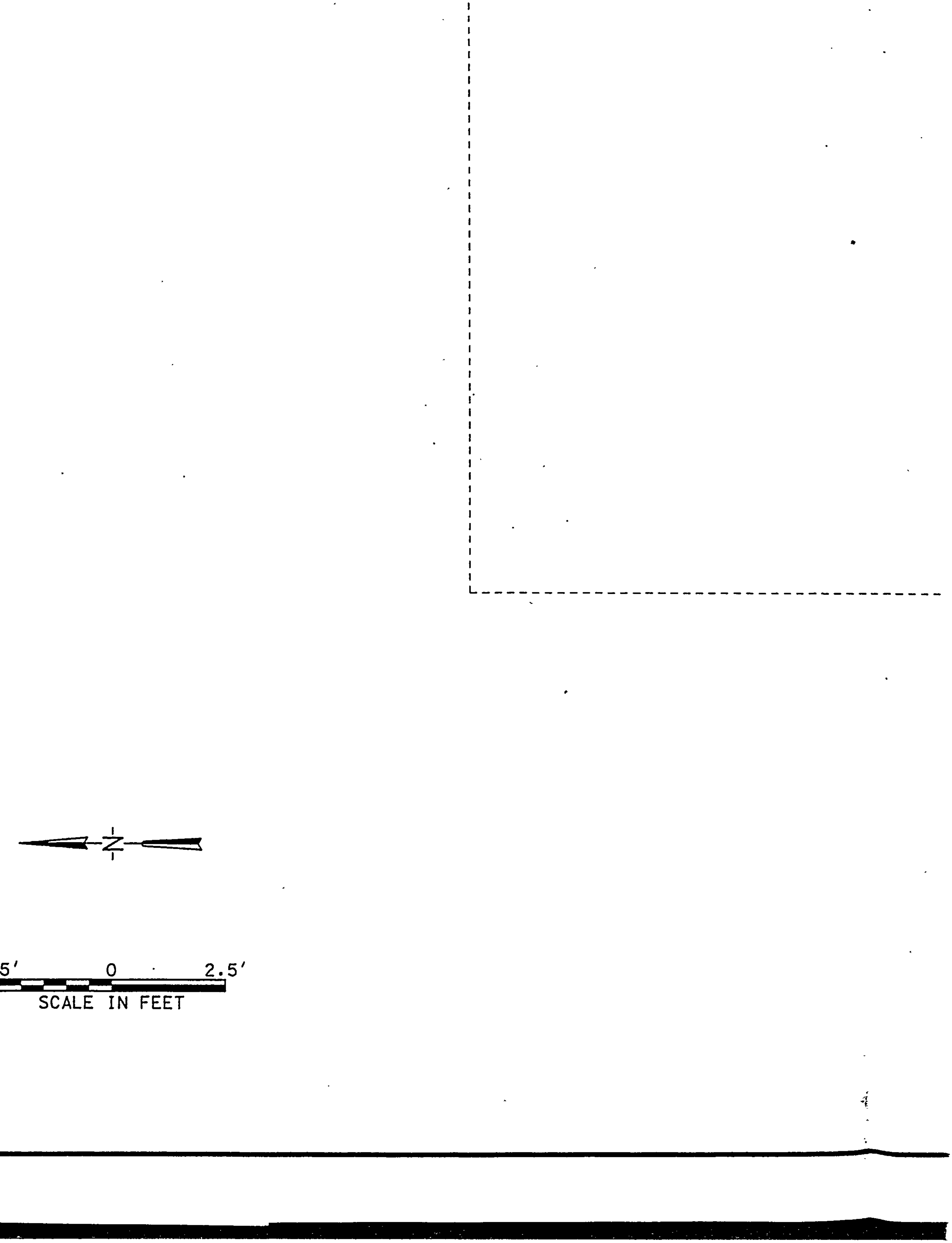

TD6
TD5
A2
T3
T2
F5
E8
C1

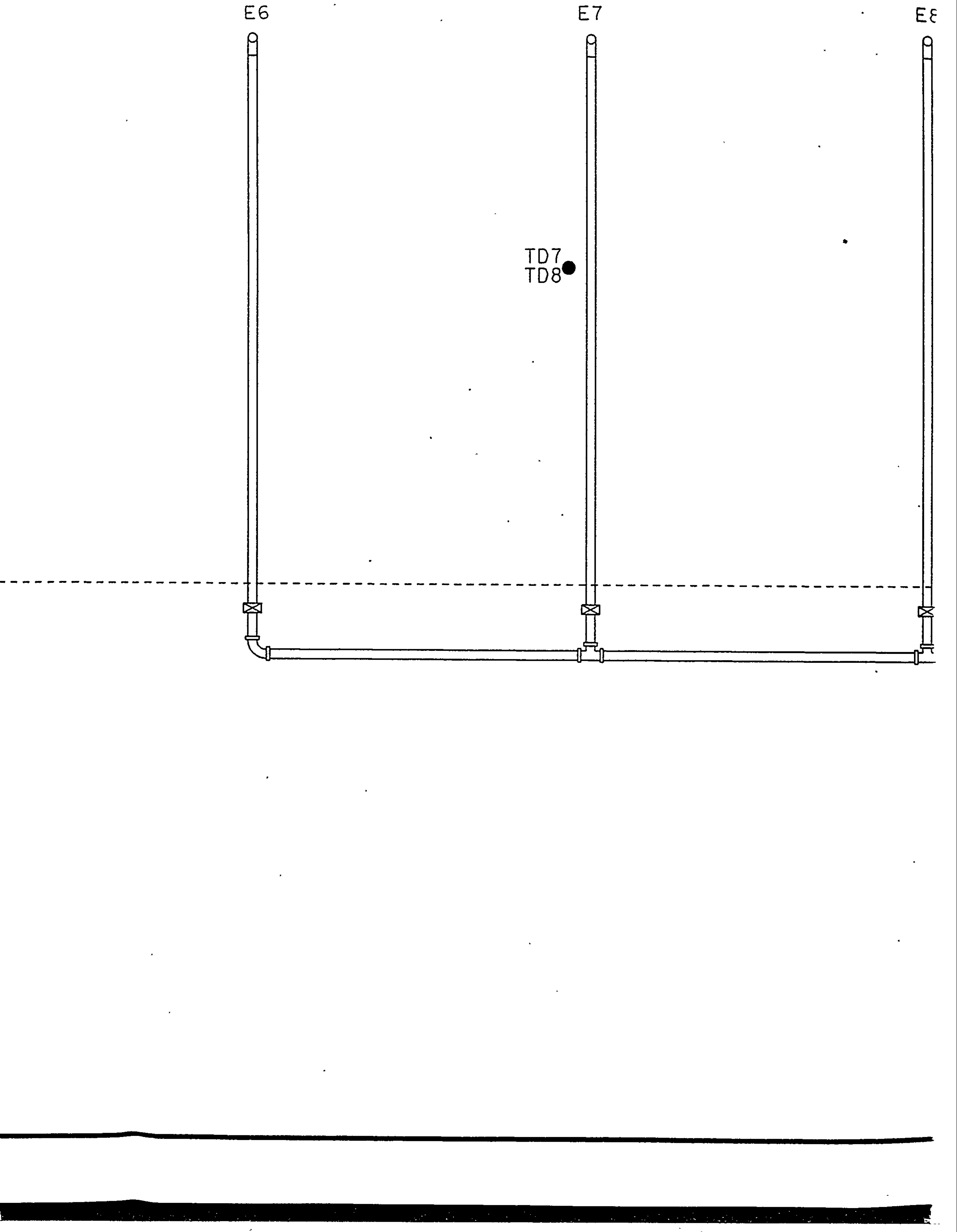


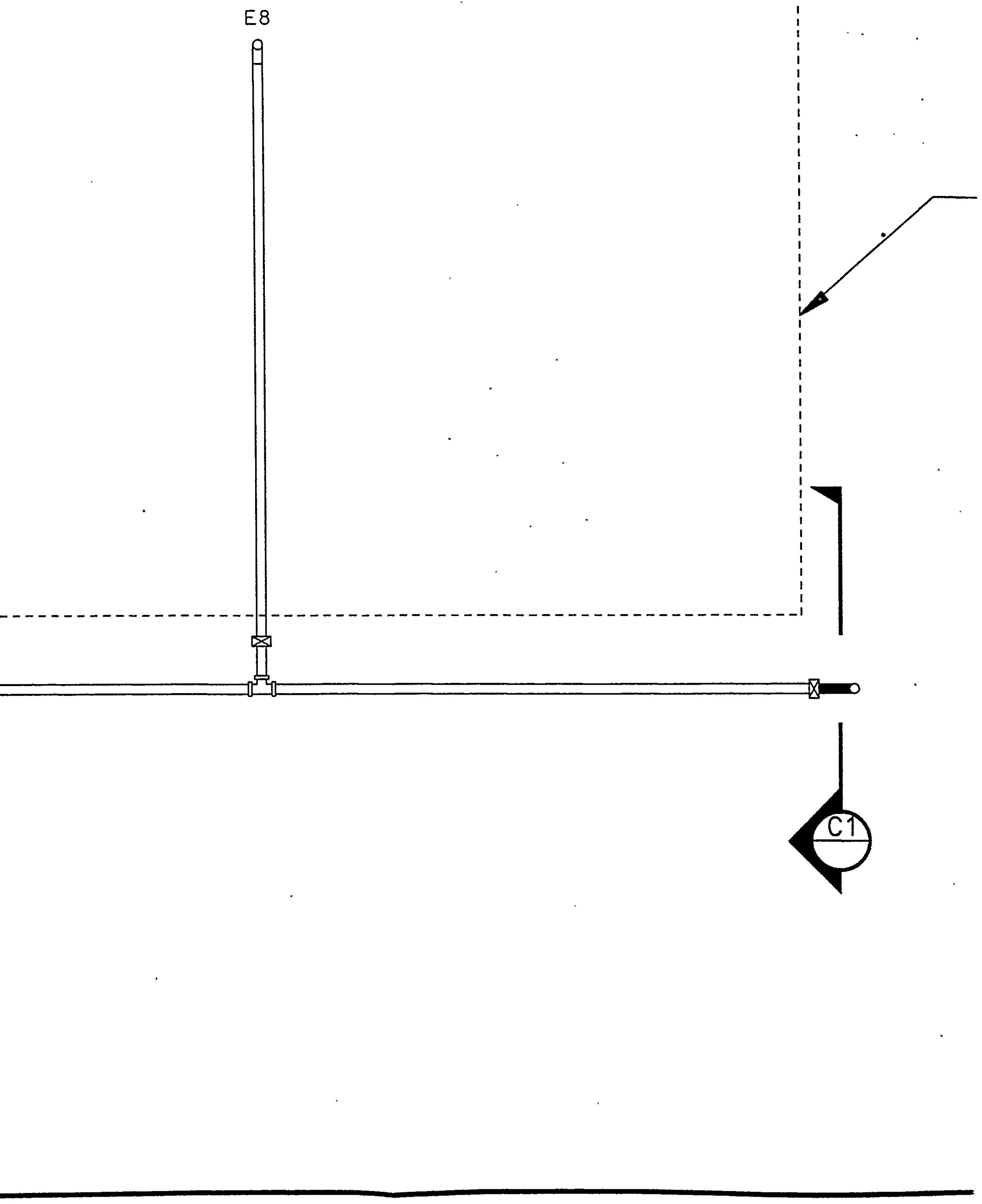
TITLE

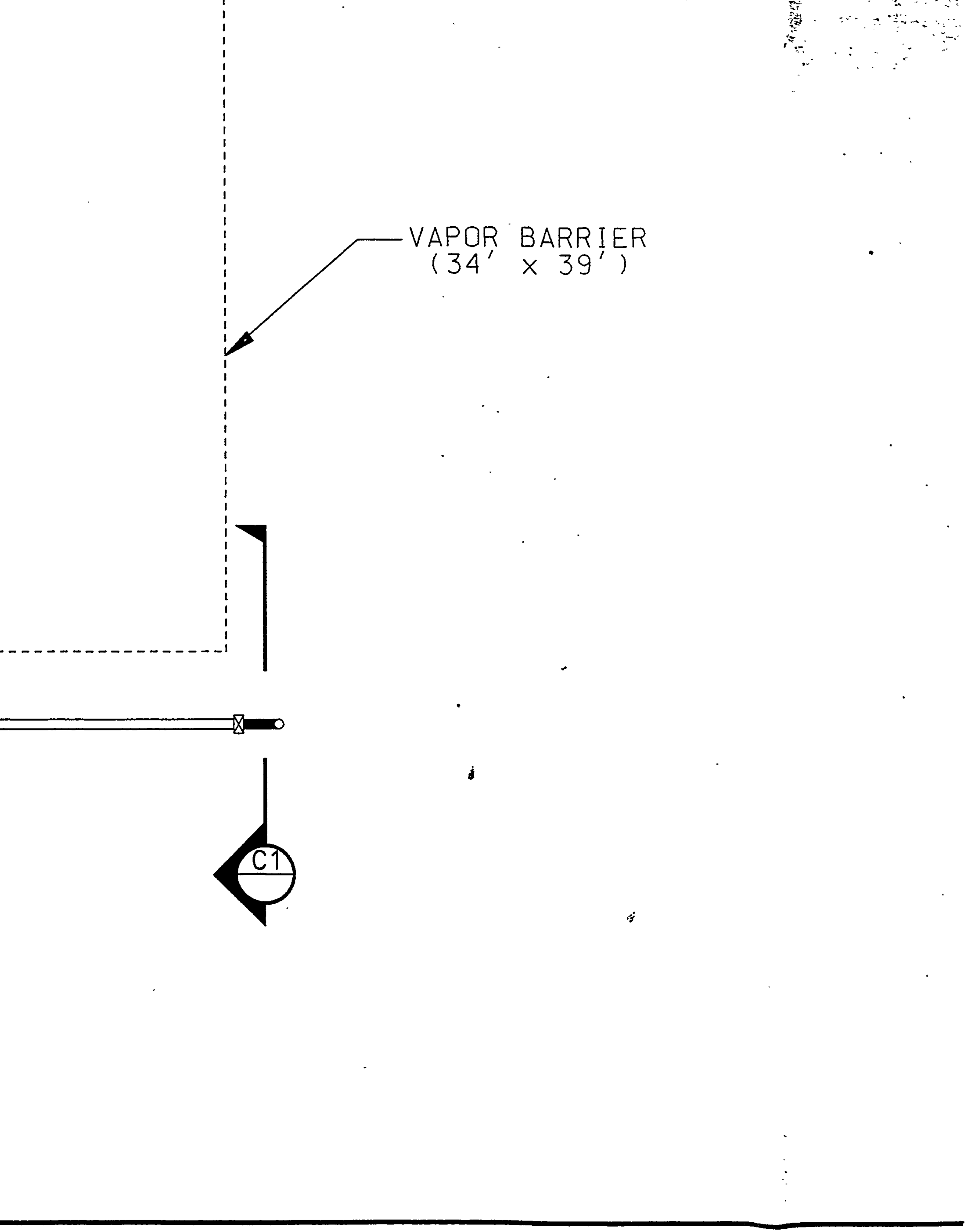
TITLE

WELLS AND PIPLINE LAYOUT


N
5'
0
2.5'
SCALE IN FEET


E6
E7
E8
TD7
TD8


E8
C1

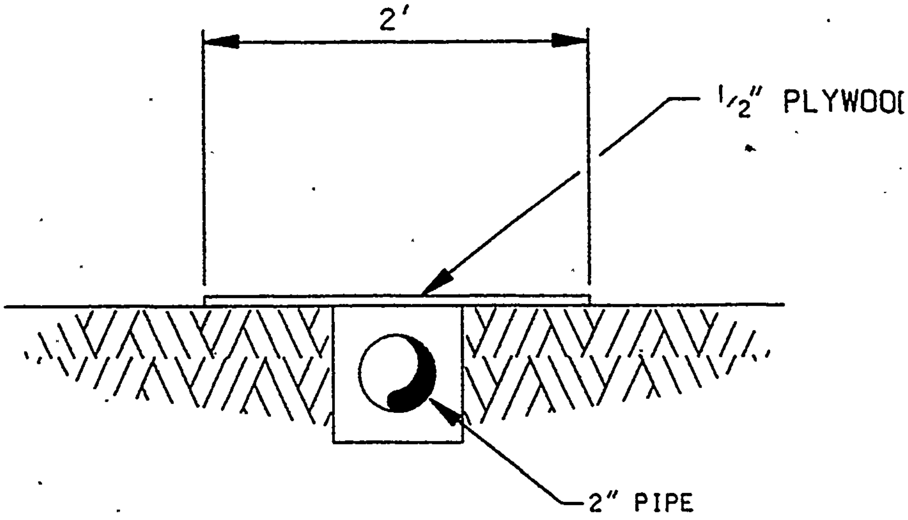

VAPOR BARRIER
(34' x 39')
C1

TITLE

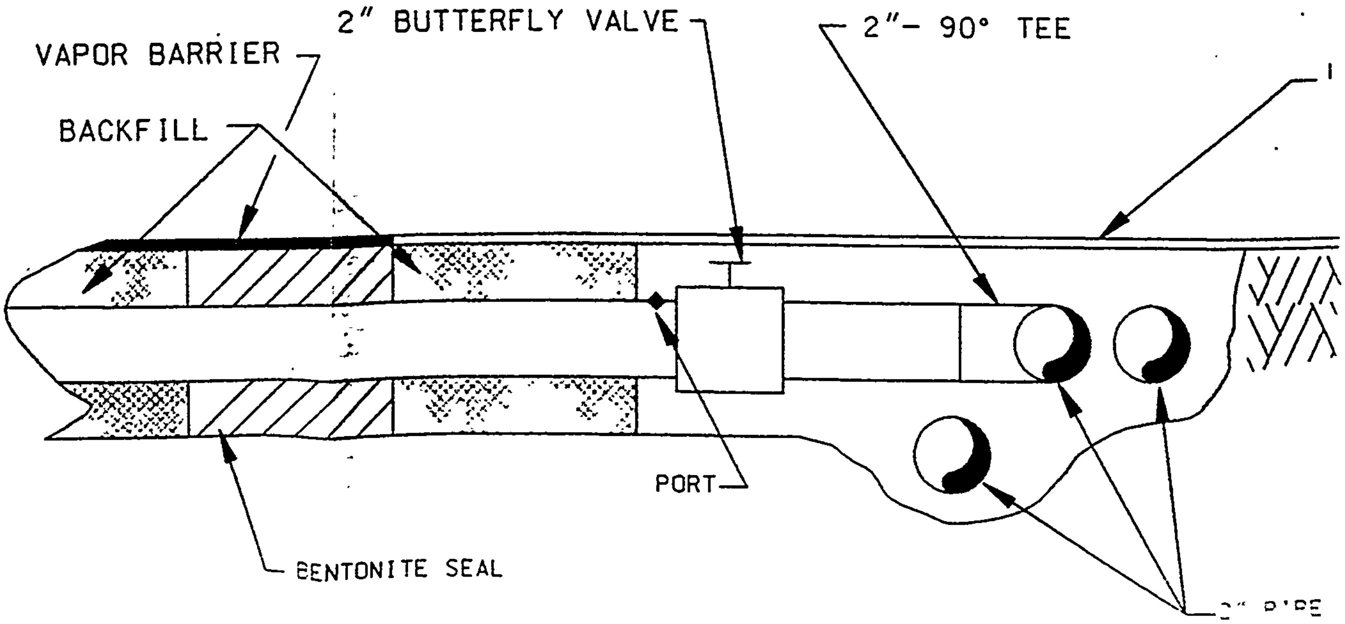
WELLS AND PIPLINE LAYOUT

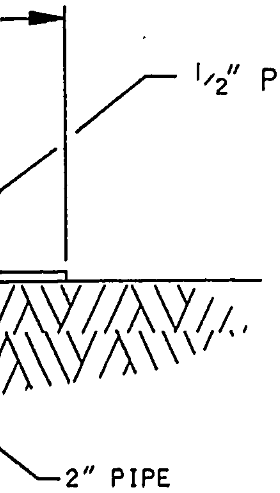
RADIO FREQUENCY HEATING
DECONTAMINATION DEMONSTRATION
SITE S-1
KELLY AIR FORCE BASE, TEXAS

DRAWING NO. 3688G012	DATE 12-6-94



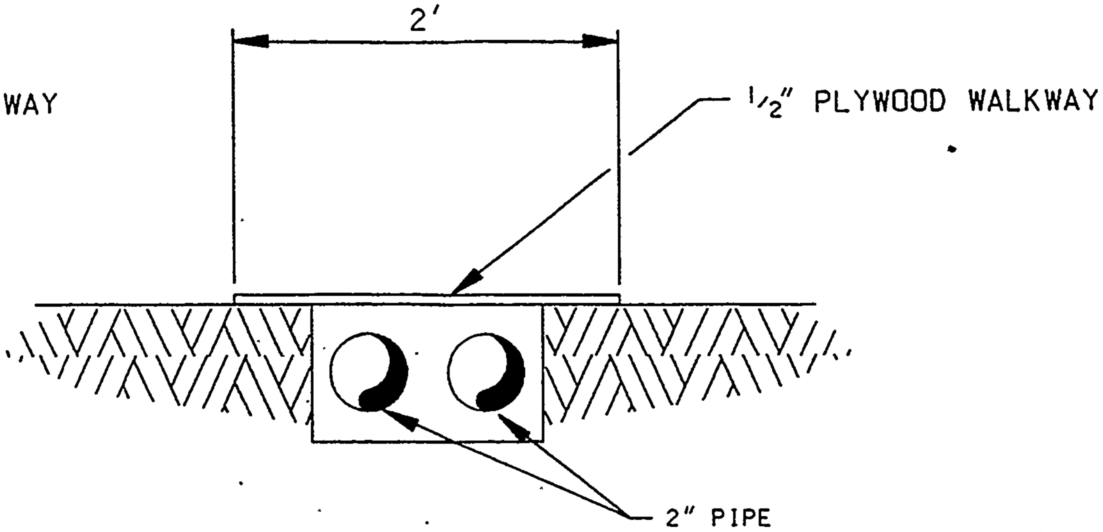
B1 **TRENCH DETAIL**
NOT TO SCALE





L

SCALE



B2 TRENCH DETAIL

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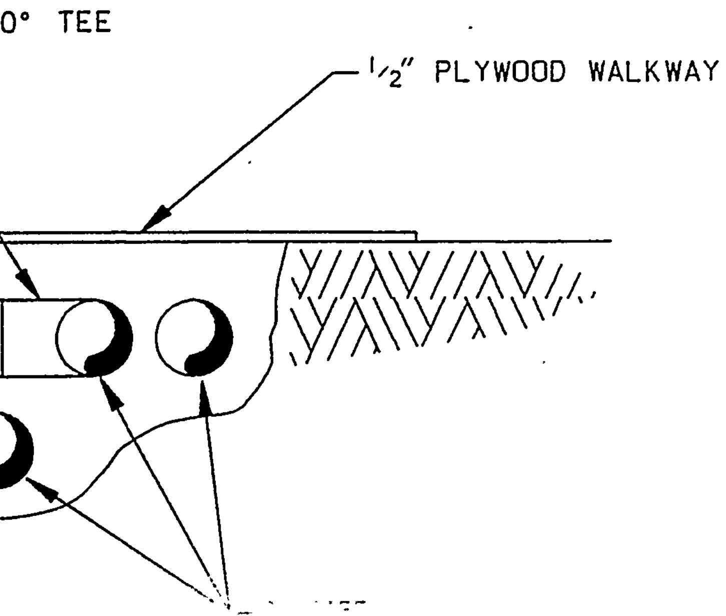
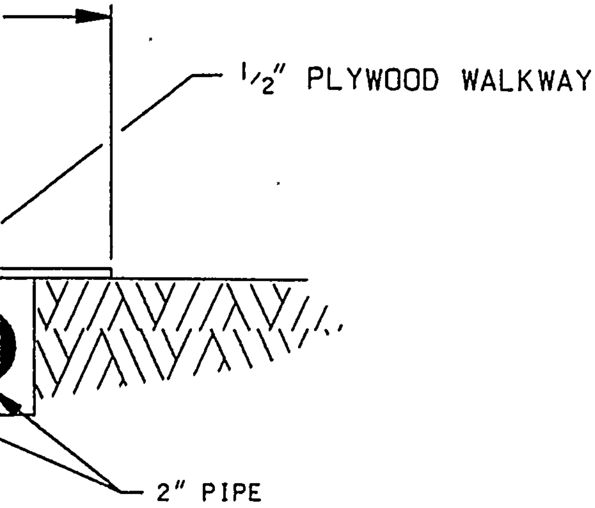
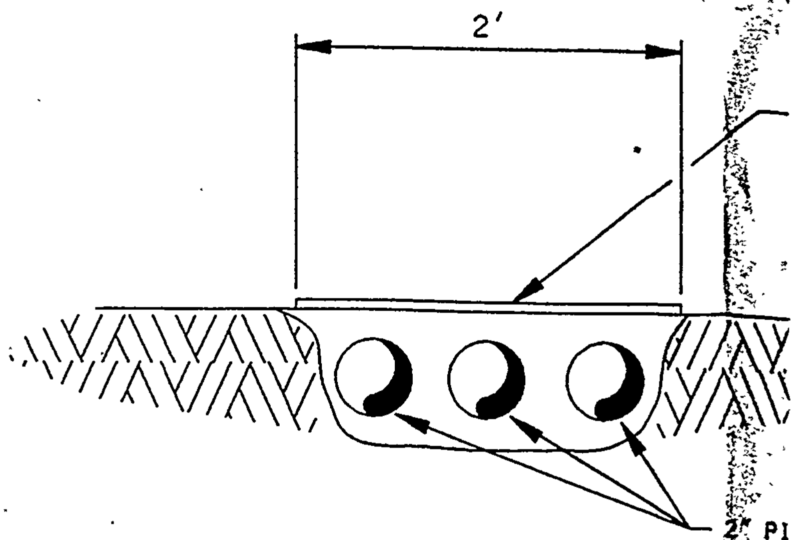




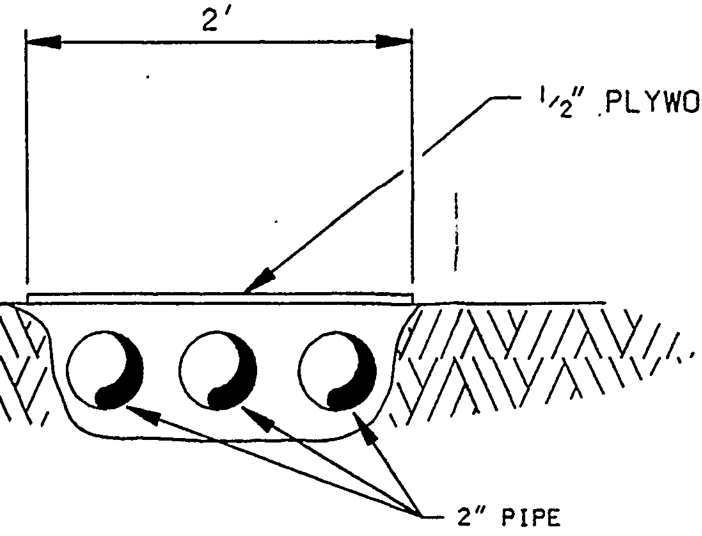
AIL

TO SCALE

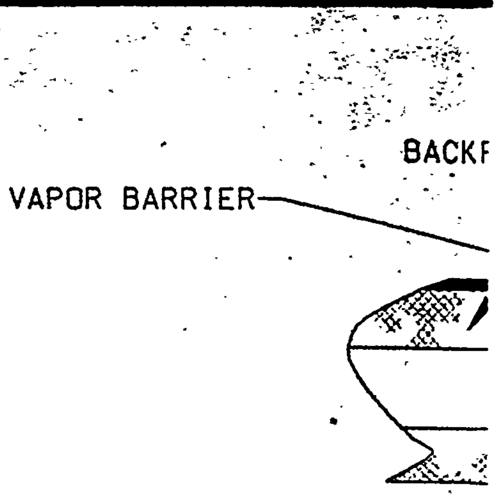


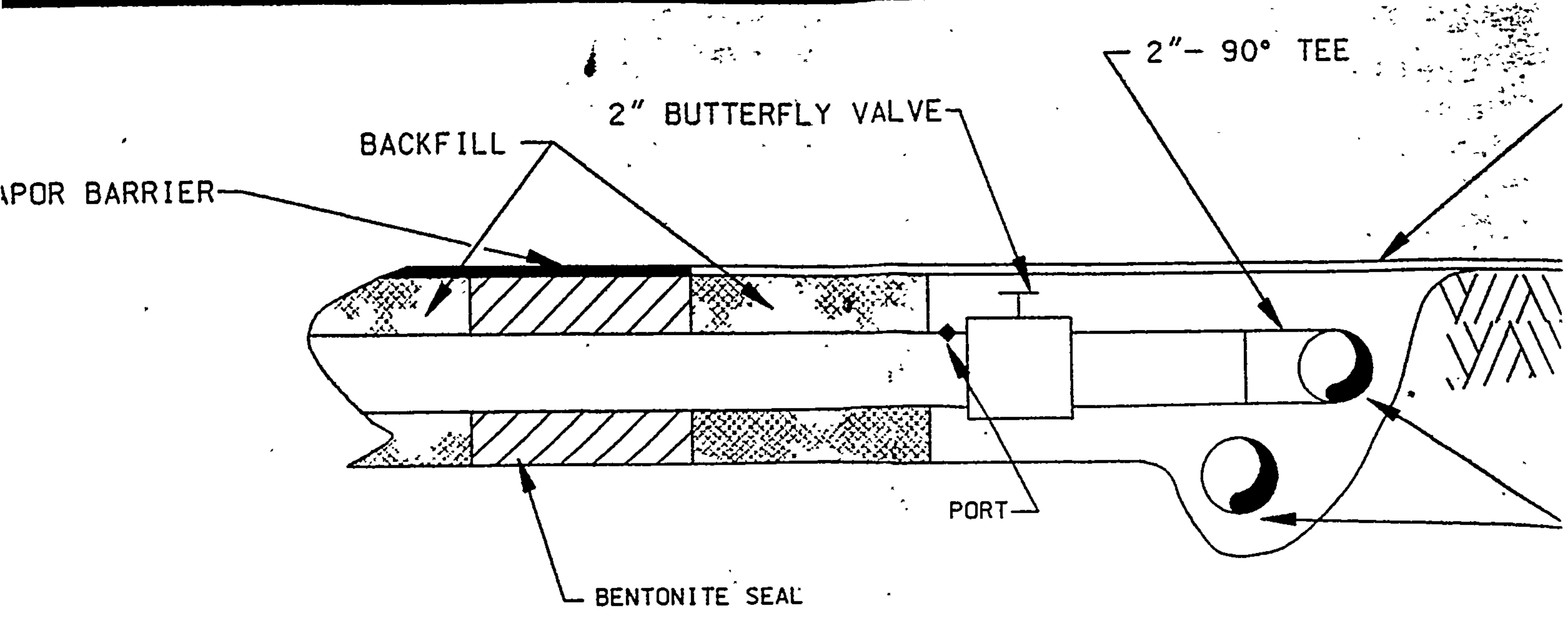
B5 TRENCH DETAIL

NOT TO SCALE



B5 **TRENCH DETAIL**
NOT TO SCALE





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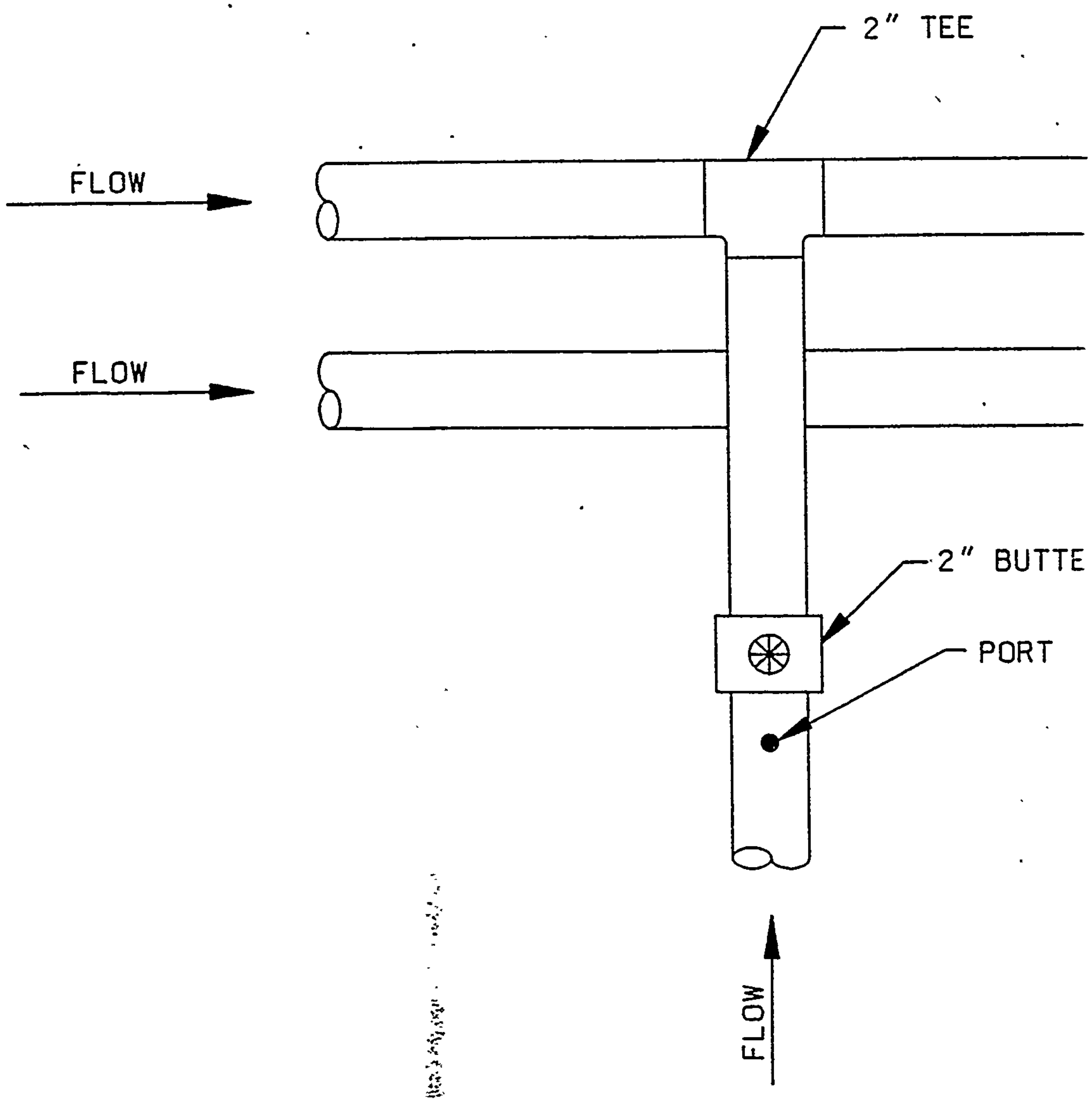
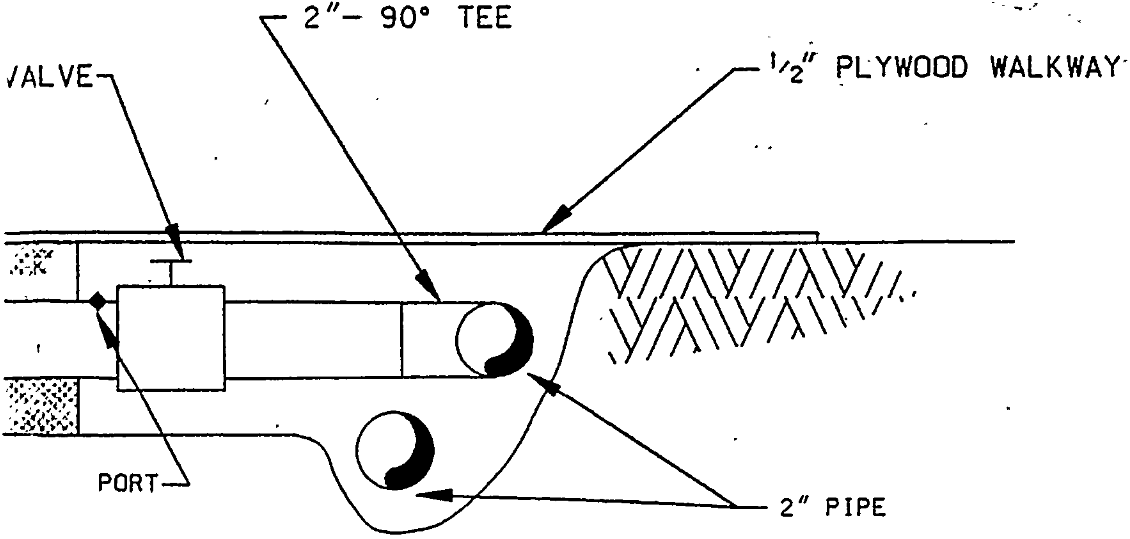


PLAN

B3 TRENCH DETAIL

NOT TO SCALE



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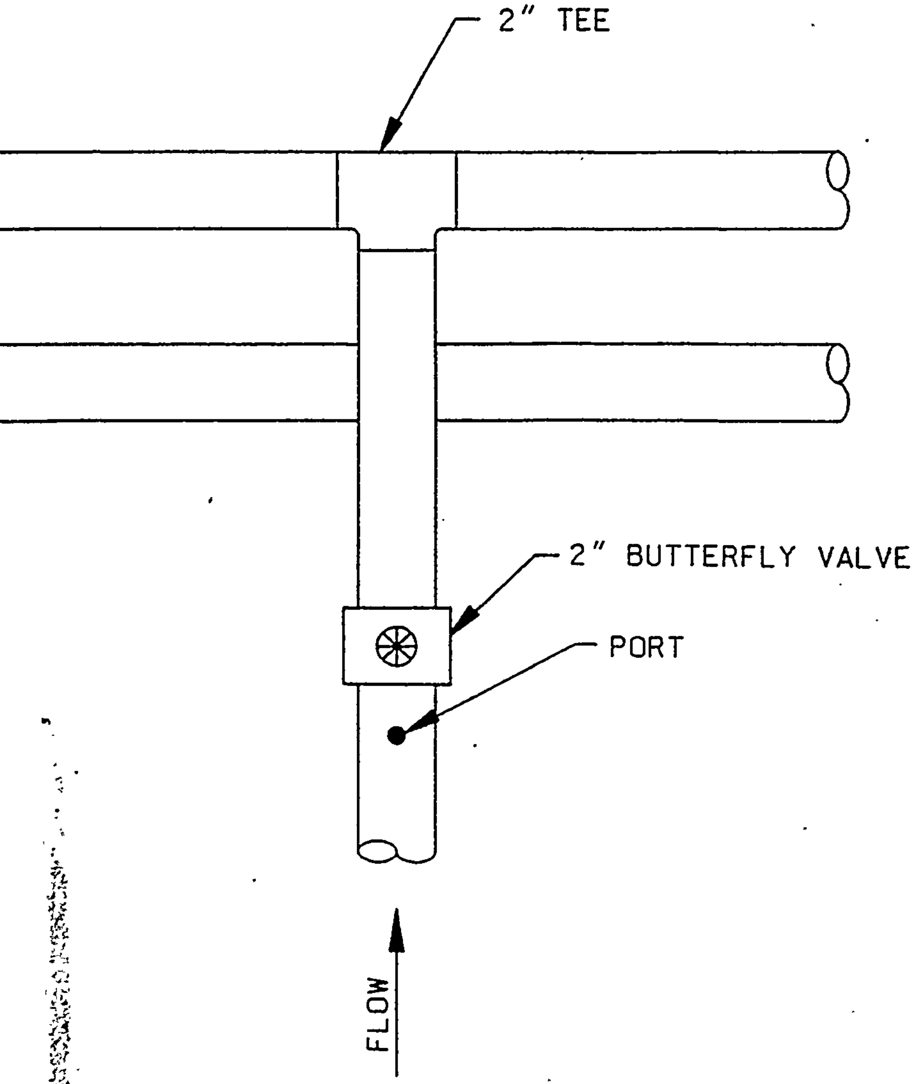
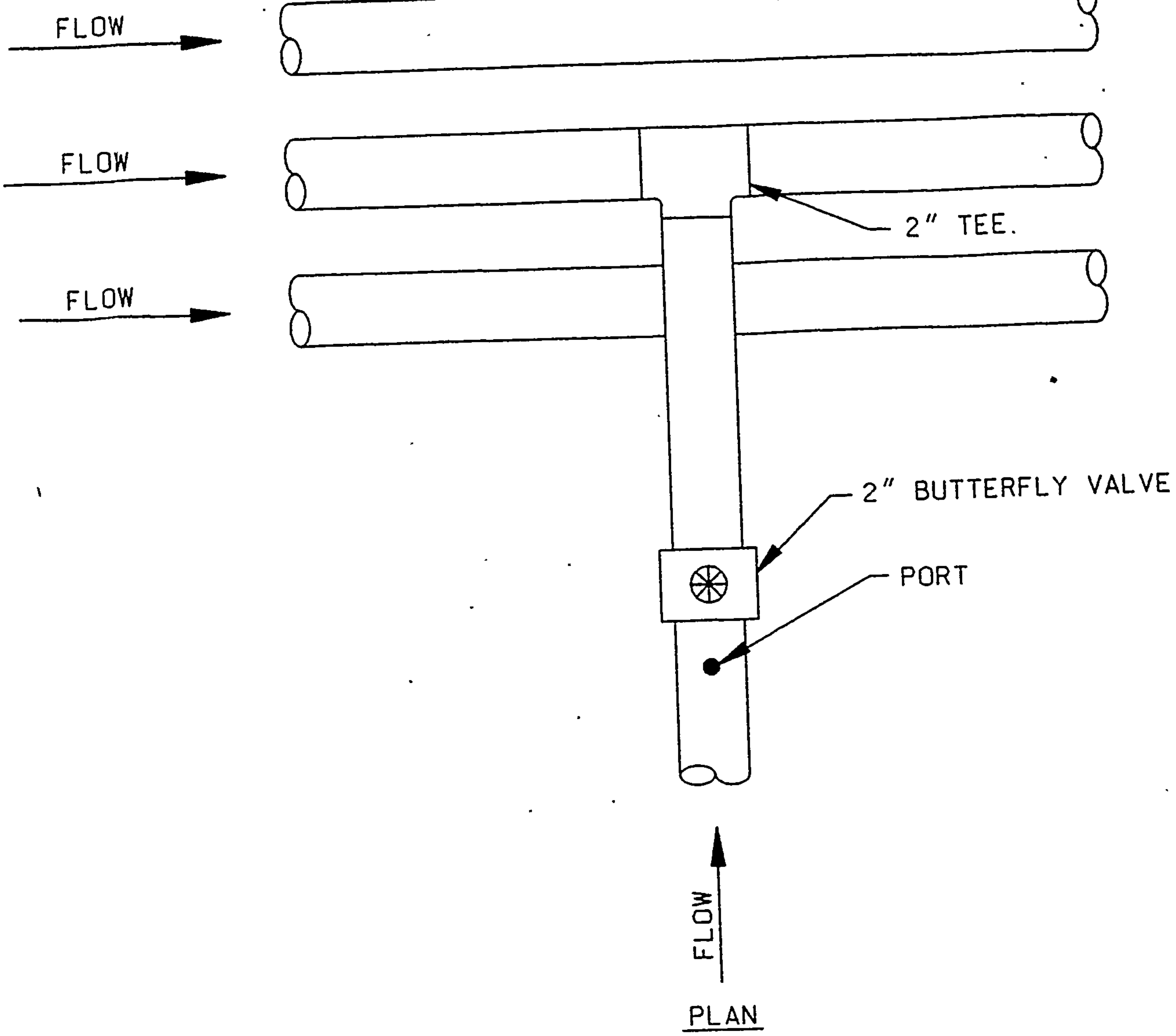


PLAN

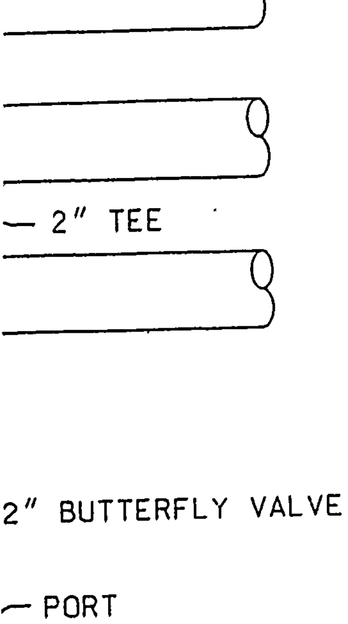
B3 TRENCH DETAIL

NOT TO SCALE

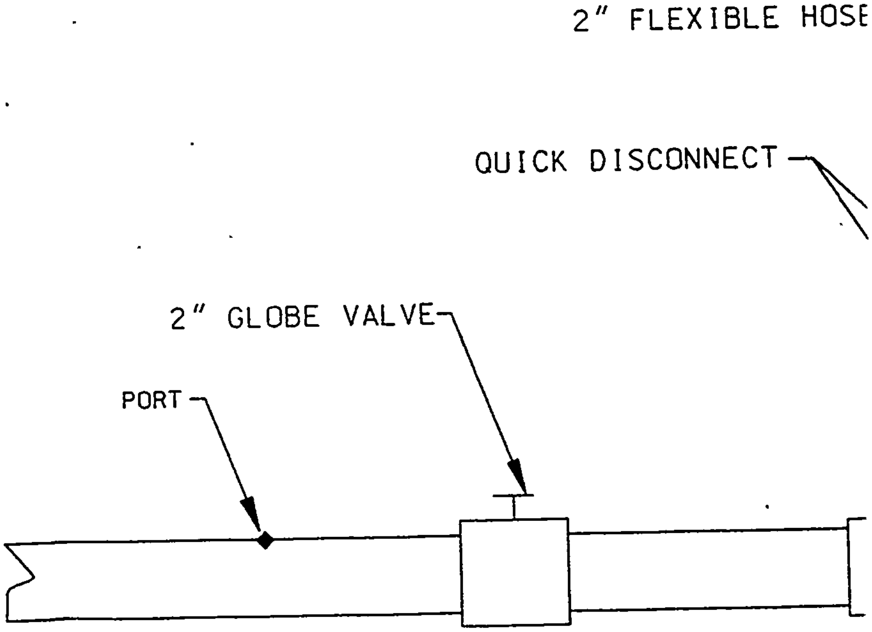


TRENCH DETAIL

NOT TO SCALE

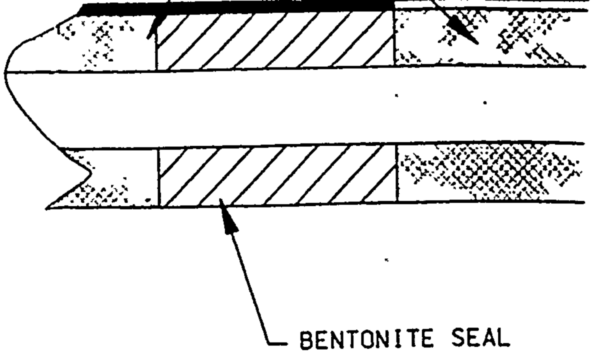


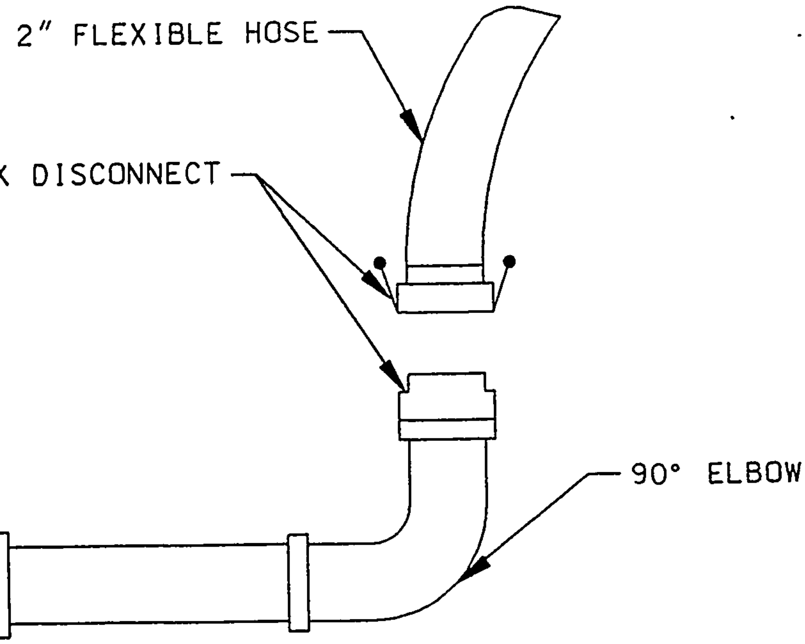
LE



C1 PIPE TO HOSE CONNE

NOT TO SCA.





TO HOSE CONNECTION DETAIL

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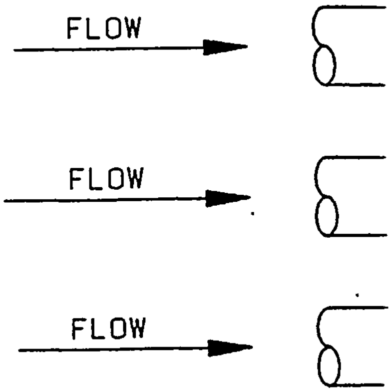

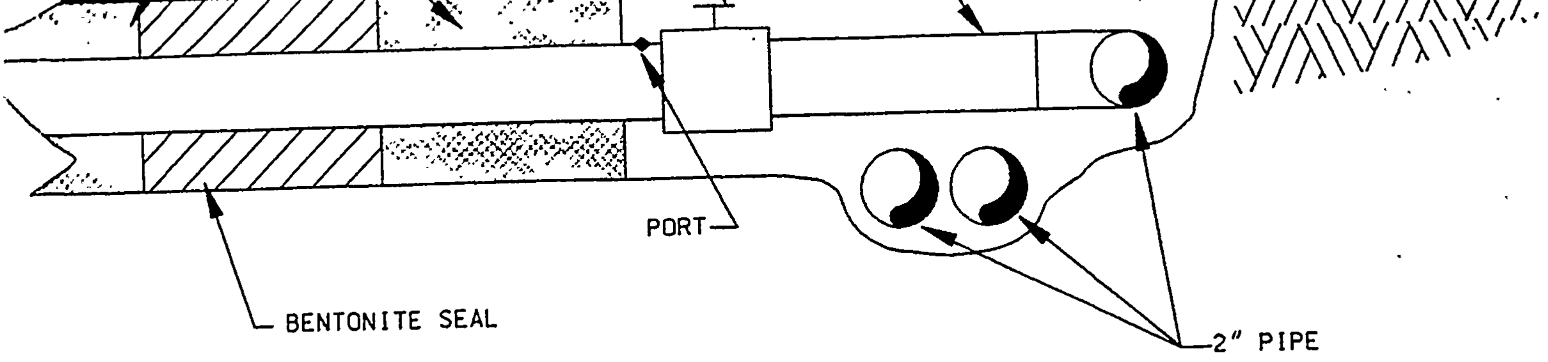

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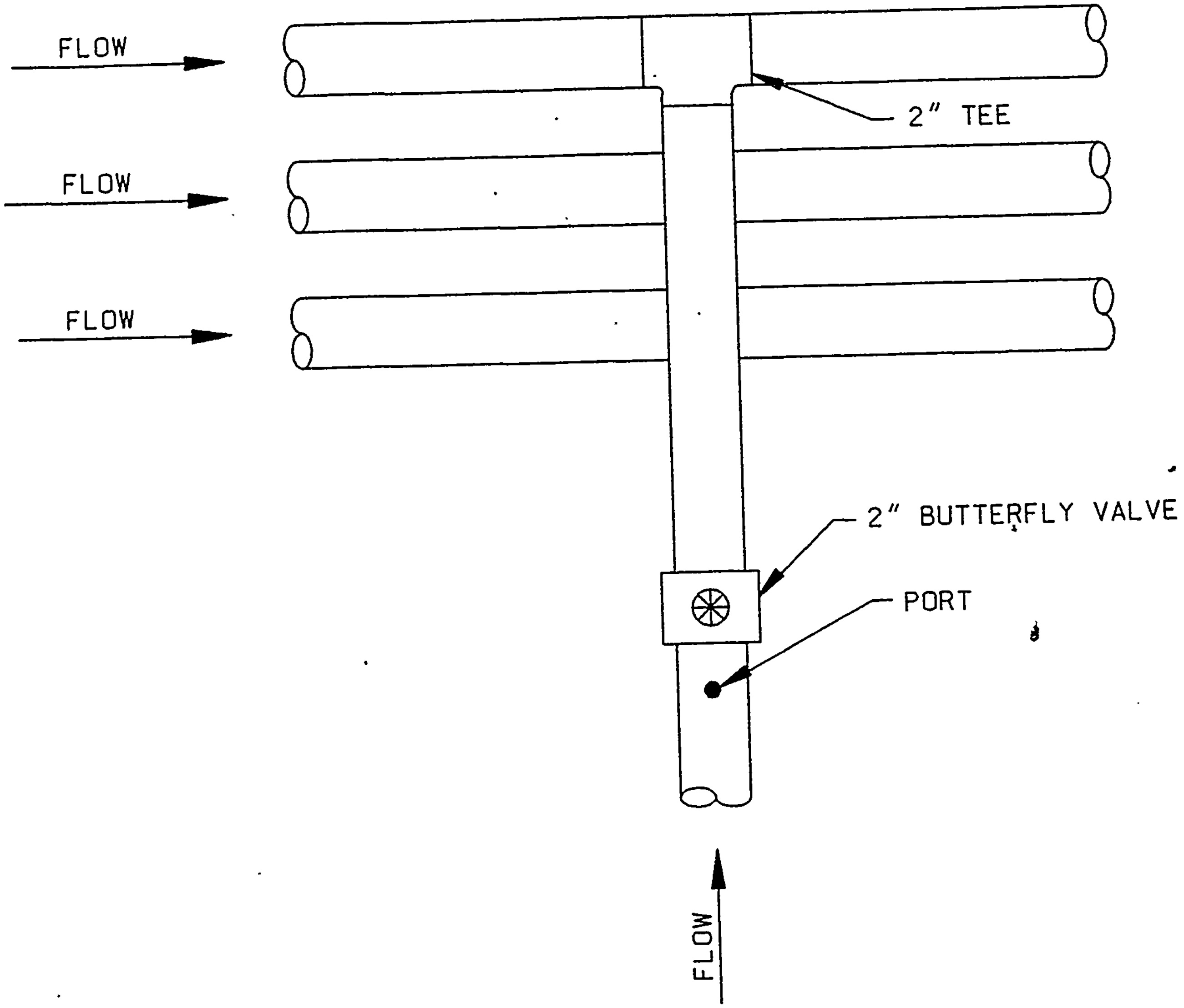


PLAN

B6 TRENCH DETAIL

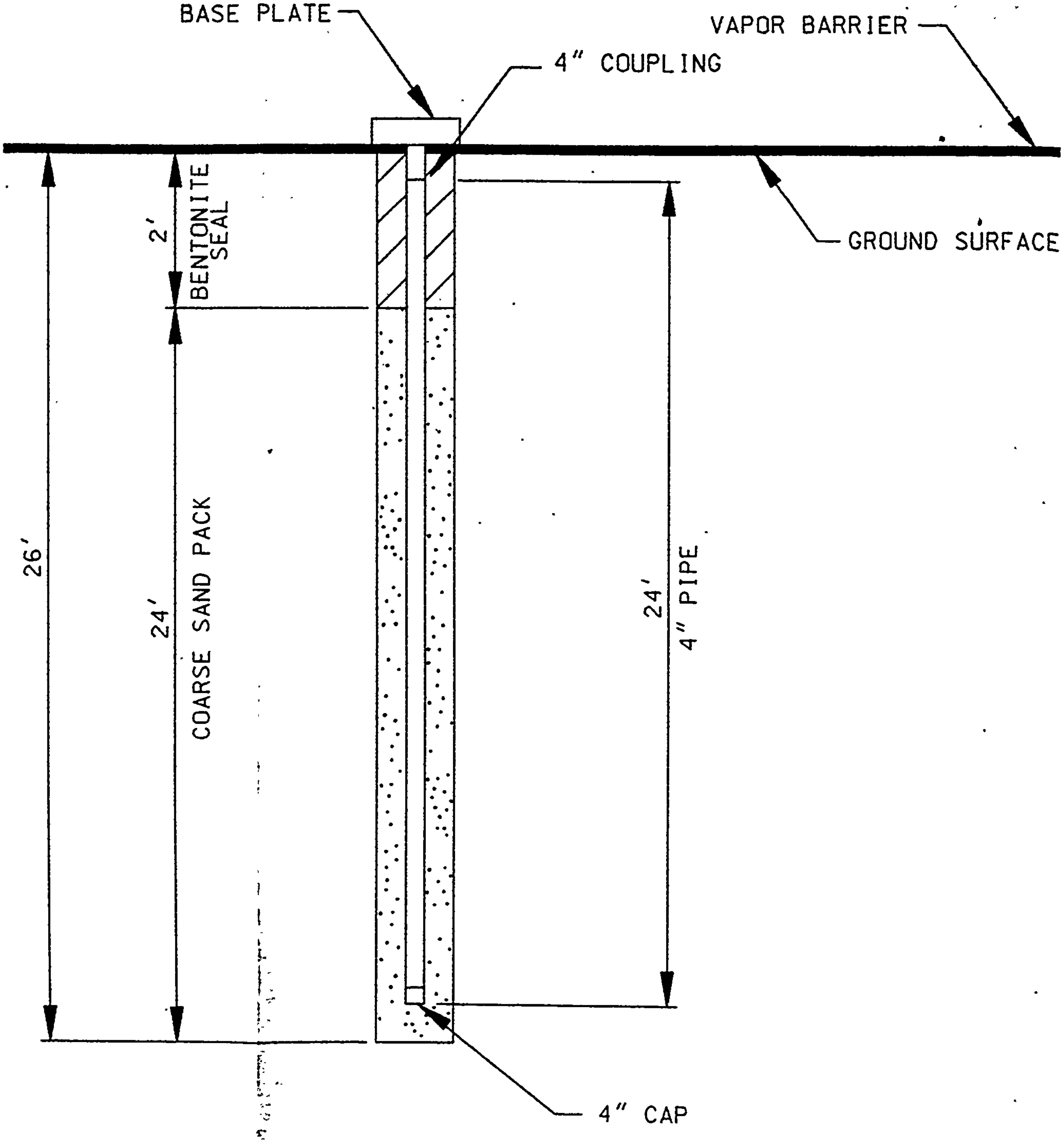
NOT TO SCALE

TITLE

PIPLINE DETAILS

RADIO FREQUENCY HEATING
DECONTAMINATION DEMONSTRATION
SITE S-1
KELLY AIR FORCE BASE, TEXAS

DRAWING NO. 3688G013
DATE 12-6-94

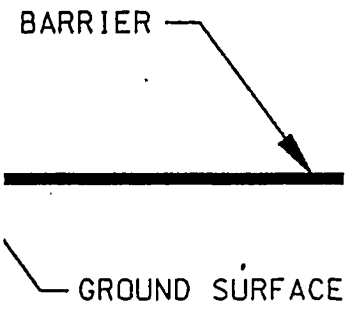


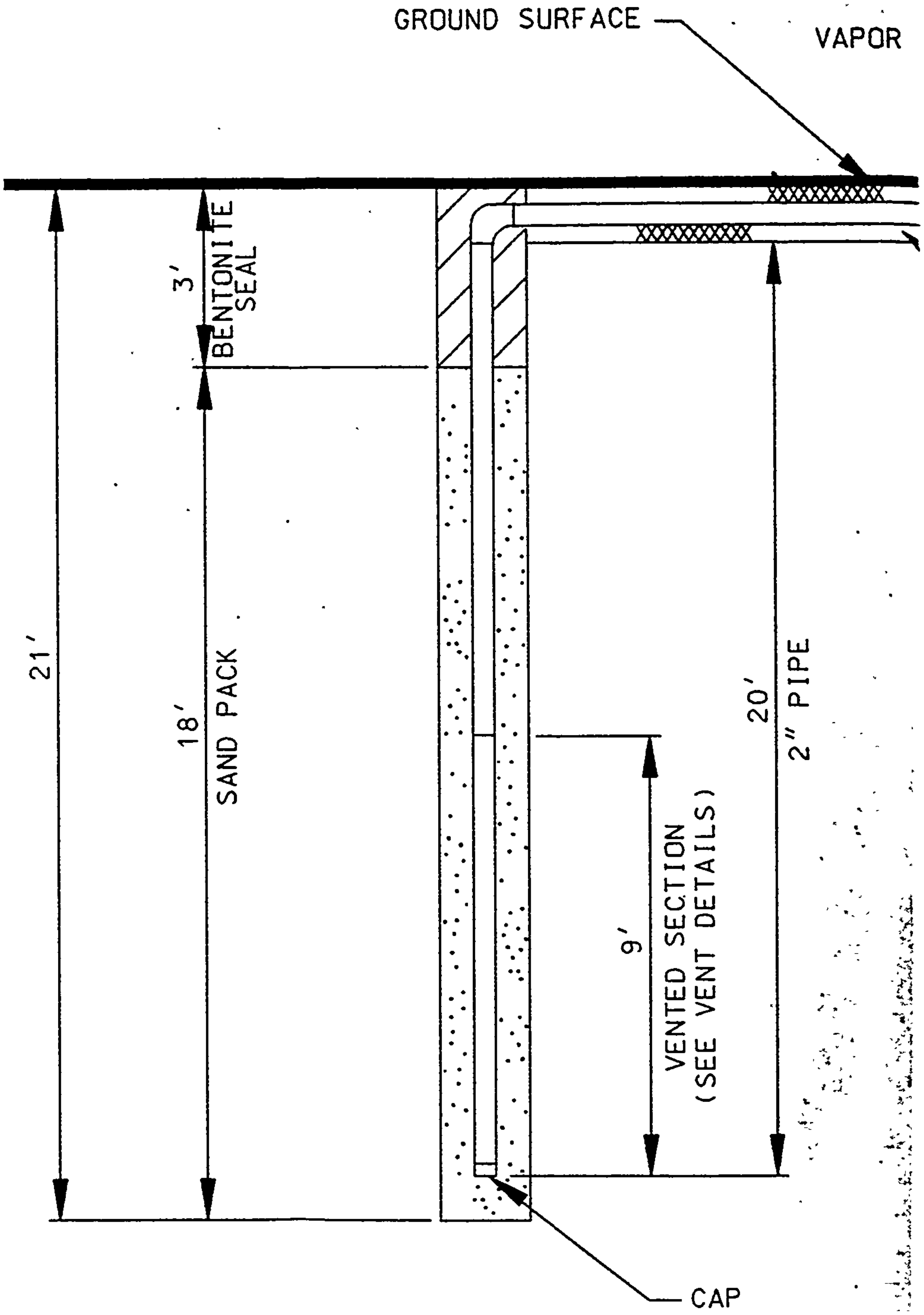
A1 **TYPICAL ANTENNA WELL**

NOT TO SCALE

NOTE:

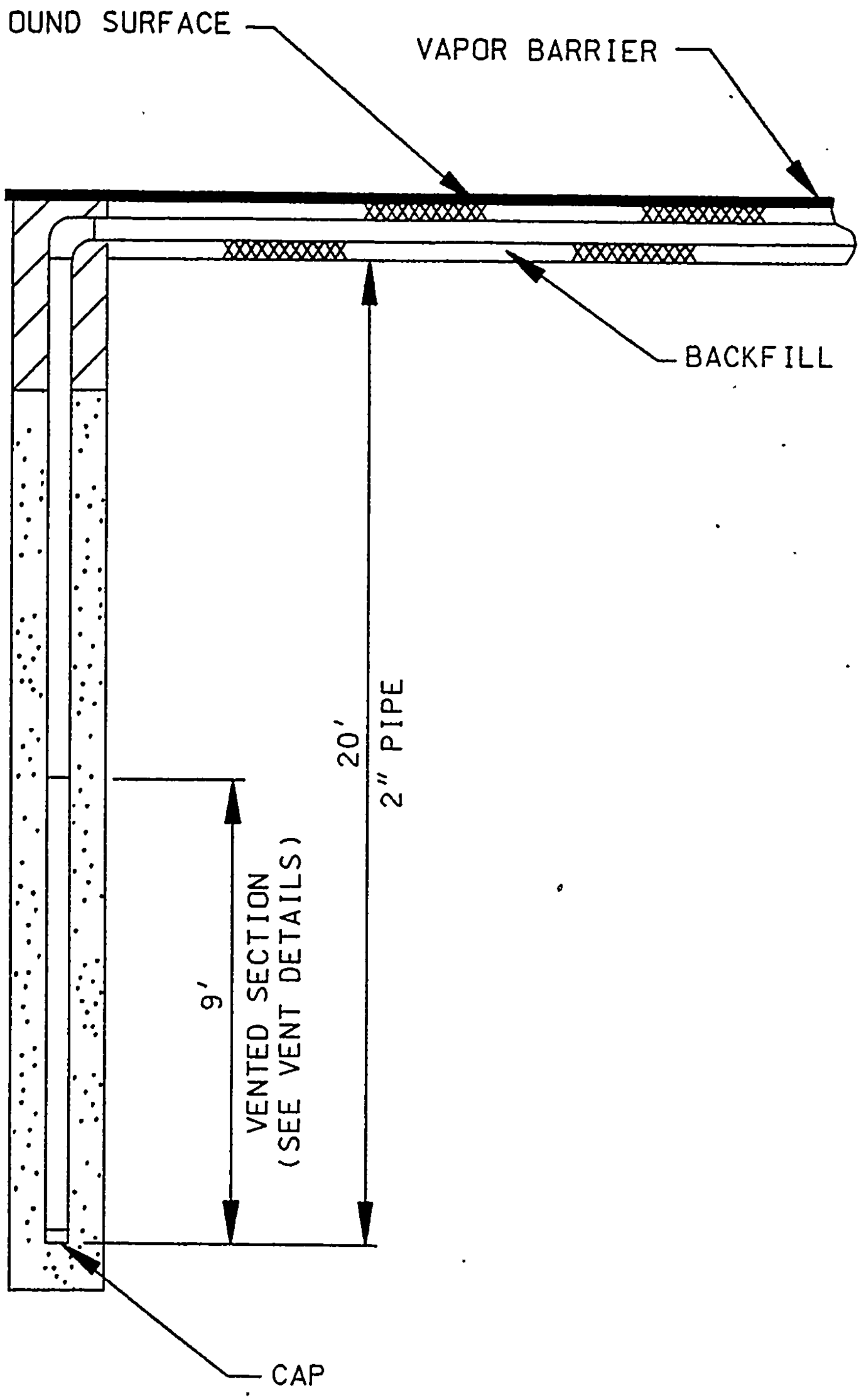
PVC WELL CASING WILL BE TEMPORARILY CAPPED BELOW THE GROUND SURFACE FOR THE VAPOR EXTRACTION TEST. THE PVC WILL BE REMOVED WHEN THE ANTENNA SLEEVE IS INSTALLED.



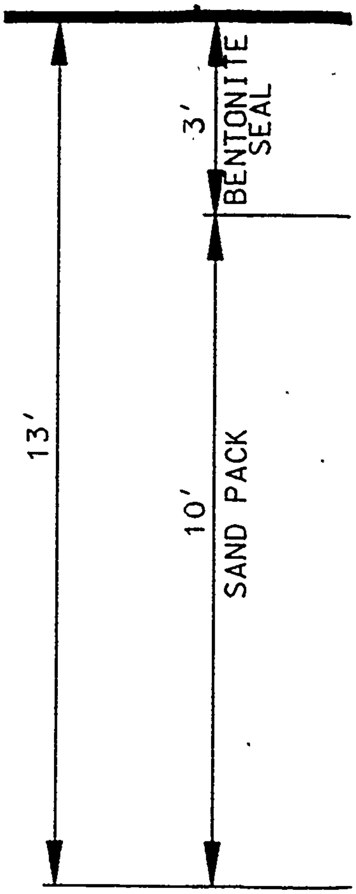


A2 VERTICAL EXTRACTION WELLS
E1.E3.E4.E5.E6. AND E8

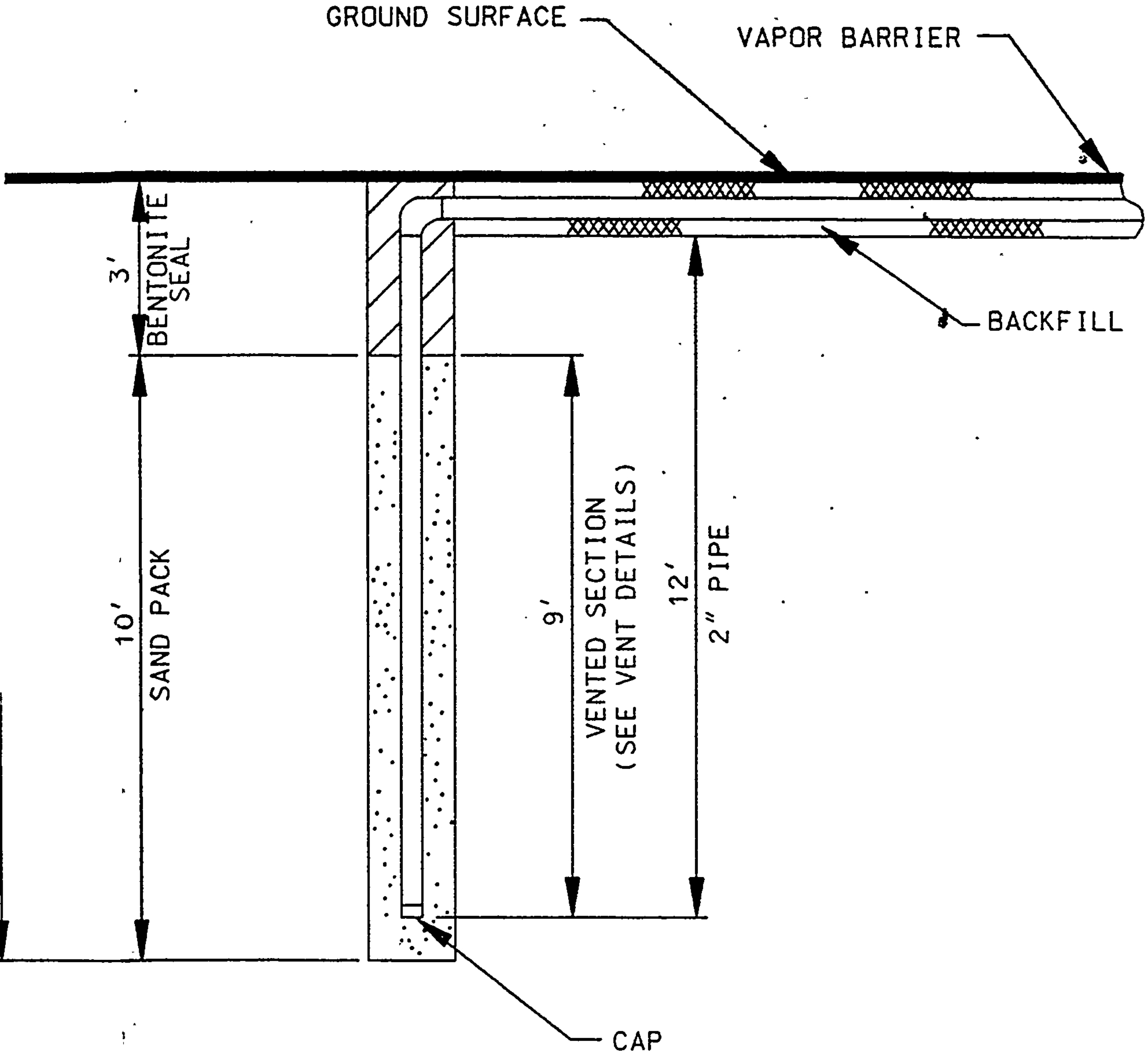
NOT TO SCALE



RACTION WELLS
.E6. AND E8 NOT TO SCALE

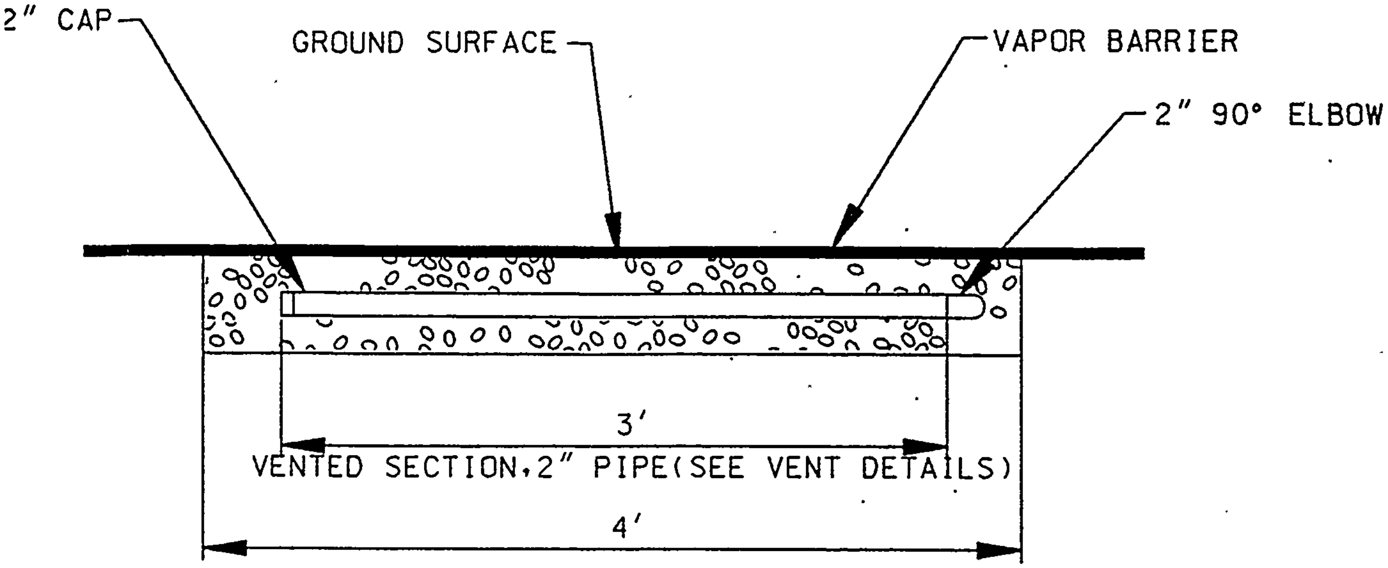


A2 VERTICAI



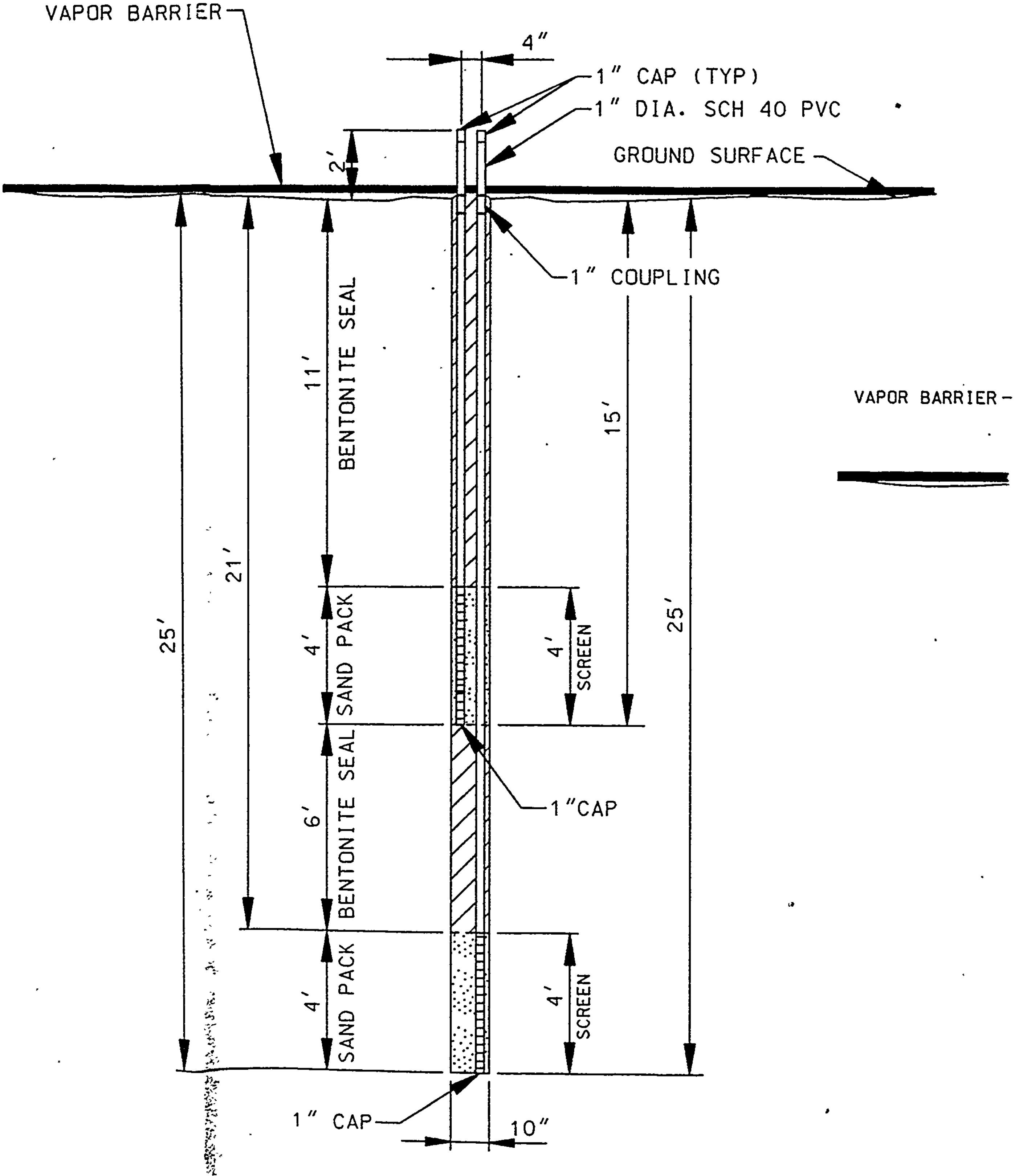
A2 VERTICAL EXTRACTION WELLS E2 AND E7

NOT TO SCALE



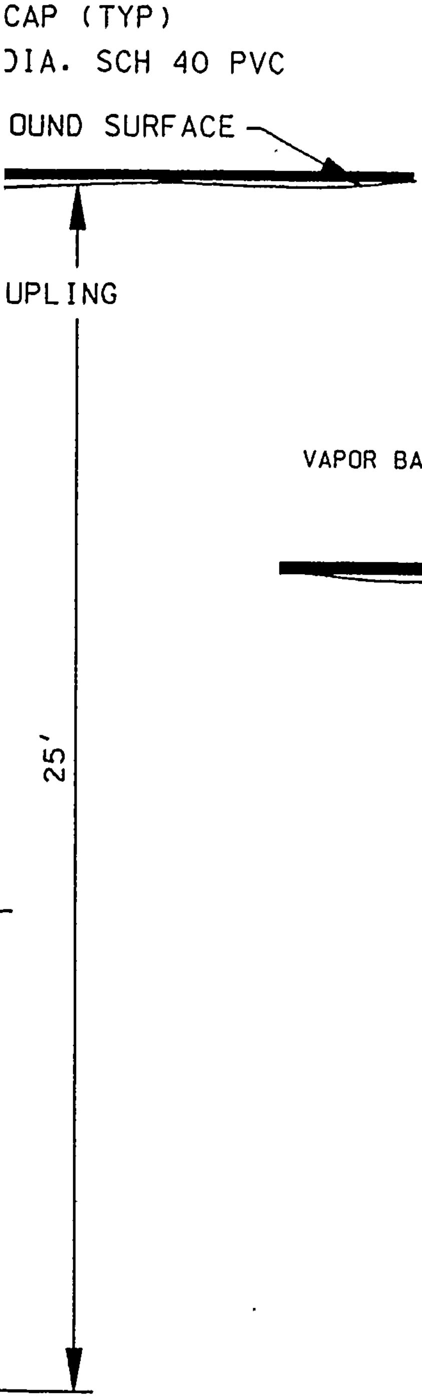
A4 **TYPICAL HORIZONTAL EXTRACTION WELL**

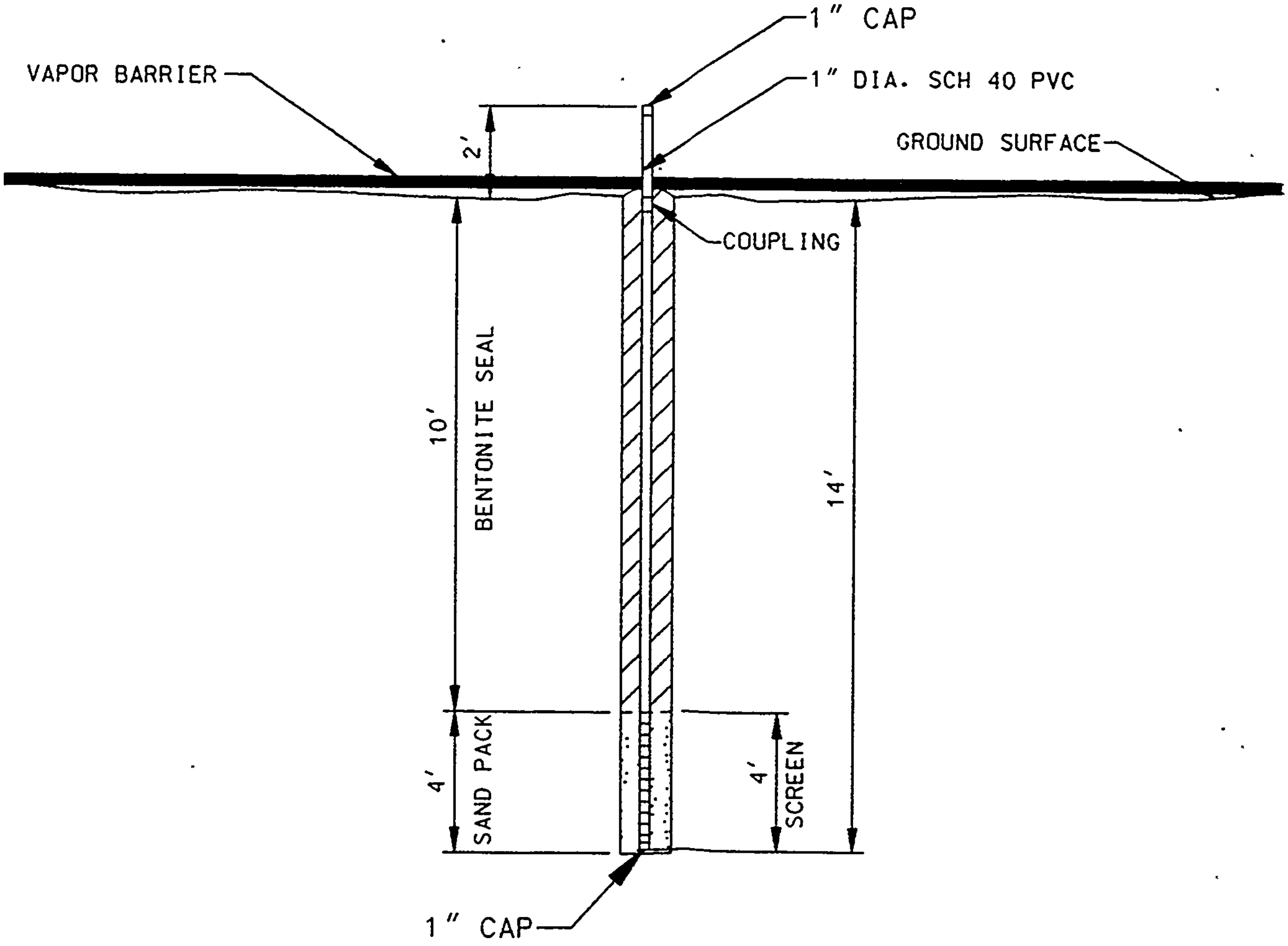
NOT TO SCALE



A5 TRANSDUCER WELL PAIRS

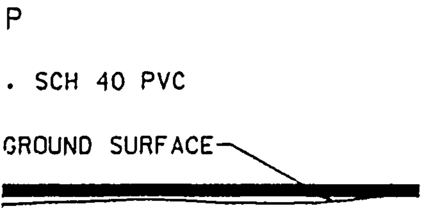
NOT TO SCALE



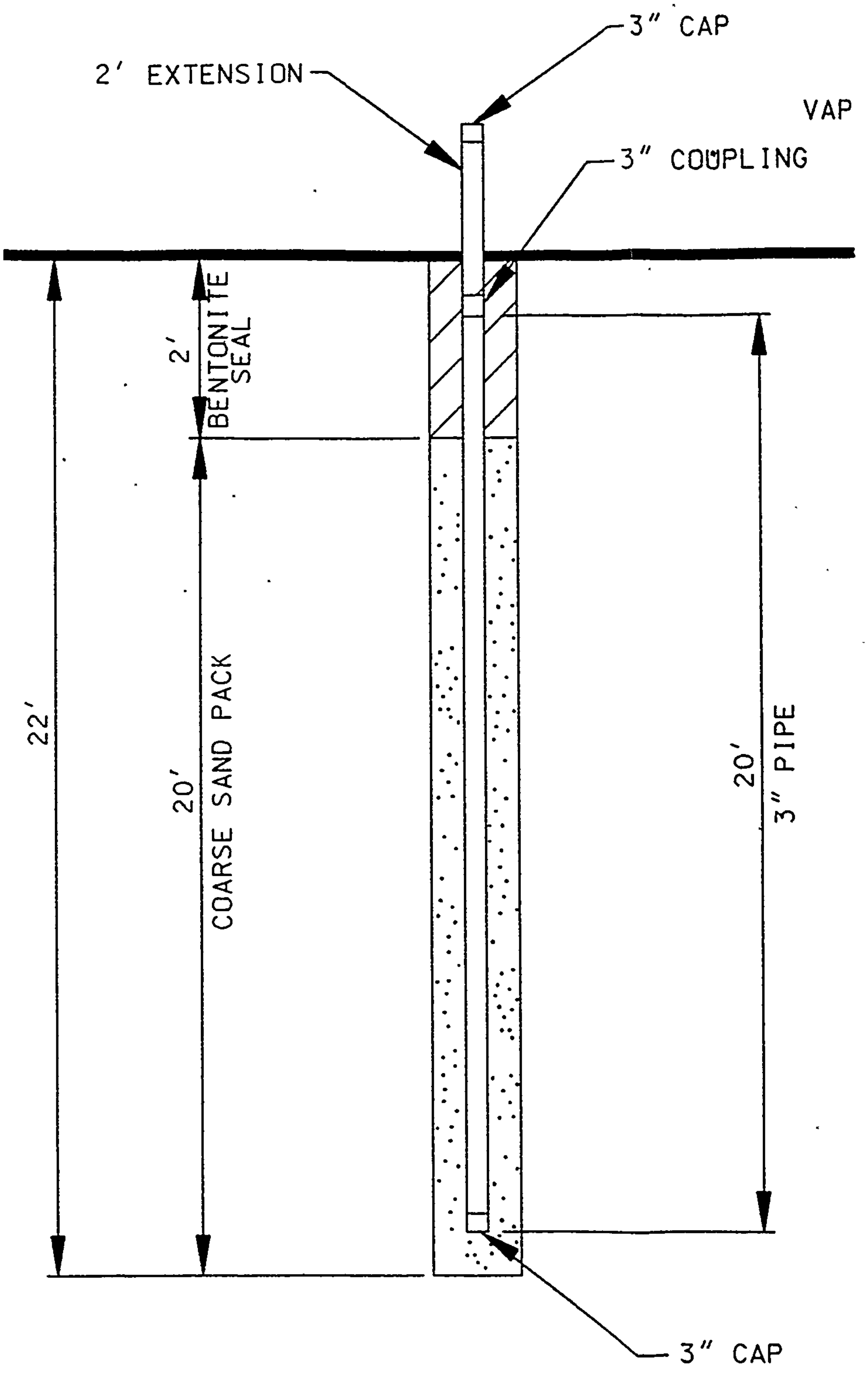


A6 **SINGLE TRANSDUCER WELL**

NOT TO SCALE



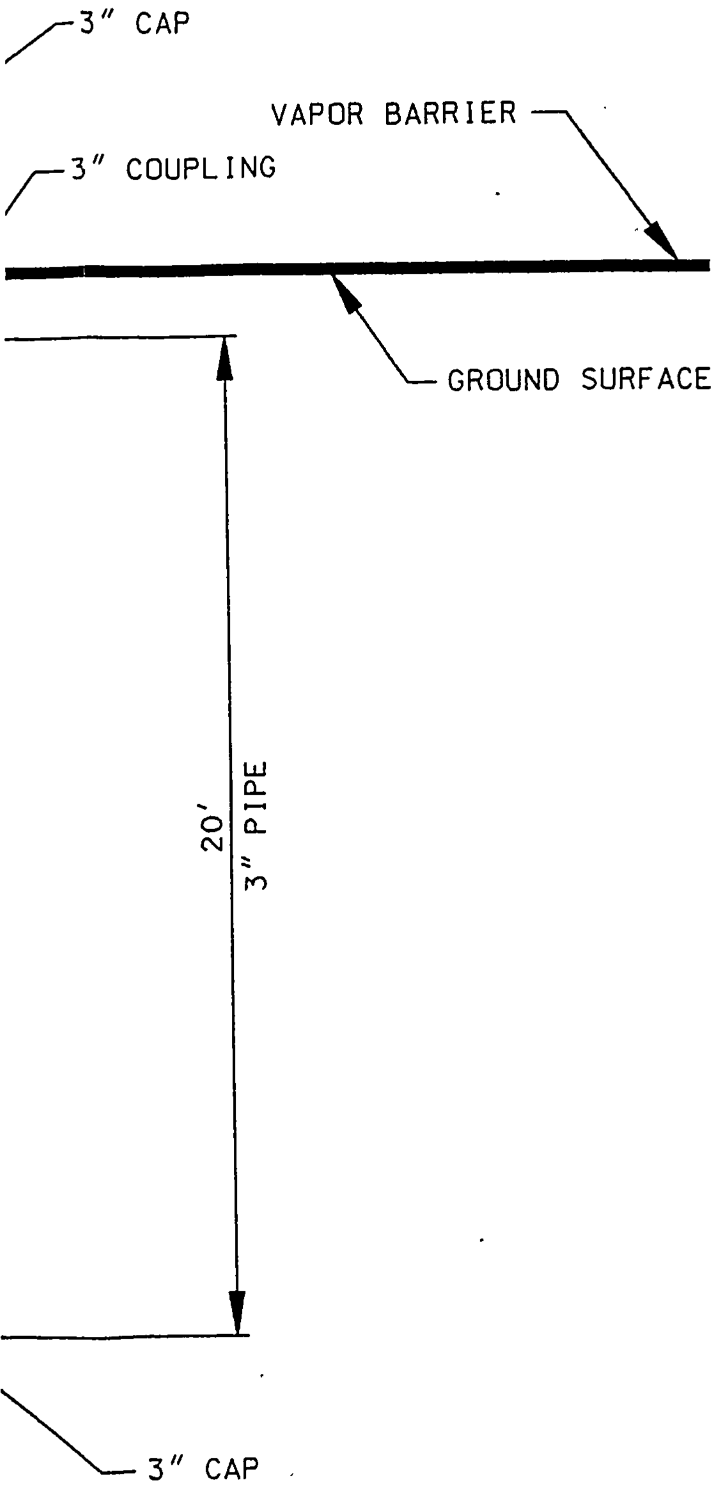
SCALE



A7 **TYPICAL FIELD MEASUREMENT WE**

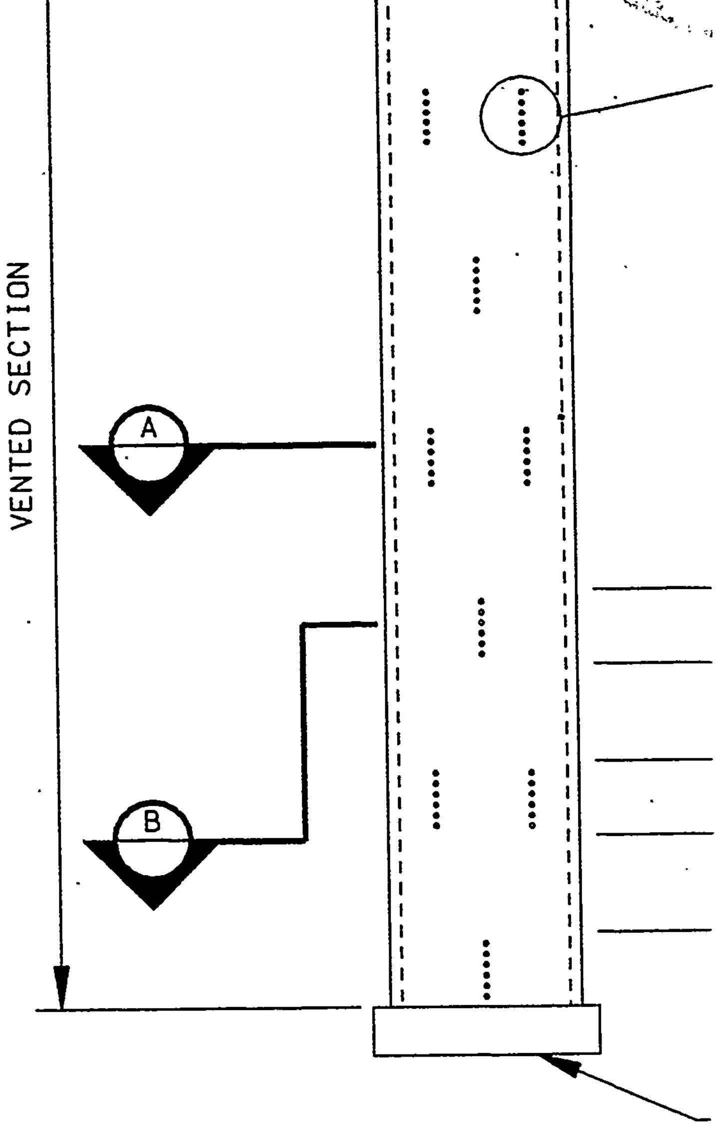
NOT TO S

NOTE:
WELL TO BE TEMPORARILY CAPPED BELOW GF
SURFACE FOR VAPOR EXTRACTION TEST. THE
EXTENSION TO BE ADDED BEFORE RF OPERA



MEASUREMENT WELL

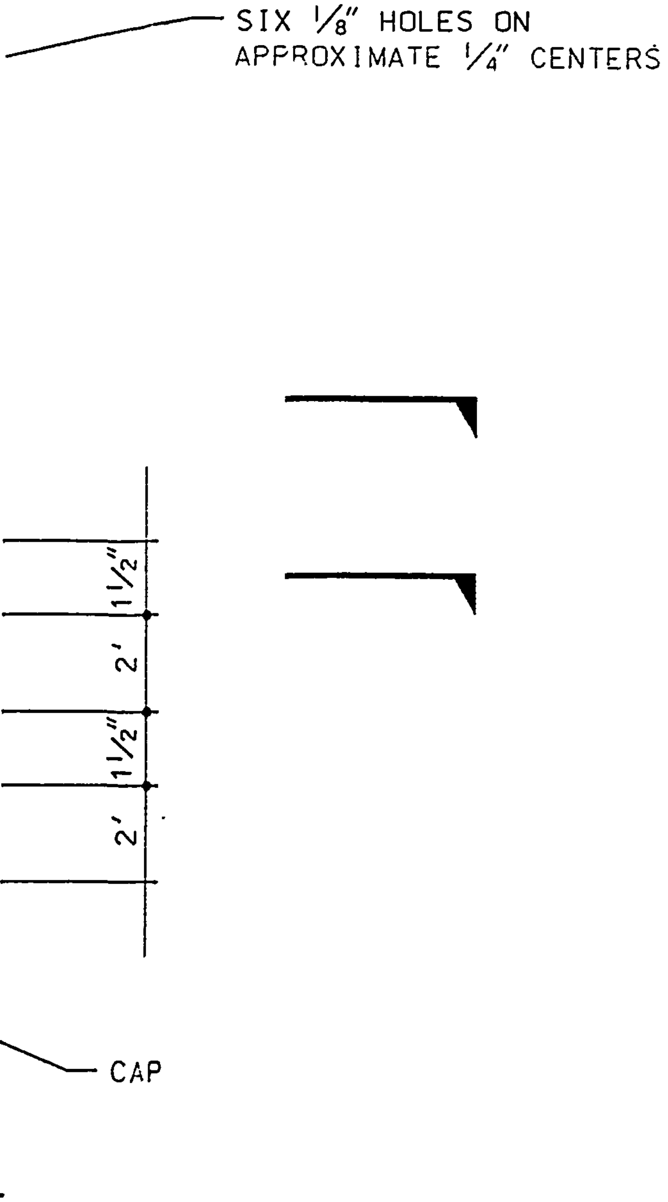
NOT TO SCALE

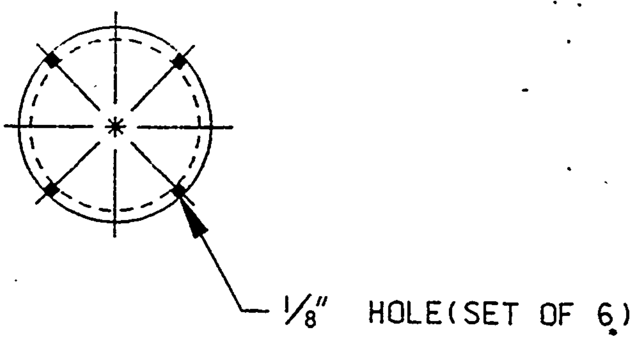


VENT DETAILS

NOT TO SCALE

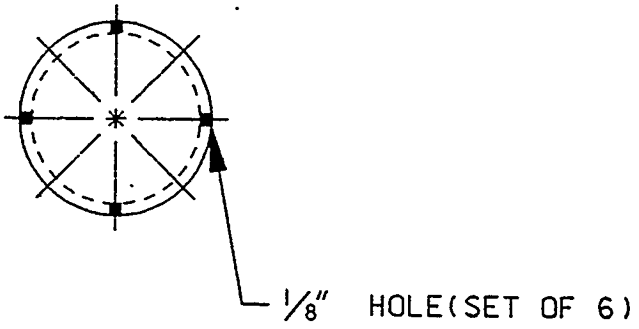
LY CAPPED BELOW GROUND
TRACTION TEST. THE 2′
D BEFORE RF OPERATION.





CROSS-SECTION A-A

NOT TO SCALE



CROSS-SECTION B-B

NOT TO SCALE

TITLE WELL DETAILS RADIO FREQUENCY HEATING DECONTAMINATION DEMONSTRATION SITE S-1 KELLY AIR FORCE BASE, TEXAS	
DRAWING NO. 3688G014	DATE 12-6-94

APPENDIX B.4.

PERMEABILITY CALCULATIONS

Radio Frequency Heating Decontamination Demonstration
Site S-1, Kelly AFB

Contract No. F33615-90-D-4011
Delivery Order No. 0007

Calculations Prepared By: Laura H. Whitt **Date:** 12/27/94

Calculations Checked By: **Date:**

PURPOSE:

Estimate the vapor permeability of the soil at Site S-1 at several times during the demonstration of KAI's heating method.

REFERENCES:

Johnson, P., M. Kemblowski, and J. Cohart. Quantitative Analysis for the Cleanup of Hydrocarbon-Contaminated Soils by In-Situ Soil Venting. GROUNDWATER. 1990 May-June;28(3): 413-429.

Operating Conditions Logbook. (Data collected by Brown & Root Environmental personnel during the demonstration.)

Radian Corporation. Final Report [Vapor Stream Analysis]: Superfund Innovative Tecnology Evaluation: KAI Technologies, Inc.: Radio Frequency Heating Demonstration. Sept. 7, 1994.

Shames, Irving. Mechanics of Fluids. New York: McGraw Hill Book Company, 1982.

Subsurface pressure contours hand drawn onto Site Layout Map (Brown & Root Environmental Drawing # 3688G016.

Surface Weather Observation forms for Kelly AFB from the National Climatic Data Center (NCDC)

ASSUMPTIONS:

The viscosity of the vapor stream is estimated as the viscosity of air at the vapor stream temperature.

The flow rates measured by Radian Corporation during vapor sampling events are considered to be more accurate than the flow rates measured daily by Brown & Root Environmental.

The radius of influence (R_I) is defined as the distance from the extraction wells to the 0.5" H_2O subsurface pressure contour. R_I for these calculations was estimated based on the contours in the heated area.

Screened length for all extraction wells is 9 feet.

PERMEABILITY CALCULATIONS

CALCULATIONS:

Equation used for calculations (from Reference 1):

$$k = \frac{Q\,\mu\left[\ln\left(R_w / R_I\right)\right]}{H\,\pi P_w\left[1 - \left(P_{ATM} / P_W\right)^2\right]}$$

where:

k = vapor permeability
Q = vapor flow rate (ASCFM)
μ = viscosity (lb·s/ft^2)
R_W = well radius (ft.)
R_I = radius of influence (ft.)
H = total screen length (ft.)
P_W = pressure at well (lb/ft^2)
P_{ATM} = atmospheric pressure (lb/ft^2)

Example Calculation (Data for 5/6/94):

Convert Barometric Pressure to **P_{ATM}** in lb/ft^2:

$$P_{ATM} = 29.3\,\mathrm{in}_{Hg}\left(\frac{14.696\ \mathrm{lb}/\mathrm{in}^2}{29.921\ \mathrm{in}_{Hg}}\right)\left(\frac{12\,\mathrm{in}}{1\mathrm{ft}}\right)^2$$

P_{ATM} = 2072

Convert Differential Pressure, V, at Well To Absolute Pressure, **P_W**, in lb/ft^2:

$$P_W = P_{ATM} + V\left(\frac{14.696\ lb/in^2}{406.8\,in_{H_2O}}\right)\left(\frac{12\,in}{1ft}\right)^2$$

$$P_w = 2072 + \left(-38.5\,in_{H_2O}\right)\left(\frac{14.696\ lb/in^2}{406.8\,in_{H_2O}}\right)\left(\frac{12\,in}{1ft}\right)^2$$

P_W = 1872

Total Screen Length , **H**,:

H = (# of wells)(9ft)
H = (3)(9)

H = 27

PERMEABILITY CALCULATIONS

Input data into Equation:

$$k = \frac{Q \mu \left[\ln \left(R_w / R_I\right)\right]}{H \pi P_w \left[1 - \left(P_{ATM} / P_W\right)^2\right]}$$

$$k = \frac{(31.7\ ASCFM)(4.6 \times 10^{-7}\ lb \cdot s / ft^2)\left[\ln\left(0.167\ ft / 9\ ft\right)\right]}{(27\ ft)\pi\left(1872\ lb/ft^2\right)\left[1 - \left(2072\ lb/ft^2 \big/ 1872\ lb/ft^2\right)^2\right]}\left(\frac{1\ min}{60\ s}\right)$$

k = 2.7E-11 ft^2

Convert Vapor Permeability, k in ft^2 to cm^2:

$$K = k\left(\frac{9.29 \times 10^2\ cm^2}{ft^2}\right)$$

$$K = 9.7 \times 10^{-11}\left(\frac{9.29 \times 10^2\ cm^2}{ft^2}\right)$$

k = 2.5E-08 cm^2

Convert Vapor Permeability, k in ft^2 to darcy:

$$K = k\left(\frac{9.42 \times 10^{10}\ cm^2}{ft^2}\right)$$

$$K = 9.7 \times 10^{-11}\left(\frac{9.42 \times 10^{10}\ cm^2}{ft^2}\right)$$

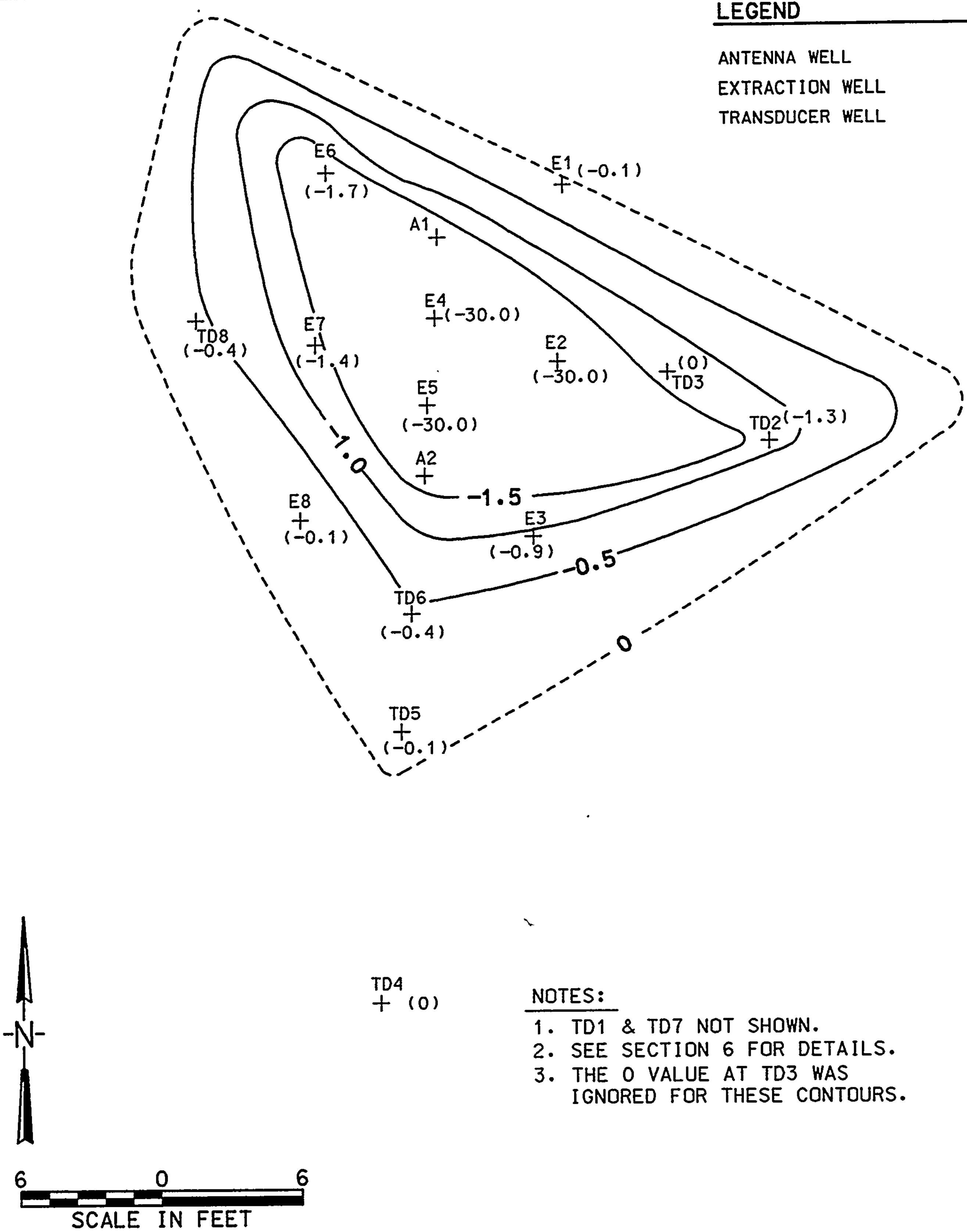
K = 2.6 darcy

Spreadsheet Calculation for Other Dates:

Data from Demonstration	4/8/94	5/6/94	5/31/94	6/7/94	6/14/94	6/24/94
Flow Rate, **Q**, (ASCFM)	54.0	31.7	71.4	66.2	75.7	47.5
Number of Wells	2	3	2	2	2	3
Well Radius, **R$_W$**, (ft.)	0.167	0.167	0.167	0.167	0.167	0.167
Total Screen Length, **H**, (ft.)	18	27	18	18	18	27
Differential Pressure at Wells, V, (in. H_2O)	-40	-38.5	-7.5	-6.0	-8.0	-6.33
Absolute Pressure at Wells, **P$_W$**, (lb/ft^2)	1864	1872	2026	2020	2024	2025
Barometric Pressure (In. Hg)	29.3	29.3	29.2	29.0	29.2	29.1
Atmospheric Pressure, **P$_{ATM}$**, (lb/ft2)	2072	2072	2065	2051	2065	2058
Radius of Influence, **R$_I$** (ft.)	7	9	10	9	12	8
Vapor Temperature (°F)	105	126	157	157	100	116
Estimated Vapor Viscosity, **μ** (lb·s/ft^2)	4.4E-07	4.6E-07	4.8E-07	4.8E-07	4.4E-07	4.5E-07
Estimated Vapor Permeability, **k**, (ft^2)	6.4E-11	2.7E-11	5.1E-10	5.9E-10	4.7E-10	2.5E-10
Estimated Vapor Permeability, **k**, (cm^2)	5.9E-08	2.5E-08	4.7E-07	5.5E-07	4.3E-07	2.3E-07
Estimated Vapor Permeability, **k**, (darcy)	6.0	2.6	48.2	55.9	43.8	23.7

LEGEND

ANTENNA WELL	A
EXTRACTION WELL	E
TRANSDUCER WELL	TD



NOTES:

1. TD1 & TD7 NOT SHOWN.
2. SEE SECTION 6 FOR DETAILS.
3. THE 0 VALUE AT TD3 WAS IGNORED FOR THESE CONTOURS.

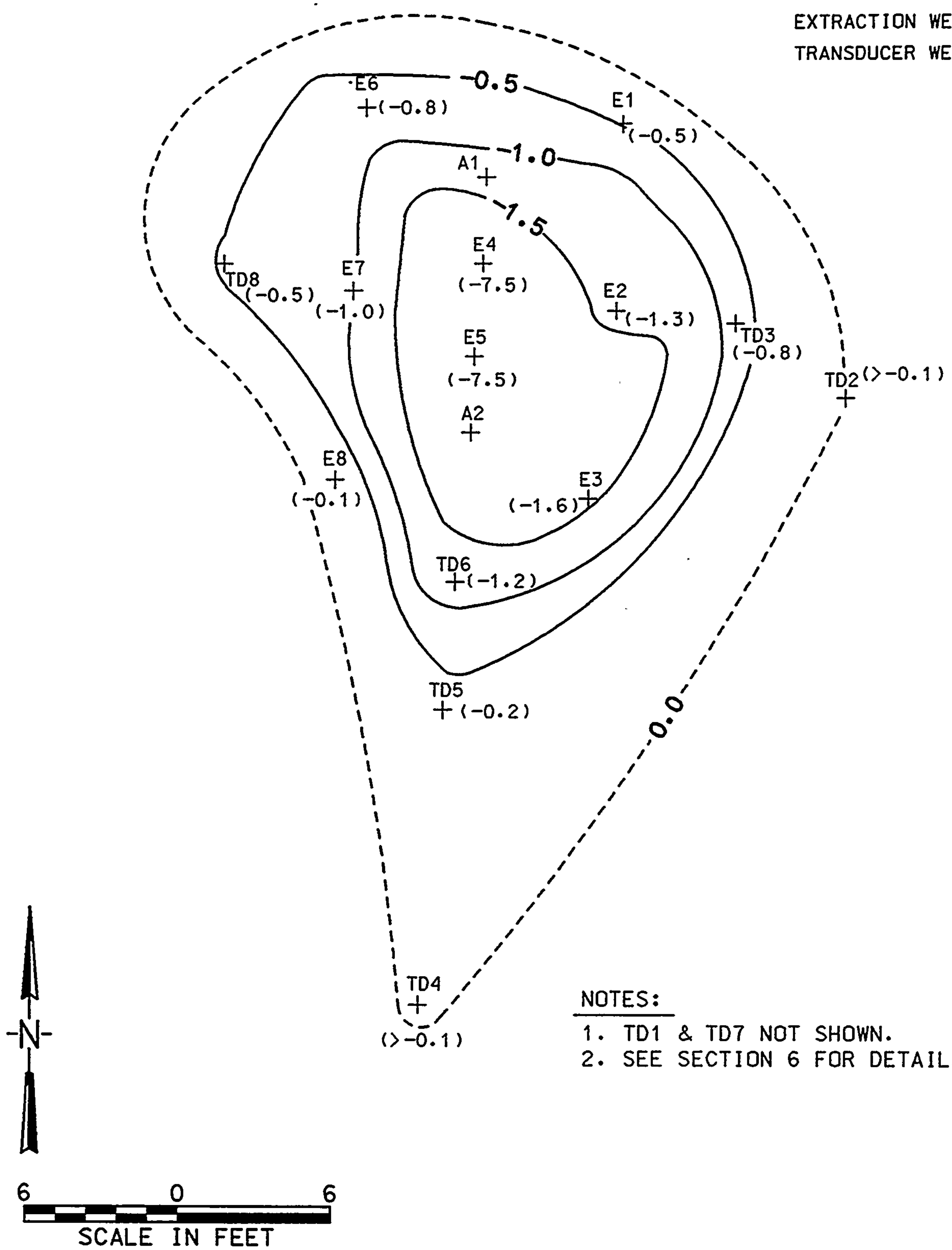
DRAWN	
CHECKED	
GEOLOGIST	
ENGINEER	
DISC. MAN.	
PROJ. MAN.	

TITLE
SUBSURFACE PRESSURES FOR
MAY 6, 1994
KAI DEMONSTRATION
RADIO FREQUENCY HEATING
DECONTAMINATION DEMONSTRATION
SITE S-1
KELLY AIR FORCE BASE, TEXAS

SCALE	AS SHOWN	DATE	12-6-94
DRAWING NO.	3688G016	REV. 0	SHEET 1 OF 1

LEGEND

ANTENNA WELL	A
EXTRACTION WELL	E
TRANSDUCER WELL	TD



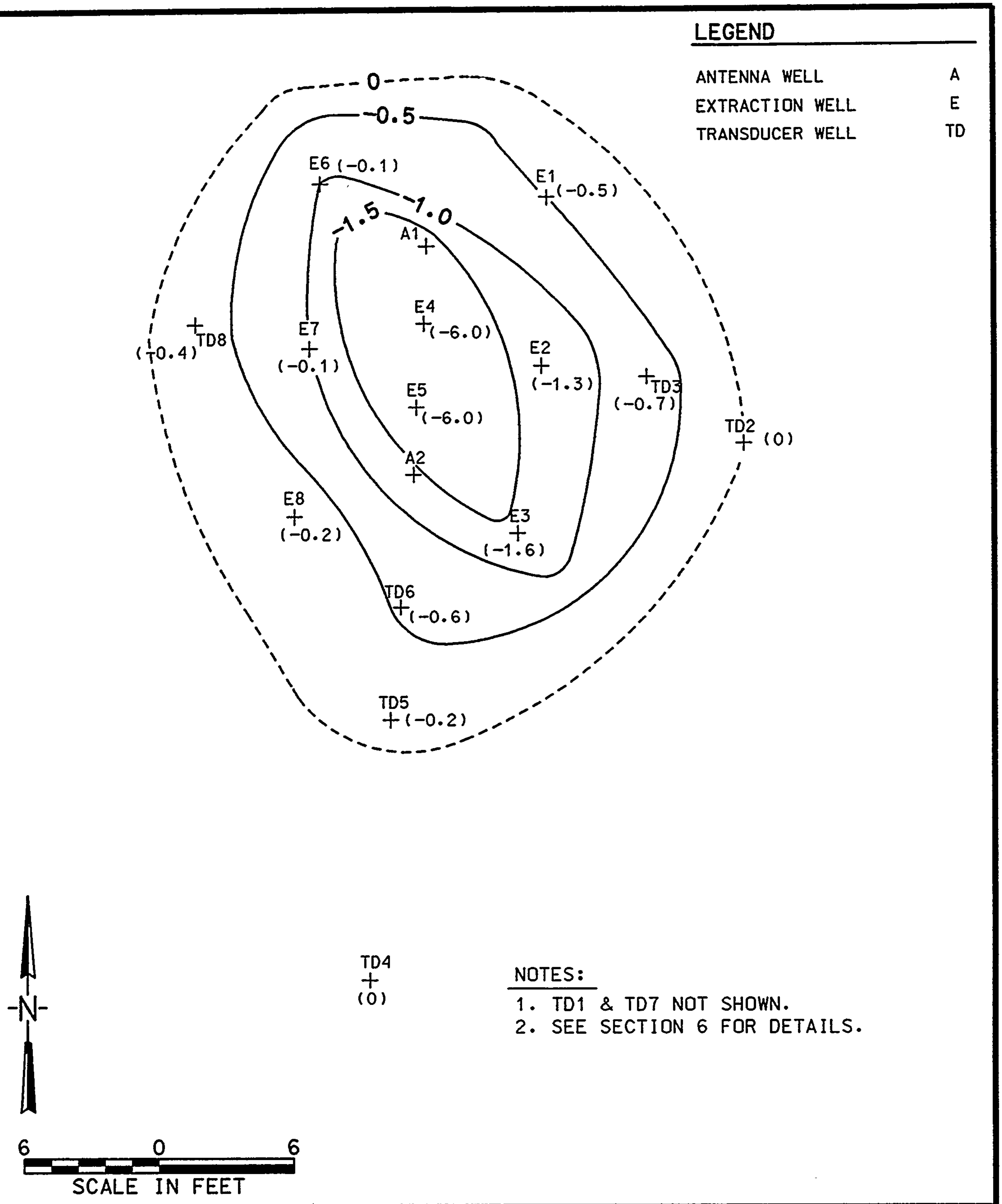
NOTES:

1. TD1 & TD7 NOT SHOWN.
2. SEE SECTION 6 FOR DETAILS.

DRAWN	
CHECKED	
GEOLOGIST	
ENGINEER	
DISC. MAN.	
PROJ. MAN.	

TITLE
SUBSURFACE PRESSURES FOR
MAY 31, 1994
KAI DEMONSTRATION
RADIO FREQUENCY HEATING
DECONTAMINATION DEMONSTRATION
SITE S-1
KELLY AIR FORCE BASE, TEXAS

SCALE AS SHOWN
DATE 12-6-94
DRAWING NO. 3688G016
REV. 0
SHEET 1 OF 1



LEGEND

ANTENNA WELL	A
EXTRACTION WELL	E
TRANSDUCER WELL	TD

NOTES:
1. TD1 & TD7 NOT SHOWN.
2. SEE SECTION 6 FOR DETAILS.

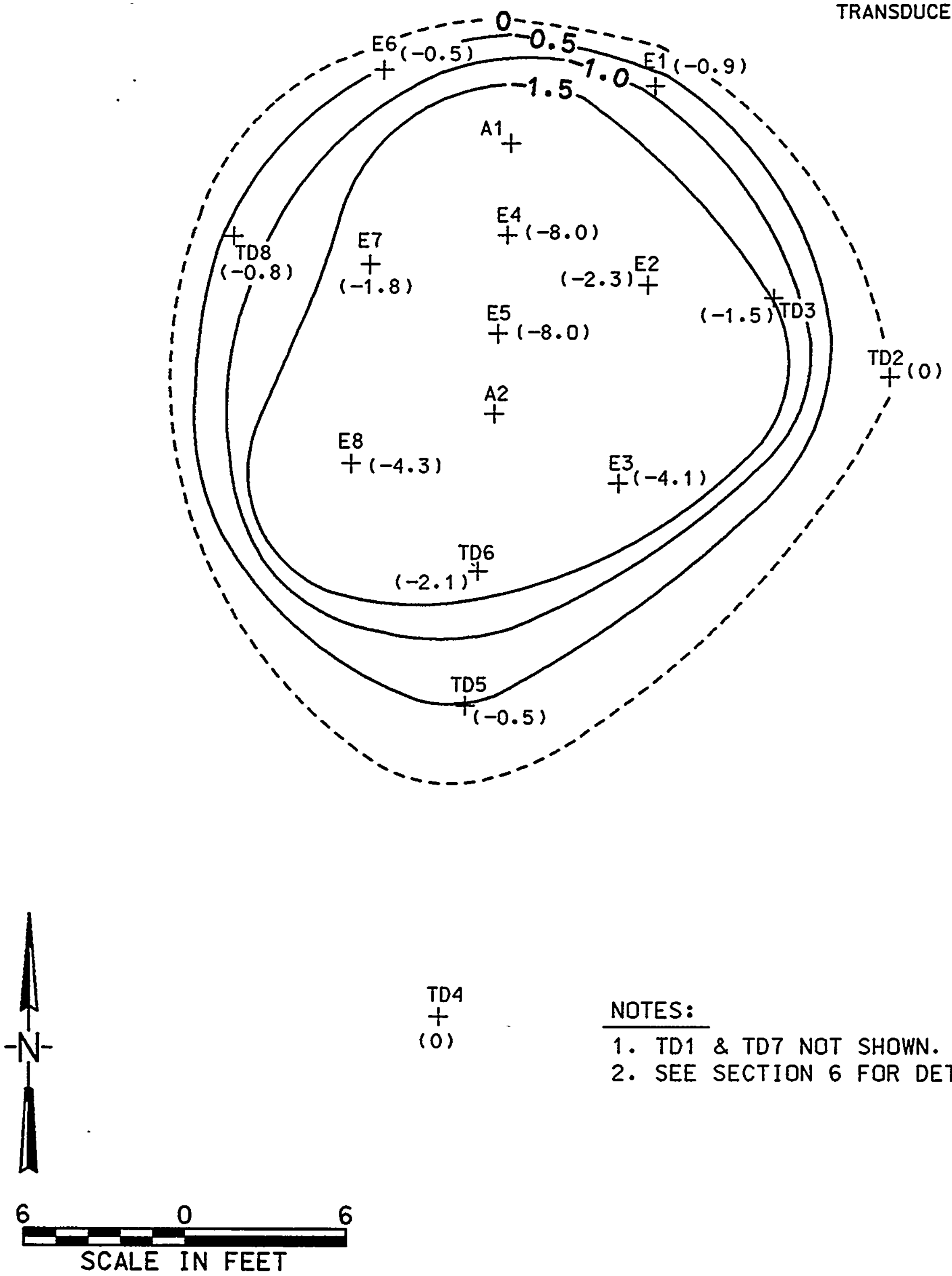
DRAWN
CHECKED
GEOLOGIST
ENGINEER
DISC. MAN.
PROJ. MAN.

TITLE
SUBSURFACE PRESSURES FOR
JUNE 7, 1994
KAI DEMONSTRATION
RADIO FREQUENCY HEATING
DECONTAMINATION DEMONSTRATION
SITE S-1
KELLY AIR FORCE BASE, TEXAS

SCALE AS SHOWN
DATE 12-6-94
DRAWING NO. 3688G016
REV. 0
SHEET 1 OF 1

LEGEND

ANTENNA WELL	A
EXTRACTION WELL	E
TRANSDUCER WELL	TD



NOTES:

1. TD1 & TD7 NOT SHOWN.
2. SEE SECTION 6 FOR DETAILS.

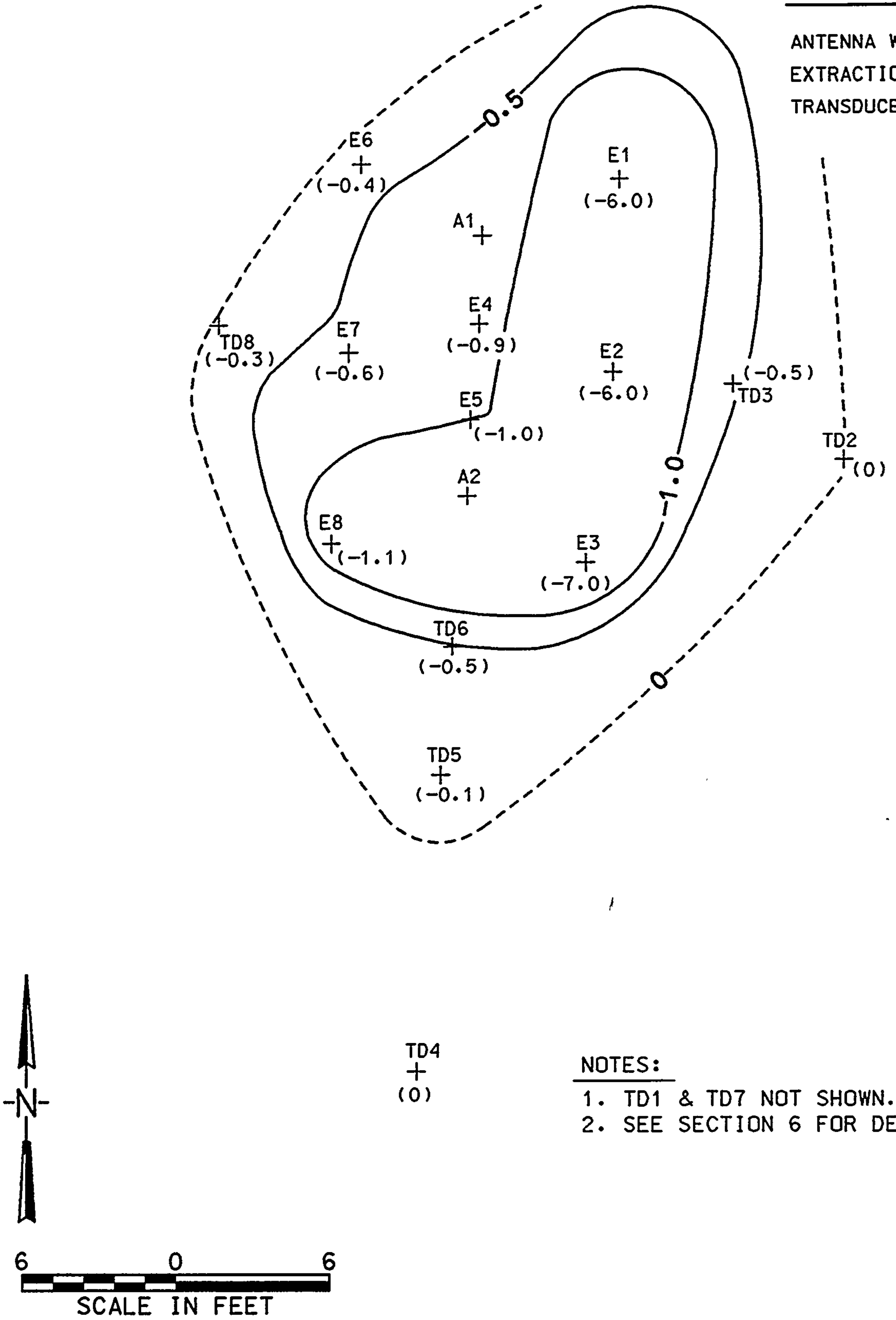
DRAWN
CHECKED
GEOLOGIST
ENGINEER
DISC. MAN.
PROJ. MAN.

TITLE
SUBSURFACE PRESSURES FOR
JUNE 14, 1994
KAI DEMONSTRATION
RADIO FREQUENCY HEATING
DECONTAMINATION DEMONSTRATION
SITE S-1
KELLY AIR FORCE BASE, TEXAS

SCALE	AS SHOWN	DATE	12-6-94
DRAWING NO.	3688G016	REV. 0	SHEET 1 OF 1

LEGEND

ANTENNA WELL	A
EXTRACTION WELL	E
TRANSDUCER WELL	TD



NOTES:
1. TD1 & TD7 NOT SHOWN.
2. SEE SECTION 6 FOR DETAILS.

DRAWN	
CHECKED	
GEOLOGIST	
ENGINEER	
DISC. MAN.	
PROJ. MAN.	

TITLE
SUBSURFACE PRESSURES FOR JUNE 24, 1994 KAI DEMONSTRATION
RADIO FREQUENCY HEATING
DECONTAMINATION DEMONSTRATION
SITE S-1
KELLY AIR FORCE BASE, TEXAS

SCALE	AS SHOWN	DATE	12-6-94
DRAWING NO.	3688G016	REV. 0	SHEET 1 OF 1

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extraction System

Date	4/22/94	4/23/94	4/23/94	4/24/94	4/24/94	4/24/94	4/25/94	4/25/94	4/25/94	4/26/94	4/26/94	4/26/94
Time	14:41	14:02	9:23	8:12	14:00	20:04	8:00	13:24	18:35	8:03	12:54	16:50
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	-1.0	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0	-0.5	-0.5	-1.0	-1.0
E2	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E3	-2.0	-1.0	-1.0	-1.0	-2.0	-1.5	-1.5	-2.0	-1.0	-1.5	-1.0	-1.0
E4	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E5	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E6	-3.0	-1.5	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
E7	-2.5	-1.5	-1.5	-2.5	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-1.5
E8	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	0.0	0.0	0.0
HE	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD2	-2.0	-1.0	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
TD3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD5	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD6	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-0.5	-1.0	-1.0
TD7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD8	-1.5	-0.5	-0.5	-1.0	-1.0	-0.5	-1.0	-1.0	-0.5	-0.5	-0.5	-0.5
Suction	-40.0	-42.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0
Discharge	41.0	45.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	41.0	41.0
Compressor	664.3	442.9	442.9	470.6	470.6	470.6	442.9	442.9	442.9	442.9	442.9	442.9
Flare	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	50	40	40	40	40	40	40	40	40	40	40	40
Flare	60	60	50	60	60	60	60	60	60	60	60	60

Radio Frequency System

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	-	-	-	-	-	-	17.2	17.1	-	17.0	17.2	17.4
A2	-	-	-	-	-	-	95.1	95	-	95.0	113.5	95.7

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	30.6	27.8	23.4	19.4	27.1	26.8	22.1	26.0	30.0	23.0	31.0	33.0
E1	30.1	-	-	18.9	-	24.1	21.1	25.3	28.3	21.3	36.0	-
E2	29.3	29.1	22.3	21.8	28.1	26.5	22.8	25.6	28.5	23.2	31.1	31.5
E3	30.7	-	-	19.4	29.2	25.1	21.4	26.3	29.0	22.7	34.1	-
E4	29.4	27.9	21.9	21.7	27.3	26.8	22.9	25.7	29.0	23.3	32.3	32.8
E5	31.5	29.3	23.3	24.2	27.9	28.2	26.3	35.5	48.5	50.8	56.7	52.5
E6	31.7	-	-	19.5	-	24.3	21.8	23.7	25.7	21.7	-	-
E7	31.3	-	-	19.5	-	24.3	21.6	24.0	26.5	22.0	-	-
E8	31.4	-	-	19.7	-	25.0	21.9	25.1	28.3	23.1	-	-
HE	25.8	-	-	19.9	24.7	23.3	21.3	24.4	26.3	23.0	-	-
E1,2,&3	33.8	28.9	23.3	20.8	-	25.3	22.1	26.5	31.1	23.7	36.3	33.8
E4&5	31.9	27.9	22.1	21.6	-	25.2	23.1	27.0	32.7	31.4	39.3	38.0
E6,7, &8	33.4	-	-	19.1	-	25.6	21.6	26.1	29.7	23.1	-	-
Christmas Tree	36.1	28.3	23.3	18.9	27.8	28.9	22.2	26.7	33.9	23.3	32.2	37.8
Mixed Vapor	37.2	32.8	23.3	18.9	30.0	26.1	21.1	26.7	32.8	21.7	34.4	35.6

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	4/27/94	4/27/94	4/27/94	4/28/94	4/28/94	4/29/94	4/29/94	4/30/94	5/1/94	5/2/94	5/2/94	5/3/94
Time	8:18	13:29	17:12	7:57	15:52	11:20	17:34	18:44	10:52	12:17	19:10	14:00
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	-0.5	-0.7	-0.6	-0.5	0.0	0.0	-0.5	-0.7	-0.4	-0.3	-0.3	-0.4
E2	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E3	-1.0	-1.8	-1.4	-1.3	-1.3	-2.1	-1.3	-2.0	-1.3	-1.3	-0.9	-0.9
E4	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E5	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E6	-2.0	-2.3	-2.2	-2.0	-1.5	-2.3	-1.6	-2.3	-1.4	-1.5	-1.3	-1.5
E7	-1.0	0.0	-2.3	-2.0	-2.3	-2.7	0.0	-2.5	-1.8	-1.7	-1.3	-1.4
E8	0.0	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
HE	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	+	0.0	0.0	0.0	-0.1
TD1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+	0.0
TD2	-1.0	-1.7	-1.4	-0.1	-1.3	-2.7	-1.2	-1.7	-1.2	-1.0	-0.9	-1.0
TD3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD5	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1
TD6	-0.5	-1.0	-0.7	-0.7	-0.9	-1.1	-0.9	-1.3	-0.9	-0.8	-0.6	-0.5
TD7	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3
TD8	-0.5	-0.7	-0.6	-0.5	-0.5	-0.5	-0.4	-0.6	-0.4	-0.3	-0.3	0.0
Suction	-43.0	-41.0	-40.0	-41.0	-46.0	-46.0	-39.0	-38.0	-39.0	-45.0	-33.0	-40.0
Discharge	45.0	43.0	43.0	43.0	48.0	48.0	38.0	39.0	41.0	48.0	35.0	43.0
Compressor	498.3	498.3	498.3	470.6	498.3	498.3	415.2	415.2	415.2	415.2	276.8	415.2
Flare	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	11.1	11.1	11.1	11.1

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	40	40	40	40	40	40	40	40	40	40	40	40
Flare	60	60	60	60	60	60	60	60	60	60	60	60

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	17.1	17.1	17.3	17.1	17.2	17.5	17.5	17.7	17.5	18.0	18.1	18.2
A2	114.0	105.6	109.4	102.8	107.0	104.6	96.5	72.4	69.4	99.5	95.1	104.4

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	24.0	29.0	30.0	24.0	25.0	23.0	21.0	18.0	14.0	21.0	21.0	28.0
E1	-	27.5	-	-	-	-	-	-	-	-	-	-
E2	24.1	28.1	29.0	23.4	24.0	26.4	29.0	23.6	20.1	21.1	22.6	28.5
E3	-	28.6	-	-	-	29.8	-	-	-	-	-	-
E4	24.7	28.8	30.0	24.6	23.5	26.0	28.5	23.4	20.2	21.0	20.1	29.7
E5	56.7	51.6	58.3	56.5	56.4	64.6	62.1	37.2	36.8	62.3	40.7	92.1
E6	-	27.7	-	-	-	-	-	-	-	-	-	-
E7	-	28.6	-	-	-	-	-	-	-	-	-	-
E8	-	28.6	-	-	-	-	-	-	-	-	-	-
HE	-	-	-	-	-	-	-	-	-	-	-	-
E1,2,&3	24.8	30.8	30.5	24.6	25.0	27.8	29.7	20.1	18.0	21.0	21.4	33.8
E4&5	36.3	36.2	40.1	37.3	31.7	43.2	42.6	22.8	21.7	29.5	22.8	59.5
E6,7, &8	-	30.7	-	-	-	-	-	-	-	-	-	-
Christmas Tree	25.0	31.1	31.1	25.0	26.1	30.0	33.3	19.4	13.3	18.9	23.3	35.0
Mixed Vapor	23.3	15.6	30.0	22.8	26.7	26.7	32.2	18.3	13.3	19.4	21.1	31.1

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	5/3/94	5/4/94	5/4/94	5/5/94	5/5/94	5/6/94	5/6/94	5/7/94	5/7/94	5/8/94	5/8/94	5/9/94
Time	18:24	9:36	18:00	7:00	17:17	9:23	16:54	11:20	18:10	8:43	15:14	8:35
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	0.0	-0.4	-0.4	-0.4	-0.5	-0.3	-0.1	-0.4	-0.5	-0.5	-0.5	-0.4
E2	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E3	0.1	-0.7	-0.7	-0.8	-0.9	-0.7	-0.9	-1.0	-1.3	-1.5	-1.7	-1.0
E4	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E5	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E6	-1.6	-1.3	-1.3	-1.3	-1.7	-1.2	-1.7	-1.4	-1.7	-1.6	-1.9	-1.5
E7	-1.4	-1.3	-1.3	-1.3	-1.5	-1.1	-1.4	-1.4	-1.7	-1.6	-1.9	-1.5
E8	-0.1	0.0	-0.1	-0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0
HE	0.0	0.0	-0.1	0.0	-0.1	-0.1	0.0	-0.1	-0.2	-0.2	-0.3	-0.2
TD1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD2	-0.1	-1.0	-1.0	-0.9	-1.3	-0.9	-1.3	-1.0	-1.2	-0.1	0.0	0.0
TD3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0
TD4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD5	0.0	-0.1	-0.1	-0.1	0.0	-0.2	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2
TD6	-0.5	-0.3	-0.4	-0.3	-0.5	-0.3	-0.4	-0.5	-0.8	-0.9	-1.1	-0.6
TD7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD8	-0.3	-0.2	-0.3	-0.3	-0.4	-0.3	-0.4	-0.3	-0.5	-0.5	-0.6	-0.4
Suction	-40.0	-38.0	-42.0	-38.0	-39.0	-38.0	-39.0	-36.0	-38.0	-36.0	-34.0	-34.0
Discharge	42.0	40.0	39.0	40.0	37.0	37.0	41.0	39.0	40.0	38.0	36.0	36.0
Compressor	415.2	415.2	442.9	415.2	442.9	415.2	442.9	415.2	442.9	387.5	415.2	415.2
Flare	11.1	11.1	11.1	11.1	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	40	40	40	40	40	40	40	40	40	40	40	40
Flare	60	60	60	60	60	60	60	60	60	60	60	60

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	18.3	18.6	18.8	18.6	18.9	19.1	18.9	19.3	19.3	19.7	19.7	19.8
A2	115.4	134.9	97.5	110.2	128.1	124.4	134.5	99.7	95.4	94.0	89.7	125.9

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	23.0	18.0	24.0	20.0	27.0	23.0	28.0	27.0	32.0	25.0	30.0	24.0
E1	-	-	-	-	-	-	-	-	-	-	-	-
E2	23.7	21.3	27.0	25.1	29.5	29.9	33.0	33.1	33.7	32.5	35.7	31.2
E3	-	-	-	-	-	-	-	-	-	-	-	-
E4	18.1	22.1	28.1	25.3	31.6	30.1	35.3	34.2	37.4	34.3	40.5	33.5
E5	90.6	93.5	86.3	91.2	85.6	82.6	85.5	77.2	72.3	64.3	63.5	89.5
E6	-	-	-	-	-	-	-	-	-	-	-	-
E7	-	-	-	-	-	-	-	-	-	-	-	-
E8	-	-	-	-	-	-	-	-	-	-	-	-
HE	-	-	-	-	-	-	-	-	-	-	-	-
E1,2,&3	26.7	22.6	27.8	24.6	30.7	29.8	33.7	33.7	34.3	31.5	36.6	30.9
E4&5	57.6	63.0	59.6	65.4	64.8	64.7	70.4	65.2	62.2	53.1	54.8	77.9
E6,7, &8	-	-	-	-	-	-	-	-	-	-	-	-
Christmas Tree	28.3	20.6	35.6	29.4	36.1	38.9	47.2	46.1	46.7	37.8	43.3	56.7
Mixed Vapor	23.3	15.6	26.1	18.9	40.6	23.9	34.4	32.2	35.0	27.2	35.0	35.0

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	5/9/94	5/10/94	5/10/94	5/11/94	5/11/94	5/12/94	5/12/94	5/13/94	5/13/94	5/14/94	5/14/94	5/15/94
Time	17:40	8:35	16:25	10:04	17:11	7:41	16:45	7:33	18:08	7:56	18:17	10:52
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.8	-0.7	-0.7	-0.1	-0.2	-0.1	-0.1
E2	-30.0	-30.0	-30.0	-30.0	-24.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E3	-30.0	-30.0	-30.0	-30.0	-24.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
E4	-30.0	-30.0	-30.0	-30.0	-24.0	-30.0	-30.0	-30.0	-0.5	-1.0	-0.5	-0.4
E5	-30.0	-30.0	-30.0	-30.0	-24.0	-30.0	-30.0	-30.0	-0.5	0.0	-0.5	+
E6	-1.8	-1.8	-1.9	-2.1	-1.7	-2.5	-2.5	-2.3	-0.5	-0.8	-0.5	-0.5
E7	-1.7	-1.7	-1.9	-2.2	-1.7	-2.5	-2.5	-2.4	-0.5	-0.6	-0.5	-0.3
E8	0.0	0.0	0.0	-0.1	0.0	-0.1	atm.	atm.	atm.	0.0	atm.	atm.
HE	-0.2	-0.1	-0.1	-0.3	-0.3	-0.7	-0.7	-0.8	+	0.0	0.0	+
TD1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD3	0.0	0.0	0.0	-0.3	-0.1	-0.2	0.0	-0.1	0.0	0.0	0.0	0.0
TD4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD5	-0.2	-0.2	-0.2	-0.3	-0.2	-0.3	-0.8	-0.3	-0.1	-0.1	0.0	-0.1
TD6	-0.9	-0.9	-1.0	-1.6	-1.0	-1.7	-1.7	-1.8	-0.4	-0.3	-0.1	0.0
TD7	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
TD8	-0.5	-0.5	-0.5	-0.8	-0.5	-1.0	-1.0	-0.9	-0.2	-0.2	0.0	0.0
Suction	-36.0	-36.0	-38.0	-37.0	-31.0	-40.0	-38.0	-34.0	-45.0	-45.0	-45.0	-45.0
Discharge	38.0	34.0	39.0	38.0	33.0	42.0	40.0	36.0	48.0	48.0	48.0	49.0
Compressor	470.6	498.3	525.9	609.0	470.6	1024.2	996.5	1190.3	387.5	387.5	387.5	387.5
Flare	13.8	16.6	13.8	16.6	13.8	19.4	19.4	19.4	13.8	11.1	11.1	11.1

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	40	45	45	45	45	40	50	60	40	40	40	45
Flare	60	65	65	65	65	80	85	85	60	60	60	60

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	19.9	20.1	20.3	20.5	20.6	21.0	20.9	21.3	21.4	22.1	21.8	22.5
A2	130.3	134.1	139.4	115.6	137.0	128.1	126.4	121.5	116.8	142.4	137.8	143.4

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	30.0	24.0	30.0	24.0	28.0	23.0	28.1	23.1	19.0	30.0	17.0	30.0
E1	-	-	-	-	-	-	-	-	-	-	-	-
E2	34.3	31.8	34.0	31.7	33.1	29.4	32.0	30.1	27.1	43.3	28.4	47.6
E3	34.3	26.3	34.3	27.4	30.7	25.2	33.7	25.8	24.6	30.6	20.3	29.6
E4	38.7	33.8	37.5	35.3	35.3	34.2	37.8	33.5	-	-	-	-
E5	88.3	88.5	88.5	72.7	84.2	75.5	77.3	76.8	-	-	-	-
E6	-	-	-	-	-	-	-	-	-	-	-	-
E7	-	-	-	-	-	-	-	-	-	-	-	-
E8	-	-	-	-	-	-	-	-	-	-	-	-
HE	-	-	-	-	-	-	-	-	-	-	-	-
E1,2,&3	35.0	30.1	35.6	31.1	32.7	29.0	32.1	29.0	23.7	36.9	21.8	36.0
E4&5	78.7	79.6	80.6	66.1	78.1	71.3	73.3	73.3	-	-	-	-
E6,7, &8	-	-	-	-	-	-	-	-	-	-	-	-
Christmas Tree	61.1	62.2	63.9	48.9	62.2	58.3	62.2	62.2	19.4	35.0	16.7	26.7
Mixed Vapor	44.4	42.2	46.1	32.2	44.4	40.6	46.1	45.6	18.3	37.8	18.3	35.0

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	5/15/94	5/16/94	5/16/94	5/17/94	5/17/94	5/18/94	5/18/94	5/19/94	5/19/94	5/20/94	5/20/94	5/21/94
Time	19:30	8:01	16:21	7:23	16:25	7:48	16:53	17:34	8:55	8:07	15:50	7:28
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	0.0	-0.1	-0.4	-0.3	-0.6	-0.6	-0.8	-1.1	-1.5	-0.4	-0.4	-0.4
E2	-30.0	-22.0	-30.0	-23.0	-30.0	23.0	-24.0	-30.0	-30.0	-12.0	-1.5	-1.8
E3	-30.0	-22.0	-30.0	-23.0	-30.0	-25.0	-24.0	-30.0	-30.0	-9.0	-1.6	-1.8
E4	-0.5	-0.5	-1.9	-1.4	-2.5	-2.6	-3.0	-4.2	-4.5	-1.8	-1.4	-1.5
E5	+	+	-30.0	-23.0	-30.0	-25.0	-21.0	-30.0	-30.0	-11.0	-11.0	-11.0
E6	-0.5	-0.4	-1.5	-1.2	-2.2	-2.0	-2.4	-3.1	-3.3	-1.2	-1.1	-1.1
E7	-0.5	-0.3	-1.7	-1.2	-2.3	-2.3	-2.6	-3.6	-3.8	-1.3	-1.3	-1.5
E8	0.0	atm.	atm.	atm.	atm.	atm.	atm.	atm.	atm.	atm.	atm.	atm.
HE	0.0	0.0	-0.2	-0.2	-0.4	-0.9	-1.3	-2.0	-2.1	-0.7	-0.8	-0.8
TD1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
TD5	0.0	0.0	-0.2	-0.2	-0.3	-0.3	-1.0	-1.1	-1.0	-0.3	-0.2	-0.4
TD6	-0.1	-0.1	-1.8	-1.2	-2.3	-2.3	-3.0	-3.9	-4.2	-1.4	-1.5	-1.8
TD7	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	0.0	-0.1	-0.1
TD8	0.0	0.0	-0.4	-0.3	-0.8	-1.0	-1.2	-1.7	-1.8	-0.6	-0.6	-0.5
Suction	-46.0	-38.0	-47.0	-28.0	-42.0	-34.0	-33.0	-42.0	-43.0	-24.0	-22.0	-20.0
Discharge	50.0	39.0	50.0	30.0	43.0	36.0	35.0	-46.0	48.0	26.0	23.0	23.0
Compressor	387.5	249.1	1439.4	553.6	1245.6	1245.6	1079.6	1910.0	2048.4	581.3	553.6	664.3
Flare	11.1	8.3	13.8	22.1	22.1	22.1	8.3	22.1	16.6	13.8	13.8	13.8

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	40	35	60	45	55	60	50	70	60	40	40	50
Flare	60	60	95	70	85	90	110	130	140	90	85	85

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	23.0	23.3	23.1	23.7	23.8	23.9	24.0	24.5	24.5	24.4	24.3	110.1
A2	145.2	143.7	126.6	120.1	124.6	110.5	106.8	115.6	121.0	201.5	223.5	179.2

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	26.0	22.0	25.0	22.0	32.0	23.0	33.0	20.0	32.0	21.0	32.0	19.0
E1	-	-	-	-	-	-	-	-	-	21.1	-	19.8
E2	56.0	60.7	54.2	42.6	44.2	37.6	38.8	34.2	34.7	32.6	30.8	19.8
E3	25.1	27.0	28.8	23.5	41.7	26.7	43.5	27.0	45.3	27.3	34.4	22.6
E4	-	-	-	-	-	-	-	-	-	23.5	35.8	24.5
E5	-	-	87.0	85.4	82.6	78.2	74.3	74.5	75.7	74.4	86.6	86.6
E6	-	-	-	-	-	-	-	-	-	-	-	-
E7	-	-	-	-	-	-	-	-	-	-	-	-
E8	-	-	-	-	-	-	-	-	-	-	-	-
HE	-	-	-	-	-	-	-	-	-	-	-	-
E1,2,&3	32.8	39.5	47.7	35.6	44.2	34.5	39.1	30.1	37.5	28.6	44.7	23.9
E4&5	-	-	-	86.8	82.5	77.3	71.1	70.5	70.3	73.5	73.2	68.6
E6,7, &8	-	-	-	-	-	-	-	-	-	-	-	-
Christmas Tree	29.4	21.1	80.0	77.8	74.4	70.0	63.9	62.8	62.8	64.4	65.6	58.9
Mixed Vapor	28.3	20.0	61.7	63.3	63.3	52.8	51.7	48.9	51.7	47.8	51.7	43.3

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	5/21/94	5/22/94	5/22/94	5/23/94	5/23/94	5/24/94	5/24/94	5/25/94	5/25/94	5/26/94	5/26/94	5/27/94
Time	18:03	8:56	17:43	8:30	18:41	9:13	16:44	9:54	16:14	8:06	17:52	
Well Number	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)	Pressure ("H2O)
E1	-0.4	-0.3	-17.0	-13.0	-0.3	-0.3	-0.2	-0.2	-0.3	-	-	
E2	-1.8	-1.3	-17.0	-13.0	-1.3	-1.1	-0.9	-0.9	-0.7	-	-	
E3	-1.8	-1.3	-18.0	-13.0	-2.5	-2.2	-2.0	-2.0	-1.6	-	-	
E4	-1.8	-1.1	-14.0	-13.0	-11.0	-10.0	-9.0	-9.0	-7.0	-12.0	-10.5	
E5	-12.0	-10.0	-14.0	-13.0	-11.0	-11.0	-8.5	-8.5	-6.5	-10.5	-10.0	
E6	-0.9	-0.6	atm.	-2.0	-0.7	-0.5	-0.7	-0.5	-0.3	-	-	
E7	-1.6	-1.4	atm.	-2.2	-1.5	-0.9	-1.4	-1.1	-0.9	-	-	
E8	atm.	atm.	atm.	-0.5	-0.3	-0.2	-0.3	-0.2	-0.2	-	-	
HE	-1.0	-0.9	1.5	-1.4	-1.2	-0.9	-0.9	-0.1	-0.7	-1.0	-0.9	
TD1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	
TD2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	> -0.1	0.0	0.0	> -0.1	
TD3	0.0	0.0	-1.0	-1.0	-0.7	-0.7	-0.6	-0.4	-0.5	-0.1	-0.7	
TD4	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	-0.1	
TD5	-0.4	-0.3	-0.7	-0.7	-0.6	-0.5	-0.3	-0.3	-0.2	> -0.1	-0.3	
TD6	-2.0	-1.7	-2.9	-2.7	-2.1	-2.4	-1.8	-1.7	-1.3	> -0.1	-1.2	
TD7	0.0	-0.1	-0.1	-0.1	0.0	-0.6	-	-0.1	-0.1	-0.3	> -0.1	
TD8	-0.7	-0.6	-1.3	-1.1	-0.8	0.0	-	-0.6	-0.4	-0.8	-0.6	
Suction	-20.0	-21.0	-26.0	-27.0	-23.0	-21.0	-21.0	-19.0	-16.0	-21.0	-20.0	
Discharge	23.0	22.0	34.0	-33.0	28.0	23.0	21.0	22.0	19.0	24.0	24.0	
Compressor	692.0	636.7	1439.4	1218.0	885.8	747.4	636.7	609.0	498.3	650.5	650.5	
Flare	13.8	13.8	16.6	13.8	16.6	16.6	13.8	16.6	13.8	13.8	13.8	

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	53	50	60	52	50	55	50	50	45	50	50	
Flare	85	85	125	120	90	85	95	90	95	85	95	

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	117.5	119.2	122.9	122.4	130.4	133.2	138.6	135.8	139.2	139.2	142.7	
A2	171.1	136.2	127.3	181.9	180.7	168.1	159.2	142.5	136.2	123.3	116.1	

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	29.0	24.0	29.0	22.0	29.1	30.6	33.3	32.0	32.0	26.0	33.3	
E1	30.9	25.0	29.6	26.8	-	-	-	-	-	-	-	
E2	30.3	31.1	58.0	58.6	-	31.4	-	-	-	-	-	
E3	30.8	31.8	40.0	29.3	-	-	-	-	-	-	-	
E4	36.9	25.6	69.0	70.7	83.1	88.2	89.9	91.6	91.5	92.5	93.5	
E5	89.6	78.0	79.3	70.1	70.3	65.2	64.8	59.8	58.7	58.5	59.1	
E6	-	-	-	-	-	-	-	-	-	-	-	
E7	-	-	-	-	-	-	-	-	-	-	-	
E8	-	-	-	-	-	-	-	-	-	-	-	
HE	-	-	-	-	-	30.0	-	-	-	-	-	
E1,2,&3	34.0	28.7	35.0	30.3	-	-	-	-	-	-	-	
E4&5	72.8	64.8	67.3	58.8	62.7	64.6	63.4	63.2	62.5	64.8	65.9	
E6,7, &8	-	-	-	-	-	-	-	-	-	-	-	
Christmas Tree	57.8	56.7	56.7	44.4	57.2	56.7	58.9	57.8	58.3	58.3	61.1	
Mixed Vapor	45.0	43.3	43.3	37.2	45.0	46.1	46.7	46.1	46.1	42.8	46.1	

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	5/27/94	5/28/94	5/28/94	5/29/94	5/29/94	5/30/94	5/30/94	5/31/94	6/1/94	6/1/94	6/2/94	6/3/94
Time	16:45	8:41	18:25	10:10	17:22	8:55	19:14	17:28	10:18	19:37		10:05
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	-0.3	-0.4	-0.4	-0.5	-0.4	-0.4	-0.4	-0.5	-0.5	-0.5		-0.6
E2	-0.9	-1.0	-1.0	-1.0	-1.0	-1.0	-1.2	-1.3	-1.3	-1.3		-1.4
E3	-2.1	-1.9	-2.1	-2.3	-2.6	-2.1	-2.0	-1.6	-1.5	-1.5		-1.4
E4	-9.0	-9.0	-9.0	-8.5	-9.0	-8.0	-8.5	-7.5	-7.0	-7.0		-6.5
E5	-0.8	-9.5	-0.6	-11.5	-9.0	-7.5	-8.0	-7.5	-7.0	-7.2		-6.5
E6	-0.4	-0.6	-0.5	-0.8	-0.6	-0.6	-0.7	-0.8	-0.9	-1.1		-1.0
E7	-1.1	-1.3	-1.2	-1.2	-1.1	-1.0	-1.2	-1.0	-1.0	-1.1		-1.0
E8	-0.2	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2		-0.2
HE	-8.5	-0.9	-1.1	-1.1	-0.7	-0.7	-0.7	-0.7	-0.6	-0.8		-0.6
TD1	0.0	> -0.1	0.0	> -0.1	0.0	>-0.1	0.0	0.0	0.0	>-0.1		0.0
TD2	0.0	> -0.1	0.0	> -0.1	0.0	>-0.1	0.0	>-0.1	>-0.1	>-0.1		0.0
TD3	-0.7	-0.8	-0.6	-0.7	-0.6	-0.7	-0.6	-0.8	-1.0	-0.7		-0.7
TD4	-0.1	> -0.1	0.0	> -0.1	0.0	>-0.1	0.0	>-0.1	0.0	0.0		0.0
TD5	-0.4	-0.3	-0.4	-0.4	-0.4	-0.4	-0.5	-0.2	-0.1	-0.2		-0.2
TD6	-1.9	-1.6	-1.6	-1.7	-1.6	-1.6	-1.6	-1.2	-0.3	-1.1		-0.9
TD7	> -0.1	-0.1	> -0.1	> -0.1	> -0.1	> -0.1	> -0.1	-0.1	-0.7	-0.2		-0.1
TD8	-0.5	-0.6	-0.5	-0.6	-0.6	-0.2	> -0.1	-0.5	-0.5	-0.8		-0.8
Suction	-18.0	-25.0	-25.0	-19.0	-18.0	-18.0	-24.0	-17.0	-24.0	-16.0		-17.0
Discharge	24.0	28.0	28.0	22.0	21.0	22.0	28.0	28.0	28.5	20.0		22.0
Compressor	719.7	692.0	719.7	3460.1	3487.8	3460.1	719.7	719.7	636.7	3487.8		3543.2
Flare	16.6	16.6	16.6	13.8	13.8	16.6	16.6	16.6	13.8	16.6		16.6

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	45	50	50	52	50	50	45	50	50	45		45
Flare	90	90	85	90	95	95	95	95	95	115		95

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1		143.4	147.1	142.3	146.3	144.3	143.4	148.2	135.5	129.1		
A2		95.7	92.3	87.6	85.6	81.6	88.3	108.9	107.1	86.4		

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	-	26.0	24.0	27.0	36.0	26.0	35.0	36.0	31.0	31.0		
E1	-	-	-	-	-	-	-	-	-	-		-
E2	-	-	-	-	-	-	-	-	-	-		-
E3	-	-	-	-	-	-	-	-	-	-		-
E4	92.5	92.3	90.6	89.3	89.5	90.6	80.8	67.8	62.5	65.0		58.6
E5	93.3	57.2	57.7	56.2	57.1	55.6	62.7	65.3	67.5	65.6		66.3
E6	-	-	-	-	-	-	-	-	-	-		-
E7	-	-	-	-	-	-	-	-	-	-		-
E8	-	-	-	-	-	-	-	-	-	-		-
HE	-	-	-	-	-	-	-	-	-	-		-
E1,2,&3	-	-	-	-	-	-	-	-	-	-		-
E4&5	26.0	65.3	66.4	66.7	66.7	67.5	65.9	68.8	68.8	65.0		66.3
E6,7, &8	-	-	-	-	-	-	-	-	-	-		-
Christmas Tree	60.0	60.0	61.7	61.7	63.3	62.2	63.9	65.6	64.4	60.0		63.3
Mixed Vapor	47.8	46.1	47.8	47.8	48.9	48.9	46.1	51.7	51.7	46.1		48.9

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	6/3/94	6/4/94	6/4/94	6/5/94	6/5/94	6/6/94	6/6/94	6/7/94	6/7/94	6/8/94	6/8/94	6/9/94
Time	16:20	08:52	20:58	9:05	17:55	9:10	18:10	9:22	16:54	10:08	17:58	9:19
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	-0.6	-0.6		-0.6	-0.6	-0.5	-0.5	-0.5	-0.6	-0.5	-0.5	-0.5
E2	-1.7	-1.5		-1.6	-1.4	-1.5	-1.5	-1.3	-1.5	-1.7	-1.4	-1.4
E3	-1.6	-1.4		-1.4	-1.5	-1.4	-1.4	-1.4	-1.5	-1.3	-1.4	-1.4
E4	-7.0	-6.5		-6.0	-6.0	-7.5	-6.0	-6.0	-6.0	-7.0	-6.0	-5.5
E5	-8.0	-6.5		-7.0	-6.0	-6.0	-6.0	-6.0	-6.5	-5.5	-6.0	-5.5
E6	-1.1	-1.1		-1.0	-1.0	-1.0	-1.0	-1.0	-1.1	-1.0	-1.1	-1.0
E7	-1.0	-1.2		-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
E8	-0.2	-0.2		-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3
HE	-0.6	-0.6		-0.7	-0.6	-0.5	-0.6	-0.5	-0.6	-0.5	-0.5	-0.5
TD1	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD2	>-0.1	>-0.1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0
TD3	-0.8	-1.0		-0.8	-0.9	-0.7	-1.0	-0.7	-0.5	-0.7	-0.6	-0.7
TD4	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD5	-0.1	>-0.1		-0.2	-0.2	-0.1	-0.1	-0.2	-0.2	-0.1	-0.2	-0.2
TD6	-0.9	-0.5		-0.6	-0.6	-0.6	-0.7	-0.6	-0.5	-0.4	-0.5	-0.7
TD7	-0.1	> -0.1		-0.1	-0.2	> -0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.1
TD8	-0.5	-0.7		-0.5	-0.6	-0.5	-0.5	-0.4	-0.5	-0.5	-0.5	>-0.1
Suction	-18.0	-20.0		-27.0	-17.0	-16.0	-17.0	-23.0	-17.0	-16.0	-16.0	-15.0
Discharge	22.0	26.0		21.0	21.0	20.0	21.0	27.0	21.0	20.0	-21.0	18.0
Compressor	3543.2	802.7		775.1	830.4	775.1	802.7	802.7	830.4	775.1	830.4	775.1
Flare	16.6	16.6		16.6	13.8	16.6	16.6	16.6	13.8	16.6	13.8	13.8

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	45	45		50	45	45	45	45	45	50	50	50
Flare	95	95		95	95	95	95	85	95	95	95	95

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	106.0	99.3		90.9	88.5	83.9	82.3	74.4	73.7	69.9	68.6	66.1
A2	116.6	115.9		123.5	130.3	135.5	135.4	117.2	113.7	107.0	110.9	103.6

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	33.0	25.0		26.0	35.0	30.0	35.0	31.0	37.0	32.0	37.0	29.0
E1	-	-		-	-	-	-	-	-	-	-	-
E2	-	-		-	-	-	-	-	-	-	-	-
E3	-	-		-	-	-	-	-	-	-	-	-
E4	57.7	55.0		52.5	54.1	51.2	51.7	49.4	50.5	50.0	50.2	48.0
E5	68.4	67.6		71.2	73.6	71.7	76.8	71.3	77.3	74.2	76.8	70.5
E6	-	-		-	-	-	-	-	-	-	-	-
E7	-	-		-	-	-	-	-	-	-	-	-
E8	-	-		-	-	-	-	-	-	-	-	-
HE	-	-		-	-	-	-	-	-	-	-	-
E1,2,&3	-	-		-	-	-	-	-	-	-	-	-
E4&5	61.3	65.1		67.7	68.1	66.7	66.9	64.9	67.2	66.7	66.6	66.2
E6,7, &8	-	-		-	-	-	-	-	-	-	-	-
Christmas Tree	62.8	62.8		69.4	65.6	65.6	62.8	62.8	63.9	62.8	62.8	62.8
Mixed Vapor	51.7	57.2		51.7	54.4	51.7	48.9	51.7	57.2	54.4	51.7	51.7

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	6/9/94	6/10/94	6/10/94	6/10/94	6/11/94	6/11/94	6/12/94	6/12/94	6/13/94	6/13/94	6/14/94	6/14/94
Time	17:52	17:57	10:54	17:57	9:01	17:23	8:37	21:29	8:00	19:22	9:10	17:49
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	-0.5	-0.6	-0.6		-0.5	-0.6	-1.0	-0.8	-0.8	-0.9	-0.9	-0.8
E2	-1.3	-1.8	-1.9		-1.6	-1.8	-2.6	-2.4	-2.3	-2.4	-2.3	-2.5
E3	-1.4	-3.2	-3.3		-3.0	-3.3	-4.7	-4.2	-4.1	-4.3	-4.1	-4.4
E4	-6.0	-6.0	-6.0	-49.0	-5.0	-6.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0
E5	-6.0	-6.0	-6.0	-72.1	-5.0	-6.0	-8.0	-8.0	-8.0	-8.0	-8.0	-8.0
E6	-1.0	-1.3	-1.3		-1.0	-1.1	-1.7	-1.6	-1.6	-1.6	-1.5	-1.7
E7	-1.0	-1.3	-1.3		-1.3	-1.2	-2.0	-1.8	-1.8	-1.9	-1.8	-2.1
E8	-0.4	-0.8	-0.5		-2.6	-3.0	-4.0	-4.4	-4.4	-4.5	-4.3	-4.6
HE	-0.5	-0.7	-0.7		-0.6	-0.7	-1.0	-0.9	-0.9	-0.9	-0.9	-0.7
TD1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD2	-0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD3	-0.6	-1.3	-1.5		-1.0	-1.2	-1.8	-1.8	-1.7	-2.2	-1.5	-2.1
TD4	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD5	-0.1	-0.4	-0.4		-0.3	-0.3	-0.4	-0.5	-0.7	-0.6	-0.6	-0.2
TD6	-0.6	-1.6	-1.3		-1.4	-1.3	-2.3	-2.2	-2.1	-2.3	-2.1	-2.7
TD7	-0.2	-0.2	-0.2		-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.2	-0.2
TD8	-0.4	-0.7	-0.7		-0.5	-0.6	-1.0	-0.9	-0.9	-0.9	-0.8	-1.0
Suction	-15.0	-16.0	-15.0		-16.0	-15.0	-19.0	-18.0	-19.0	-19.0	-18.0	-18.0
Discharge	20.0	19.0	19.0		20.0	19.0	25.0	24.0	24.0	24.0	24.0	24.0
Compressor	802.7	802.7	775.1		802.7	830.4	802.7	830.4	830.4	830.4	830.4	802.7
Flare	16.6	13.8	13.8		13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	45	50	50		50	50	50	50	50	55	50	55
Flare	95	90	90		90	90	95	90	105	105	105	100

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	64.9	59.6	60.4		60.0	58.8	60.0	58.6	57.5	56.6	54.7	54.2
A2	111.4	110.2	110.1		119.1	118.4	117.5	115.5	114.0	112.2	109.1	107.6

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	37.0	34.0	33.0		27.0	31.0	26.0	26.0	24.0	28.0	25.0	25.0
E1	-	-	-		-	-	-	-	-	-	-	-
E2	-	-	-		-	-	-	-	-	-	-	-
E3	-	-	-		-	-	-	-	-	-	-	-
E4	49.3	49.3	49.8		46.7	47.5	45.2	44.0	44.0	45.3	43.3	42.2
E5	75.2	73.9	73.1		63.3	63.9	61.6	59.0	57.3	58.4	54.1	51.8
E6	-	-	-		-	-	-	-	-	-	-	-
E7	-	-	-		-	-	-	-	-	-	-	-
E8	-	-	-		-	-	-	-	-	-	-	-
HE	-	-	-		-	-	-	-	-	-	-	-
E1,2,&3	-	-	-		-	-	-	-	-	-	-	-
E4&5	66.2	67.3	68.1		57.5	54.8	52.8	50.0	47.6	50.0	46.0	45.0
E6,7, &8	-	-	-		-	-	-	-	-	-	-	-
Christmas Tree	62.8	63.3	62.2		53.3	50.6	48.3	45.6	43.9	42.8	40.6	38.9
Mixed Vapor	54.4	51.7	51.7		40.6	40.6	40.6	37.8	35.0	36.7	33.3	29.4

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	6/15/94	6/15/94	6/16/94	6/16/94	6/17/94	6/17/94	6/18/94	6/18/94	6/19/94	6/19/94	6/20/94	6/20/94
Time	8:52	19:14	0:00	17:20	7:19	18:12	7:27	18:29	8:37	16:34	8:25	16:31
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	-8.0	-12.0	-7.0	-11.0	-7.0	-9.0	-6.0	-11.0	-5.0	-7.0	-6.0	-7.0
E2	-8.0	-12.0	-7.0	-12.0	-7.0	-10.0	-6.0	-12.0	-5.0	-7.0	-6.0	-7.0
E3	-8.0	-12.0	-7.0	-12.0	-7.0	-10.0	-6.0	-12.0	-7.0	-7.0	-6.0	-7.0
E4	-1.4	-2.2	-1.3	-1.8	-1.2	-1.4	-1.1	-1.6	-0.8	-0.9	-1.0	-0.9
E5	-1.5	-2.2	-1.4	-1.8	-1.2	-1.4	-1.1	-1.6	-1.0	-0.8	-1.0	-0.9
E6	-1.0	-2.0	-1.5	-1.7	-1.2	-1.4	-1.0	-1.6	-1.0	-0.9	-0.9	-1.0
E7	-1.0	-1.5	-1.3	-1.2	-0.8	-1.0	-0.7	-1.0	-0.7	-0.6	-0.7	-0.6
E8	-1.0	-2.6	0.0	-2.0	-1.4	-1.5	-1.3	-1.8	-1.3	-0.9	-1.0	-1.0
HE	-0.3	-0.5	0.0	-0.5	-0.3	-0.3	-0.2	0.4	-0.2	-0.2	-0.2	-0.2
TD1	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD3	-1.5	-1.7	-1.0	-1.3	-0.8	-1.0	-0.8	-1.2	-0.8	-0.7	-0.3	-0.6
TD4	0.0	0.0	>-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD5	-0.4	-0.5	-0.5	-0.4	-0.3	-0.3	-0.2	-0.3	-0.2	-0.4	0.0	0.1
TD6	-1.9	-1.6	-1.3	-1.5	-1.1	-1.0	-0.9	-1.3	-0.9	-0.6	-0.1	-0.5
TD7	-0.2	-0.2	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2	-0.1	-0.1	-0.2	-0.2
TD8	-0.7	-0.8	-0.6	-0.6	-0.4	-0.5	-0.3	-0.6	-0.4	-0.3	-0.3	-0.2
Suction	-17.0	-17.0	-16.0	-16.0	-15.0	-14.0	-13.0	-17.0	-9.0	-9.0	-12.0	-10.0
Discharge	21.0	23.0	24.0	21.0	19.0	18.0	17.0	22.0	12.0	13.0	16.0	13.0
Compressor	747.4	747.4	609.0	581.3	581.3	581.3	747.4	498.3	304.5	387.5	387.5	387.5
Flare	13.8	13.8	13.8	13.8	11.1	11.1	8.3	8.3	11.1	11.1	11.1	11.1

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	50	50	50	45	50	50	50	50	40	40	40	60
Flare	85	100	80	85	75	80	75	85	70	70	70	65

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	53.8	52.2	51.4	51.3	50.2	49.6	49.0	48.8	48.0	47.6	46.9	46.7
A2	101.5	99.9	96.1	93.7	89.8	87.6	84.6	83.3	80.6	79.5	77.1	76.6

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	26.0	25.0	25.0	32.0	24.0	35.0	25.0	35.0	27.0	26.0	27.0	34.0
E1	30.2	31.4	29.7	34.8	30.5	36.6	31.6	36.4	33.1	34.2	31.1	36.4
E2	39.7	39.8	39.3	42.7	38.4	42.4	38.7	41.8	38.7	39.9	37.8	41.4
E3	40.8	41.5	39.8	42.4	39.1	42.5	39.2	42.8	39.3	38.2	38.1	41.0
E4	33.5	36.0	33.8	43.6	36.1	43.2	31.8	46.1	34.5	36.0	29.6	-
E5	37.5	40.1	33.6	40.0	35.6	42.0	34.2	42.0	35.7	38.3	32.5	-
E6	-	-	-	-	-	-	-	-	-	-	-	-
E7	-	-	-	-	-	-	-	-	-	-	-	-
E8	-	-	-	-	-	-	-	-	-	-	-	-
HE	-	-	-	-	-	-	-	-	-	-	-	-
E1,2,&3	32.1	33.2	31.8	36.7	32.1	38.8	32.7	38.6	33.3	31.6	32.3	38.1
E4&5	-	-	-	-	-	-	-	-	-	-	-	-
E6,7, &8	-	-	-	-	-	-	-	-	-	-	-	-
Christmas Tree	31.1	25.6	30.0	36.1	30.0	38.3	30.0	38.3	30.6	29.4	30.6	34.4
Mixed Vapor	26.7	26.1	25.6	38.3	25.6	41.7	26.7	41.1	29.4	26.7	29.4	40.6

TABLE B.4.
OPERATING CONDITIONS
KAI DEMONSTRATION

Vapor Extracti

Date	6/21/94	6/21/94	6/22/94	6/22/94	6/23/94	6/23/94	6/24/94
Time	8:56	17:43	8:28	16:14	7:48	18:42	19:10
Well Number	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)	Pressure (" H2O)
E1	-6.0	-7.0	-6.0	-8.0	-7.0	-8.0	-6.0
E2	-7.0	-7.0	-6.0	-8.0	-7.0	-8.0	-6.0
E3	-7.0	-7.0	-6.0	-8.0	-7.0	-8.0	-7.0
E4	-0.8	-0.9	-0.9	-1.0	-0.9	-1.0	-0.9
E5	-0.7	-0.9	-0.9	-0.9	-0.8	-0.9	-1.0
E6	-0.8	-0.9	-0.8	-1.0	-0.9	-1.0	-0.4
E7	-0.5	-0.6	-0.6	-0.6	-0.5	-0.6	-0.6
E8	-0.8	-1.0	-1.1	-1.0	-0.9	-1.0	-1.1
HE	-0.1	-0.2	-0.1	-0.2	-0.2	-0.2	-0.1
TD1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD3	-0.5	-0.7	-0.5	-0.7	-0.6	-0.6	-0.5
TD4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TD5	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1
TD6	-0.4	-0.6	-0.5	-0.6	-0.6	-0.7	-0.5
TD7	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
TD8	-0.1	-0.2	-0.3	-0.3	-0.2	-0.3	-0.3
Suction	-11.0	-10.0	-12.0	-11.0	-12.0	-11.0	-12.0
Discharge	14.0	12.0	16.0	14.0	15.0	14.0	14.0
Compressor	387.5	387.5	387.5	387.5	387.5	415.2	387.5
Flare	11.1	11.1	11.1	11.1	11.1	11.1	11.1

Flow Rates

Flow Meter	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)	Flow Rate (SCFM)
Compressor	40	40	40	40	40	40	40
Flare	65	60	60	60	70	70	65

Radio Freque

Antenna	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
A1	46.1	45.9	45.4	45.4	44.9	44.8	44.3
A2	74.1	73.3	71.5	71.3	69.3	68.3	67.1

Temperatures

Location	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)	Temp. (C)
Ambient	28.0	33.5	27.6	34.0	25.4	*29.4*	*?*
E1	34.7	34.7	31.8	36.6	31.5	36.3	34.6
E2	40.8	39.8	37.6	40.5	37.0	39.5	39.5
E3	39.7	38.4	37.8	40.7	35.0	.9.3	38.6
E4	31.2	29.8	-	34.0	28.0	33.7	41.3
E5	32.0	32.1	-	35.4	-	33.8	33.9
E6	-	-	-	-	-	-	-
E7	-	-	-	-	-	-	-
E8	-	-	-	-	-	-	-
HE	-	-	-	-	-	-	-
E1,2,&3	33.4	36.1	32.3	37.1	30.8	35.4	35.2
E4&5	-	-	-	-	-	-	-
E6,7, &8	-	-	-	-	-	-	-
Christmas Tree	31.1	33.3	32.2	33.3	28.3	37.2	32.8
Mixed Vapor	32.2	40.0	32.2	40.6	26.7	37.8	36.7

APPENDIX B.5.

SAIC®
Science Applications International Corporation
An Employee-Owned Company

November 28, 1994

Clifton F. Blanchard
Brown & Root Environmental
Jackson Plaza, Suite A-600
800 Oak Ridge Turnpike
Oak Ridge, TN 37830

Re: EPA Contract No. 68-C0-0048, WA 0-49
SAIC Project No. 01-0832-07-1123-014

Dear Cliff:

Peggy Groeber asked me to send you the enclosed final pretreatment soil and water data from the KAI RFH demonstration.

Sincerely,

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

Sharon Krietemeyer

Sharon Krietemeyer
Chemical Engineer

SMK/smk

Encl.

cc: M. Groeber (w/o enclosure)

smk:cliff.let

635 West Seventh Street, Suite 403, Cincinnati, Ohio 45203 • (513) 723-2600 • FAX: (513) 723-2605
Other SAIC Offices: Albuquerque, Colorado Springs, Dayton, Falls Church, Huntsville, Las Vegas, Los Altos, Los Angeles, McLean, Oak Ridge, Orlando, San Diego, Seattle, Tucson

TABLE A ALL RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, SITE '*', RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

	9			9			9			9		
	A1			A1			A1			A1		
	KRF-A1-U0002			KRF-A1-U1618			KRF-A1-U1618D			KRF-A1-U1820		
PARAMETER	0 - 2			16 - 18			16 - 18			18 - 20		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	458	(30.6)	[1]	79700	(1650)	[50]	38900	(1480)	[50]	39300	(618)	[20]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(1.93)	[1]	NA			NA			ND	(1950)	[1000]
1,1,2,2-Tetrachloroethane	ND	(5.24)	[1]	NA			NA			ND	(3990)	[1000]
1,1,2-Trichloroethane	ND	(1.58)	[1]	NA			NA			ND	(2380)	[1000]
1,1-Dichloroethane	ND	(1.77)	[1]	NA			NA			ND	(2280)	[1000]
1,1-Dichloroethene	ND	(2.65)	[1]	NA			NA			ND	(3220)	[1000]
1,2-Dichloroethane	ND	(1.8)	[1]	NA			NA			ND	(3390)	[1000]
1,2-Dichloropropane	ND	(2.71)	[1]	NA			NA			ND	(2120)	[1000]
2-Chloroethyl vinyl ether	ND	(2.96)	[1]	NA			NA			ND	(1230)	[1000]
2-Hexanone	ND	(0.991)	[1]	NA			NA			ND	(3810)	[1000]
4-Methyl-2-Pentanone(MIBK)	ND	(0.946)	[1]	NA			NA			ND	(3300)	[1000]
Acetone	2.51 B	(1.55)	[1]	NA			NA			ND	(5150)	[1000]
Benzene	ND	(1.78)	[1]	NA			NA			< DL	(4440)	[1000]
Bromodichloromethane	ND	(1.69)	[1]	NA			NA			ND	(2830)	[1000]
Bromomethane	ND	(2.08)	[1]	NA			NA			ND	(4530)	[1000]
Carbon disulfide	ND	(2.68)	[1]	NA			NA			ND	(4170)	[1000]
Carbon tetrachloride	ND	(2.07)	[1]	NA			NA			ND	(3370)	[1000]
Chlorobenzene	< DL	(4.8)	[1]	NA			NA			96100	(2690)	[1000]
Chloroethane	ND	(2.11)	[1]	NA			NA			ND	(4050)	[1000]
Chloroform	ND	(2.16)	[1]	NA			NA			ND	(1790)	[1000]
Chloromethane	ND	(2.52)	[1]	NA			NA			ND	(3440)	[1000]
Dibromochloromethane	ND	(1.89)	[1]	NA			NA			ND	(2010)	[1000]
Ethyl benzene	ND	(1.71)	[1]	NA			NA			< DL	(2950)	[1000]
Methyl ethyl ketone	ND	(1.58)	[1]	NA			NA			ND	(5010)	[1000]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 A1 KRF-A1-U0002 0 - 2				9 A1 KRF-A1-U1618 16 - 18	9 A1 KRF-A1-U1618D 16 - 18	9 A1 KRF-A1-U1820 18 - 20		
SW8240 - Volatile Organics, cont. (ug/kg)									
Methylene Chloride	6.23	B	(2.7)	[1]	NA	NA	ND	(4960)	[1000]
Styrene	ND		(1.67)	[1]	NA	NA	ND	(2110)	[1000]
Tetrachloroethene	ND		(4.91)	[1]	NA	NA	ND	(3180)	[1000]
Toluene	ND		(1.76)	[1]	NA	NA	3400	(1850)	[1000]
Tribromomethane(Bromoform)	ND		(1.56)	[1]	NA	NA	ND	(2520)	[1000]
Trichloroethene	ND		(5.02)	[1]	NA	NA	ND	(2390)	[1000]
Vinyl Chloride	ND		(2.14)	[1]	NA	NA	ND	(3620)	[1000]
Vinyl acetate	ND		(11.3)	[1]	NA	NA	ND	(1460)	[1000]
Xylene (total)	ND		(3.76)	[1]	NA	NA	< DL	(5750)	[1000]
cis-1,3-Dichloropropene	ND		(1.66)	[1]	NA	NA	ND	(2180)	[1000]
trans-1,2-Dichloroethene	ND		(2.41)	[1]	NA	NA	ND	(2100)	[1000]
trans-1,3-Dichloropropene	ND		(1.8)	[1]	NA	NA	ND	(2340)	[1000]
SW8270 - Semivolatile Organics (ug/g)									
1,2,4-Trichlorobenzene	ND		(0.0181)	[1]	NA	NA	ND	(0.539)	[1]
1,2-Dichlorobenzene	ND		(0.0253)	[1]	NA	NA	8.87	(0.753)	[1]
1,3-Dichlorobenzene	ND		(0.023)	[1]	NA	NA	1.73	(0.685)	[1]
1,4-Dichlorobenzene	ND		(0.0301)	[1]	NA	NA	6.79	(0.897)	[1]
2,4,5-Trichlorophenol	ND		(0.0226)	[1]	NA	NA	ND	(0.674)	[1]
2,4,6-Trichlorophenol	ND		(0.027)	[1]	NA	NA	ND	(0.803)	[1]
2,4-Dichlorophenol	ND		(0.0358)	[1]	NA	NA	ND	(1.07)	[1]
2,4-Dimethylphenol	ND		(0.0332)	[1]	NA	NA	ND	(0.989)	[1]
2,4-Dinitrophenol	ND		(0.0461)	[1]	NA	NA	ND	(1.37)	[1]
2,4-Dinitrotoluene	ND		(0.0281)	[1]	NA	NA	ND	(0.838)	[1]
2,6-Dinitrotoluene	ND		(0.0307)	[1]	NA	NA	ND	(0.914)	[1]
2-Chloronaphthalene	ND		(0.027)	[1]	NA	NA	ND	(0.805)	[1]
2-Chlorophenol	ND		(0.0233)	[1]	NA	NA	ND	(0.694)	[1]
2-Methylnaphthalene	ND		(0.0239)	[1]	NA	NA	20.7	(0.712)	[1]
2-Methylphenol	ND		(0.0129)	[1]	NA	NA	ND	(0.385)	[1]
2-Nitroaniline	ND		(0.0304)	[1]	NA	NA	ND	(0.905)	[1]
2-Nitrophenol	ND		(0.0305)	[1]	NA	NA	ND	(0.909)	[1]
3,3'-Dichlorobenzidine	ND		(0.0368)	[1]	NA	NA	ND	(1.1)	[1]
3-Nitroaniline	ND		(0.032)	[1]	NA	NA	ND	(0.955)	[1]
4,6-Dinitro-2-methylphenol	ND		(0.0404)	[1]	NA	NA	ND	(1.2)	[1]
4-Bromophenyl phenyl ether	ND		(0.0172)	[1]	NA	NA	ND	(0.514)	[1]
4-Chloro-3-methylphenol	ND		(0.0165)	[1]	NA	NA	ND	(0.491)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

	9				9	9	9			
	A1				A1	A1	A1			
	KRF-A1-U0002				KRF-A1-U1618	KRF-A1-U1618D	KRF-A1-U1820			
PARAMETER	0 - 2				16 - 18	16 - 18	18 - 20			
SW8270 - Semivolatile Organics, cont. (ug/g)										
4-Chlorophenyl phenyl ether	ND		(0.0192)	[1]	NA	NA	ND		(0.573)	[1]
4-Methylphenol/3-Methylphenol	ND		(0.015)	[1]	NA	NA	0.922	F	(0.447)	[1]
4-Nitroaniline	ND		(0.0449)	[1]	NA	NA	ND		(1.34)	[1]
4-Nitrophenol	ND		(0.0477)	[1]	NA	NA	ND		(1.42)	[1]
Acenaphthene	0.0275		(0.0263)	[1]	NA	NA	ND		(0.784)	[1]
Acenaphthylene	ND		(0.0261)	[1]	NA	NA	ND		(0.776)	[1]
Anthracene	0.0405		(0.0314)	[1]	NA	NA	< DL		(0.935)	[1]
Benzo(a)anthracene	0.303		(0.0245)	[1]	NA	NA	< DL		(0.729)	[1]
Benzo(a)pyrene	0.295		(0.0327)	[1]	NA	NA	ND		(0.974)	[1]
Benzo(b)fluoranthene	0.621	F	(0.0432)	[1]	NA	NA	< DL		(1.29)	[1]
Benzo(g,h,i)perylene	0.169		(0.0465)	[1]	NA	NA	ND		(1.38)	[1]
Benzo(k)fluoranthene	0.621	F	(0.0453)	[1]	NA	NA	< DL		(1.35)	[1]
Benzoic acid	ND		(1.07)	[1]	NA	NA	ND		(32)	[1]
Benzyl alcohol	ND		(0.0221)	[1]	NA	NA	ND		(0.66)	[1]
Butylbenzylphthalate	ND		(0.075)	[1]	NA	NA	ND		(2.24)	[1]
Chrysene	0.355		(0.0408)	[1]	NA	NA	< DL		(1.21)	[1]
Di-n-octylphthalate	ND		(0.0212)	[1]	NA	NA	ND		(0.632)	[1]
Dibenz(a,h)anthracene	0.0563		(0.0412)	[1]	NA	NA	ND		(1.23)	[1]
Dibenzofuran	< DL		(0.0228)	[1]	NA	NA	ND		(0.679)	[1]
Dibutylphthalate	ND		(0.0203)	[1]	NA	NA	1.26		(0.606)	[1]
Diethylphthalate	ND		(0.0104)	[1]	NA	NA	ND		(0.311)	[1]
Dimethylphthalate	ND		(0.0184)	[1]	NA	NA	ND		(0.549)	[1]
Diphenylamine	ND		(0.037)	[1]	NA	NA	ND		(1.1)	[1]
Fluoranthene	0.679		(0.0243)	[1]	NA	NA	5.18		(0.723)	[1]
Fluorene	0.0231		(0.0189)	[1]	NA	NA	ND		(0.562)	[1]
Hexachlorobenzene	ND		(0.0227)	[1]	NA	NA	ND		(0.675)	[1]
Hexachlorobutadiene	ND		(0.0424)	[1]	NA	NA	ND		(1.26)	[1]
Hexachlorocyclopentadiene	ND		(0.0489)	[1]	NA	NA	ND		(1.46)	[1]
Hexachloroethane	ND		(0.0227)	[1]	NA	NA	ND		(0.677)	[1]
Indeno(1,2,3-cd)pyrene	0.146		(0.0363)	[1]	NA	NA	ND		(1.08)	[1]
Isophorone	ND		(0.0133)	[1]	NA	NA	ND		(0.396)	[1]
N-Nitroso-di-n-propylamine	ND		(0.0254)	[1]	NA	NA	ND		(0.756)	[1]
Naphthalene	ND		(0.0318)	[1]	NA	NA	9.45		(0.946)	[1]
Nitrobenzene	ND		(0.0181)	[1]	NA	NA	ND		(0.538)	[1]
Pentachlorophenol	ND		(0.0392)	[1]	NA	NA	ND		(1.17)	[1]
Phenanthrene	0.223		(0.0272)	[1]	NA	NA	3.07		(0.809)	[1]

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PARAMETER	9 A1 KRF-A1-U0002 0 - 2			9 A1 KRF-A1-U1618 16 - 18			9 A1 KRF-A1-U1618D 16 - 18			9 A1 KRF-A1-U1820 18 - 20		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Phenol	ND	(0.0153)	[1]	NA			NA			ND	(0.457)	[1]
Pyrene	0.564	(0.0291)	[1]	NA			NA			1.6	(0.867)	[1]
bis(2-Chloroethoxy)methane	ND	(0.026)	[1]	NA			NA			ND	(0.775)	[1]
bis(2-Chloroethyl)ether	ND	(0.0201)	[1]	NA			NA			ND	(0.598)	[1]
bis(2-Chloroisopropyl)ether	ND	(0.0182)	[1]	NA			NA			ND	(0.543)	[1]
bis(2-Ethylhexyl)phthalate	0.379	(0.109)	[1]	NA			NA			73	(3.26)	[1]
p-Chloroaniline	ND	(0.0387)	[1]	NA			NA			ND	(1.15)	[1]
SW846 - Percent Moisture (percent)												
Percent moisture	18.5	(0)	[1]	24.2	(0)	[1]	15.8	(0)	[1]	19.3	(0)	[1]

Compiled: 22 Jun 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9			9			9			9		
	A1			A2			A2			A2		
	KRF-A1-U2728			KRF-A2-U0002			KRF-A2-U0204			KRF-A2-U0406		
	27 - 28			0 - 2			2 - 4			4 - 6		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	2240	(52.6)	[2]	2330	(154)	[5]	203	(31.3)	[1]	1530	(30.6)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(166)	[100]	ND	(1.94)	[1]	ND	(1.97)	[1]	ND	(1.93)	[1]
1,1,2,2-Tetrachloroethane	ND	(339)	[100]	ND	(5.26)	[1]	ND	(5.35)	[1]	ND	(5.25)	[1]
1,1,2-Trichloroethane	ND	(202)	[100]	ND	(1.58)	[1]	ND	(1.61)	[1]	ND	(1.58)	[1]
1,1-Dichloroethane	ND	(194)	[100]	ND	(1.78)	[1]	ND	(1.81)	[1]	ND	(1.77)	[1]
1,1-Dichloroethene	ND	(274)	[100]	ND	(2.66)	[1]	ND	(2.7)	[1]	ND	(2.66)	[1]
1,2-Dichloroethane	ND	(288)	[100]	ND	(1.8)	[1]	ND	(1.83)	[1]	ND	(1.8)	[1]
1,2-Dichloropropane	ND	(180)	[100]	ND	(2.72)	[1]	ND	(2.77)	[1]	ND	(2.72)	[1]
2-Chloroethyl vinyl ether	ND	(105)	[100]	ND	(2.97)	[1]	ND	(3.02)	[1]	ND	(2.96)	[1]
2-Hexanone	ND	(324)	[100]	ND	(0.995)	[1]	ND	(1.01)	[1]	ND	(0.992)	[1]
4-Methyl-2-Pentanone(MIBK)	ND	(280)	[100]	ND	(0.949)	[1]	ND	(0.965)	[1]	ND	(0.947)	[1]
Acetone	ND	(437)	[100]	7.63 B	(1.56)	[1]	12.3 B	(1.58)	[1]	7.79 B	(1.55)	[1]
Benzene	ND	(378)	[100]	< DL	(1.79)	[1]	< DL	(1.82)	[1]	< DL	(1.79)	[1]
Bromodichloromethane	ND	(240)	[100]	ND	(1.69)	[1]	ND	(1.72)	[1]	ND	(1.69)	[1]
Bromomethane	ND	(385)	[100]	ND	(2.09)	[1]	ND	(2.12)	[1]	ND	(2.08)	[1]
Carbon disulfide	ND	(355)	[100]	ND	(2.69)	[1]	ND	(2.73)	[1]	ND	(2.68)	[1]
Carbon tetrachloride	ND	(286)	[100]	ND	(2.07)	[1]	ND	(2.11)	[1]	ND	(2.07)	[1]
Chlorobenzene	9160	(229)	[100]	8.38	(4.82)	[1]	8.39	(4.9)	[1]	7.6	(4.81)	[1]
Chloroethane	ND	(344)	[100]	ND	(2.12)	[1]	ND	(2.16)	[1]	ND	(2.12)	[1]
Chloroform	ND	(152)	[100]	ND	(2.17)	[1]	ND	(2.21)	[1]	ND	(2.17)	[1]
Chloromethane	ND	(293)	[100]	ND	(2.53)	[1]	ND	(2.57)	[1]	ND	(2.52)	[1]
Dibromochloromethane	ND	(171)	[100]	ND	(1.9)	[1]	ND	(1.93)	[1]	ND	(1.9)	[1]
Ethyl benzene	< DL	(251)	[100]	ND	(1.72)	[1]	ND	(1.74)	[1]	ND	(1.71)	[1]
Methyl ethyl ketone	ND	(426)	[100]	13.7 B	(1.58)	[1]	13 B	(1.61)	[1]	12.8 B	(1.58)	[1]
Methylene Chloride	ND	(422)	[100]	< DL	(2.71)	[1]	2.82	(2.75)	[1]	4.01	(2.7)	[1]
Styrene	ND	(179)	[100]	ND	(1.68)	[1]	ND	(1.71)	[1]	ND	(1.68)	[1]
Tetrachloroethene	ND	(271)	[100]	ND	(4.93)	[1]	ND	(5.01)	[1]	ND	(4.92)	[1]
Toluene	< DL	(157)	[100]	2.12	(1.77)	[1]	2.09	(1.79)	[1]	2.66	(1.76)	[1]
Tribromomethane(Bromoform)	ND	(214)	[100]	ND	(1.57)	[1]	ND	(1.6)	[1]	ND	(1.57)	[1]
Trichloroethene	ND	(204)	[100]	ND	(5.04)	[1]	ND	(5.12)	[1]	ND	(5.03)	[1]
Vinyl Chloride	ND	(307)	[100]	ND	(2.15)	[1]	ND	(2.18)	[1]	ND	(2.14)	[1]
Vinyl acetate	ND	(124)	[100]	ND	(11.4)	[1]	ND	(11.6)	[1]	ND	(11.3)	[1]
Xylene (total)	667	(489)	[100]	ND	(3.78)	[1]	ND	(3.84)	[1]	ND	(3.77)	[1]
cis-1,3-Dichloropropene	ND	(186)	[100]	ND	(1.67)	[1]	ND	(1.69)	[1]	ND	(1.66)	[1]

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PARAMETER	9 A1 KRF-A1-U2728 27 - 28			9 A2 KRF-A2-U0002 0 - 2			9 A2 KRF-A2-U0204 2 - 4			9 A2 KRF-A2-U0406 4 - 6		
SW8240 - Volatile Organics, cont. (ug/kg)												
trans-1,2-Dichloroethene	ND	(178)	[100]	ND	(2.42)	[1]	ND	(2.46)	[1]	ND	(2.41)	[1]
trans-1,3-Dichloropropene	ND	(199)	[100]	ND	(1.8)	[1]	ND	(1.83)	[1]	ND	(1.8)	[1]
SW8270 - Semivolatile Organics (ug/g)												
1,2,4-Trichlorobenzene	ND	(0.433)	[1]	ND	(0.018)	[1]	ND	(0.0186)	[1]	ND	(0.018)	[1]
1,2-Dichlorobenzene	ND	(0.605)	[1]	ND	(0.0252)	[1]	ND	(0.0259)	[1]	ND	(0.0252)	[1]
1,3-Dichlorobenzene	ND	(0.551)	[1]	ND	(0.0229)	[1]	ND	(0.0236)	[1]	ND	(0.0229)	[1]
1,4-Dichlorobenzene	ND	(0.721)	[1]	ND	(0.03)	[1]	ND	(0.0309)	[1]	ND	(0.03)	[1]
2,4,5-Trichlorophenol	ND	(0.542)	[1]	ND	(0.0226)	[1]	ND	(0.0232)	[1]	ND	(0.0225)	[1]
2,4,6-Trichlorophenol	ND	(0.645)	[1]	ND	(0.0269)	[1]	ND	(0.0277)	[1]	ND	(0.0269)	[1]
2,4-Dichlorophenol	ND	(0.857)	[1]	ND	(0.0357)	[1]	ND	(0.0367)	[1]	ND	(0.0357)	[1]
2,4-Dimethylphenol	ND	(0.795)	[1]	ND	(0.0331)	[1]	ND	(0.0341)	[1]	ND	(0.0331)	[1]
2,4-Dinitrophenol	ND	(1.1)	[1]	ND	(0.0459)	[1]	ND	(0.0473)	[1]	ND	(0.0459)	[1]
2,4-Dinitrotoluene	ND	(0.674)	[1]	ND	(0.028)	[1]	ND	(0.0289)	[1]	ND	(0.028)	[1]
2,6-Dinitrotoluene	ND	(0.734)	[1]	ND	(0.0306)	[1]	ND	(0.0315)	[1]	ND	(0.0306)	[1]
2-Chloronaphthalene	ND	(0.647)	[1]	ND	(0.0269)	[1]	ND	(0.0277)	[1]	ND	(0.0269)	[1]
2-Chlorophenol	ND	(0.557)	[1]	ND	(0.0232)	[1]	ND	(0.0239)	[1]	ND	(0.0232)	[1]
2-Methylnaphthalene	1.19	(0.572)	[1]	0.0316	(0.0238)	[1]	ND	(0.0245)	[1]	ND	(0.0238)	[1]
2-Methylphenol	ND	(0.309)	[1]	ND	(0.0129)	[1]	ND	(0.0133)	[1]	ND	(0.0129)	[1]
2-Nitroaniline	ND	(0.727)	[1]	ND	(0.0303)	[1]	ND	(0.0312)	[1]	ND	(0.0303)	[1]
2-Nitrophenol	ND	(0.73)	[1]	ND	(0.0304)	[1]	ND	(0.0313)	[1]	ND	(0.0304)	[1]
3,3'-Dichlorobenzidine	ND	(0.882)	[1]	ND	(0.0367)	[1]	ND	(0.0378)	[1]	ND	(0.0367)	[1]
3-Nitroaniline	ND	(0.767)	[1]	ND	(0.0319)	[1]	ND	(0.0329)	[1]	ND	(0.0319)	[1]
4,6-Dinitro-2-methylphenol	ND	(0.968)	[1]	ND	(0.0403)	[1]	ND	(0.0415)	[1]	ND	(0.0403)	[1]
4-Bromophenyl phenyl ether	ND	(0.413)	[1]	ND	(0.0172)	[1]	ND	(0.0177)	[1]	ND	(0.0172)	[1]
4-Chloro-3-methylphenol	ND	(0.394)	[1]	ND	(0.0164)	[1]	ND	(0.0169)	[1]	ND	(0.0164)	[1]
4-Chlorophenyl phenyl ether	ND	(0.461)	[1]	ND	(0.0192)	[1]	ND	(0.0198)	[1]	ND	(0.0192)	[1]
4-Methylphenol/3-Methylphenol	ND	(0.359)	[1]	ND	(0.015)	[1]	ND	(0.0154)	[1]	ND	(0.015)	[1]
4-Nitroaniline	ND	(1.07)	[1]	ND	(0.0447)	[1]	ND	(0.046)	[1]	ND	(0.0447)	[1]
4-Nitrophenol	ND	(1.14)	[1]	ND	(0.0475)	[1]	ND	(0.049)	[1]	ND	(0.0475)	[1]
Acenaphthene	ND	(0.63)	[1]	0.0475	(0.0262)	[1]	0.0502	(0.027)	[1]	ND	(0.0262)	[1]
Acenaphthylene	ND	(0.624)	[1]	ND	(0.026)	[1]	ND	(0.0267)	[1]	ND	(0.026)	[1]
Anthracene	ND	(0.752)	[1]	0.0711	(0.0313)	[1]	0.163	(0.0322)	[1]	< DL	(0.0313)	[1]
Benzo(a)anthracene	ND	(0.586)	[1]	0.378	(0.0244)	[1]	0.625	(0.0251)	[1]	0.173	(0.0244)	[1]
Benzo(a)pyrene	ND	(0.783)	[1]	0.459	(0.0326)	[1]	0.589	(0.0336)	[1]	0.182	(0.0326)	[1]
Benzo(b)fluoranthene	ND	(1.03)	[1]	1.03 F	(0.0431)	[1]	1.12 F	(0.0444)	[1]	0.422 F	(0.0431)	[1]

() = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 A1 KRF-A1-U2728 27 - 28				9 A2 KRF-A2-U0002 0 - 2				9 A2 KRF-A2-U0204 2 - 4				9 A2 KRF-A2-U0406 4 - 6			
SW8270 - Semivolatile Organics, cont. (ug/g)																
Benzo(g,h,i)perylene	ND		(1.11)	[1]	0.195		(0.0463)	[1]	0.196		(0.0477)	[1]	0.0581		(0.0463)	[1]
Benzo(k)fluoranthene	ND		(1.08)	[1]	1.03	F	(0.0451)	[1]	1.12	F	(0.0465)	[1]	0.422	F	(0.0451)	[1]
Benzoic acid	ND		(25.7)	[1]	ND		(1.07)	[1]	ND		(1.1)	[1]	ND		(1.07)	[1]
Benzyl alcohol	ND		(0.53)	[1]	ND		(0.0221)	[1]	ND		(0.0227)	[1]	ND		(0.0221)	[1]
Butylbenzylphthalate	ND		(1.8)	[1]	ND		(0.0748)	[1]	ND		(0.077)	[1]	ND		(0.0748)	[1]
Chrysene	ND		(0.976)	[1]	0.438		(0.0406)	[1]	0.59		(0.0418)	[1]	0.215		(0.0406)	[1]
Di-n-octylphthalate	ND		(0.508)	[1]	ND		(0.0211)	[1]	ND		(0.0218)	[1]	ND		(0.0211)	[1]
Dibenz(a,h)anthracene	ND		(0.986)	[1]	0.0662		(0.041)	[1]	0.09		(0.0423)	[1]	ND		(0.041)	[1]
Dibenzofuran	ND		(0.546)	[1]	0.041		(0.0227)	[1]	< DL		(0.0234)	[1]	ND		(0.0227)	[1]
Dibutylphthalate	ND		(0.487)	[1]	ND		(0.0203)	[1]	ND		(0.0209)	[1]	0.0431		(0.0203)	[1]
Diethylphthalate	ND		(0.25)	[1]	ND		(0.0104)	[1]	ND		(0.0107)	[1]	ND		(0.0104)	[1]
Dimethylphthalate	ND		(0.441)	[1]	ND		(0.0184)	[1]	ND		(0.0189)	[1]	ND		(0.0184)	[1]
Diphenylamine	ND		(0.886)	[1]	ND		(0.0369)	[1]	ND		(0.038)	[1]	ND		(0.0369)	[1]
Fluoranthene	ND		(0.581)	[1]	0.821		(0.0242)	[1]	1.16		(0.0249)	[1]	0.339		(0.0242)	[1]
Fluorene	ND		(0.452)	[1]	0.0356		(0.0188)	[1]	0.0544		(0.0194)	[1]	ND		(0.0188)	[1]
Hexachlorobenzene	ND		(0.543)	[1]	ND		(0.0226)	[1]	ND		(0.0233)	[1]	ND		(0.0226)	[1]
Hexachlorobutadiene	ND		(1.02)	[1]	ND		(0.0423)	[1]	ND		(0.0435)	[1]	ND		(0.0422)	[1]
Hexachlorocyclopentadiene	ND		(1.17)	[1]	ND		(0.0488)	[1]	ND		(0.0502)	[1]	ND		(0.0488)	[1]
Hexachloroethane	ND		(0.544)	[1]	ND		(0.0226)	[1]	ND		(0.0233)	[1]	ND		(0.0226)	[1]
Indeno(1,2,3-cd)pyrene	ND		(0.87)	[1]	0.183		(0.0362)	[1]	0.185		(0.0373)	[1]	0.0512		(0.0362)	[1]
Isophorone	ND		(0.318)	[1]	ND		(0.0132)	[1]	ND		(0.0136)	[1]	ND		(0.0132)	[1]
N-Nitroso-di-n-propylamine	ND		(0.607)	[1]	ND		(0.0253)	[1]	ND		(0.026)	[1]	ND		(0.0253)	[1]
Naphthalene	ND		(0.761)	[1]	ND		(0.0317)	[1]	ND		(0.0326)	[1]	ND		(0.0316)	[1]
Nitrobenzene	ND		(0.433)	[1]	ND		(0.018)	[1]	ND		(0.0185)	[1]	ND		(0.018)	[1]
Pentachlorophenol	ND		(0.938)	[1]	ND		(0.039)	[1]	ND		(0.0402)	[1]	ND		(0.039)	[1]
Phenanthrene	ND		(0.65)	[1]	0.393		(0.0271)	[1]	0.506		(0.0279)	[1]	0.13		(0.0271)	[1]
Phenol	ND		(0.367)	[1]	ND		(0.0153)	[1]	ND		(0.0157)	[1]	ND		(0.0153)	[1]
Pyrene	ND		(0.697)	[1]	0.652		(0.029)	[1]	0.911		(0.0299)	[1]	0.321		(0.029)	[1]
bis(2-Chloroethoxy)methane	ND		(0.623)	[1]	ND		(0.0259)	[1]	ND		(0.0267)	[1]	ND		(0.0259)	[1]
bis(2-Chloroethyl)ether	ND		(0.48)	[1]	ND		(0.02)	[1]	ND		(0.0206)	[1]	ND		(0.02)	[1]
bis(2-Chloroisopropyl)ether	ND		(0.436)	[1]	ND		(0.0182)	[1]	ND		(0.0187)	[1]	ND		(0.0182)	[1]
bis(2-Ethylhexyl)phthalate	< DL		(2.62)	[1]	1.32		(0.109)	[1]	0.126		(0.112)	[1]	0.686		(0.109)	[1]
p-Chloroaniline	ND		(0.926)	[1]	ND		(0.0385)	[1]	ND		(0.0397)	[1]	ND		(0.0385)	[1]
SW846 - Percent Moisture (percent)																
Percent moisture	5.16		(0)	[1]	18.8		(0)	[1]	20.4		(0)	[1]	18.6		(0)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 A2 KRF-A2-U1012 10 - 12			9 A2 KRF-A2-U1012D 10 - 12			9 A2 KRF-A2-U1214 12 - 14			9 A2 KRF-A2-U1618 16 - 18		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	1290	(32.1)	[1]	571	(33.4)	[1]	622	(34.6)	[1]	23800	(622)	[20]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	NA			NA			NA			ND	(391)	[200]
1,1,2,2-Tetrachloroethane	NA			NA			NA			ND	(799)	[200]
1,1,2-Trichloroethane	NA			NA			NA			ND	(478)	[200]
1,1-Dichloroethane	NA			NA			NA			ND	(458)	[200]
1,1-Dichloroethene	NA			NA			NA			ND	(646)	[200]
1,2-Dichloroethane	NA			NA			NA			ND	(681)	[200]
1,2-Dichloropropane	NA			NA			NA			ND	(426)	[200]
2-Chloroethyl vinyl ether	NA			NA			NA			ND	(247)	[200]
2-Hexanone	NA			NA			NA			ND	(765)	[200]
4-Methyl-2-Pentanone(MIBK)	NA			NA			NA			ND	(661)	[200]
Acetone	NA			NA			NA			ND	(1030)	[200]
Benzene	NA			NA			NA			< DL	(891)	[200]
Bromodichloromethane	NA			NA			NA			ND	(567)	[200]
Bromomethane	NA			NA			NA			ND	(908)	[200]
Carbon disulfide	NA			NA			NA			ND	(836)	[200]
Carbon tetrachloride	NA			NA			NA			ND	(676)	[200]
Chlorobenzene	NA			NA			NA			29400	(539)	[200]
Chloroethane	NA			NA			NA			ND	(812)	[200]
Chloroform	NA			NA			NA			ND	(359)	[200]
Chloromethane	NA			NA			NA			ND	(690)	[200]
Dibromochloromethane	NA			NA			NA			ND	(403)	[200]
Ethyl benzene	NA			NA			NA			1120	(591)	[200]
Methyl ethyl ketone	NA			NA			NA			ND	(1000)	[200]
Methylene Chloride	NA			NA			NA			ND	(995)	[200]
Styrene	NA			NA			NA			ND	(423)	[200]
Tetrachloroethene	NA			NA			NA			ND	(638)	[200]
Toluene	NA			NA			NA			1120	(371)	[200]
Tribromomethane(Bromoform)	NA			NA			NA			ND	(505)	[200]
Trichloroethene	NA			NA			NA			ND	(480)	[200]
Vinyl Chloride	NA			NA			NA			ND	(725)	[200]
Vinyl acetate	NA			NA			NA			ND	(292)	[200]
Xylene (total)	NA			NA			NA			6520	(1150)	[200]
cis-1,3-Dichloropropene	NA			NA			NA			ND	(438)	[200]

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PARAMETER	9 A2 KRF-A2-U1012 10 - 12	9 A2 KRF-A2-U1012D 10 - 12	9 A2 KRF-A2-U1214 12 - 14	9 A2 KRF-A2-U1618 16 - 18			
SW8240 - Volatile Organics, cont. (ug/kg)							
trans-1,2-Dichloroethene	NA	NA	NA	ND		(421)	[200]
trans-1,3-Dichloropropene	NA	NA	NA	ND		(470)	[200]
SW8270 - Semivolatile Organics (ug/g)							
1,2,4-Trichlorobenzene	NA	NA	NA	ND		(0.0553)	[1]
1,2-Dichlorobenzene	NA	NA	NA	0.404		(0.0772)	[1]
1,3-Dichlorobenzene	NA	NA	NA	0.735		(0.0703)	[1]
1,4-Dichlorobenzene	NA	NA	NA	5.05		(0.092)	[1]
2,4,5-Trichlorophenol	NA	NA	NA	ND		(0.0691)	[1]
2,4,6-Trichlorophenol	NA	NA	NA	ND		(0.0824)	[1]
2,4-Dichlorophenol	NA	NA	NA	ND		(0.109)	[1]
2,4-Dimethylphenol	NA	NA	NA	ND		(0.101)	[1]
2,4-Dinitrophenol	NA	NA	NA	ND		(0.141)	[1]
2,4-Dinitrotoluene	NA	NA	NA	ND		(0.086)	[1]
2,6-Dinitrotoluene	NA	NA	NA	ND		(0.0937)	[1]
2-Chloronaphthalene	NA	NA	NA	ND		(0.0826)	[1]
2-Chlorophenol	NA	NA	NA	ND		(0.0711)	[1]
2-Methylnaphthalene	NA	NA	NA	2.13		(0.073)	[1]
2-Methylphenol	NA	NA	NA	ND		(0.0395)	[1]
2-Nitroaniline	NA	NA	NA	ND		(0.0928)	[1]
2-Nitrophenol	NA	NA	NA	ND		(0.0932)	[1]
3,3'-Dichlorobenzidine	NA	NA	NA	ND		(0.113)	[1]
3-Nitroaniline	NA	NA	NA	ND		(0.0979)	[1]
4,6-Dinitro-2-methylphenol	NA	NA	NA	ND		(0.123)	[1]
4-Bromophenyl phenyl ether	NA	NA	NA	ND		(0.0527)	[1]
4-Chloro-3-methylphenol	NA	NA	NA	ND		(0.0503)	[1]
4-Chlorophenyl phenyl ether	NA	NA	NA	ND		(0.0588)	[1]
4-Methylphenol/3-Methylphenol	NA	NA	NA	ND		(0.0458)	[1]
4-Nitroaniline	NA	NA	NA	ND		(0.137)	[1]
4-Nitrophenol	NA	NA	NA	ND		(0.146)	[1]
Acenaphthene	NA	NA	NA	ND		(0.0804)	[1]
Acenaphthylene	NA	NA	NA	ND		(0.0796)	[1]
Anthracene	NA	NA	NA	ND		(0.0959)	[1]
Benzo(a)anthracene	NA	NA	NA	< DL		(0.0748)	[1]
Benzo(a)pyrene	NA	NA	NA	0.189	X	(0.0999)	[1]
Benzo(b)fluoranthene	NA	NA	NA	0.172	XF	(0.132)	[1]

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PARAMETER	9 A2 KRF-A2-U1012 10 - 12				9 A2 KRF-A2-U1012D 10 - 12				9 A2 KRF-A2-U1214 12 - 14				9 A2 KRF-A2-U1618 16 - 18			
SW8270 - Semivolatile Organics, cont. (ug/g)																
Benzo(g,h,i)perylene	NA				NA				NA				ND	X	(0.142)	[1]
Benzo(k)fluoranthene	NA				NA				NA				0.172	XF	(0.138)	[1]
Benzoic acid	NA				NA				NA				ND		(3.28)	[1]
Benzyl alcohol	NA				NA				NA				ND		(0.0677)	[1]
Butylbenzylphthalate	NA				NA				NA				ND		(0.229)	[1]
Chrysene	NA				NA				NA				0.196		(0.125)	[1]
Di-n-octylphthalate	NA				NA				NA				ND	X	(0.0648)	[1]
Dibenz(a,h)anthracene	NA				NA				NA				ND	X	(0.126)	[1]
Dibenzofuran	NA				NA				NA				ND		(0.0696)	[1]
Dibutylphthalate	NA				NA				NA				0.147		(0.0622)	[1]
Diethylphthalate	NA				NA				NA				ND		(0.0319)	[1]
Dimethylphthalate	NA				NA				NA				ND		(0.0563)	[1]
Diphenylamine	NA				NA				NA				ND		(0.113)	[1]
Fluoranthene	NA				NA				NA				0.562		(0.0741)	[1]
Fluorene	NA				NA				NA				0.354		(0.0577)	[1]
Hexachlorobenzene	NA				NA				NA				ND		(0.0693)	[1]
Hexachlorobutadiene	NA				NA				NA				ND		(0.13)	[1]
Hexachlorocyclopentadiene	NA				NA				NA				ND		(0.15)	[1]
Hexachloroethane	NA				NA				NA				ND		(0.0694)	[1]
Indeno(1,2,3-cd)pyrene	NA				NA				NA				ND	X	(0.111)	[1]
Isophorone	NA				NA				NA				ND		(0.0406)	[1]
N-Nitroso-di-n-propylamine	NA				NA				NA				ND		(0.0775)	[1]
Naphthalene	NA				NA				NA				1.37		(0.0971)	[1]
Nitrobenzene	NA				NA				NA				ND		(0.0552)	[1]
Pentachlorophenol	NA				NA				NA				ND		(0.12)	[1]
Phenanthrene	NA				NA				NA				0.907		(0.083)	[1]
Phenol	NA				NA				NA				ND		(0.0468)	[1]
Pyrene	NA				NA				NA				0.406		(0.089)	[1]
bis(2-Chloroethoxy)methane	NA				NA				NA				ND		(0.0795)	[1]
bis(2-Chloroethyl)ether	NA				NA				NA				ND		(0 0613)	[1]
bis(2-Chloroisopropyl)ether	NA				NA				NA				ND		(0.0557)	[1]
bis(2-Ethylhexyl)phthalate	NA				NA				NA				27.1		(0.668)	[2]
p-Chloroaniline	NA				NA				NA				ND		(0.118)	[1]
SW846 - Percent Moisture (percent)																
Percent moisture	22.3		(0)	[1]	25.3		(0)	[1]	28		(0)	[1]	19.9		(0)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 A2 KRF-A2-U1618D 16 - 18			9 A2 KRF-A2-U2022 20 - 22			9 A2 KRF-A2-U2628 26 - 28			9 E1 KRF-E1-U0002 0 - 2		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	12600	(624)	[20]	21200	(646)	[20]	2730	(54.9)	[2]	352	(30.8)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(98.6)	[50]	ND	(2050)	[1000]	NA			NA		
1,1,2,2-Tetrachloroethane	ND	(202)	[50]	ND	(4190)	[1000]	NA			NA		
1,1,2-Trichloroethane	ND	(120)	[50]	ND	(2500)	[1000]	NA			NA		
1,1-Dichloroethane	ND	(115)	[50]	ND	(2400)	[1000]	NA			NA		
1,1-Dichloroethene	ND	(163)	[50]	ND	(3380)	[1000]	NA			NA		
1,2-Dichloroethane	ND	(172)	[50]	ND	(3560)	[1000]	NA			NA		
1,2-Dichloropropane	ND	(107)	[50]	ND	(2230)	[1000]	NA			NA		
2-Chloroethyl vinyl ether	ND	(62.4)	[50]	ND	(1300)	[1000]	NA			NA		
2-Hexanone	ND	(193)	[50]	ND	(4000)	[1000]	NA			NA		
4-Methyl-2-Pentanone(MIBK)	ND	(167)	[50]	ND	(3460)	[1000]	NA			NA		
Acetone	ND	(260)	[50]	ND	(5400)	[1000]	NA			NA		
Benzene	< DL	(225)	[50]	< DL	(4660)	[1000]	NA			NA		
Bromodichloromethane	ND	(143)	[50]	ND	(2970)	[1000]	NA			NA		
Bromomethane	ND	(229)	[50]	ND	(4760)	[1000]	NA			NA		
Carbon disulfide	ND	(211)	[50]	ND	(4380)	[1000]	NA			NA		
Carbon tetrachloride	ND	(170)	[50]	ND	(3540)	[1000]	NA			NA		
Chlorobenzene	6430	(136)	[50]	35600	(2820)	[1000]	NA			NA		
Chloroethane	ND	(205)	[50]	ND	(4250)	[1000]	NA			NA		
Chloroform	ND	(90.5)	[50]	ND	(1880)	[1000]	NA			NA		
Chloromethane	ND	(174)	[50]	ND	(3620)	[1000]	NA			NA		
Dibromochloromethane	ND	(102)	[50]	ND	(2110)	[1000]	NA			NA		
Ethyl benzene	330	(149)	[50]	7280	(3100)	[1000]	NA			NA		
Methyl ethyl ketone	ND	(253)	[50]	ND	(5260)	[1000]	NA			NA		
Methylene Chloride	ND	(251)	[50]	ND	(5210)	[1000]	NA			NA		
Styrene	ND	(107)	[50]	ND	(2220)	[1000]	NA			NA		
Tetrachloroethene	ND	(161)	[50]	6470	(3340)	[1000]	NA			NA		
Toluene	< DL	(93.6)	[50]	102000	(1940)	[1000]	NA			NA		
Tribromomethane(Bromoform)	ND	(127)	[50]	ND	(2640)	[1000]	NA			NA		
Trichloroethene	ND	(121)	[50]	33900	(2510)	[1000]	NA			NA		
Vinyl Chloride	ND	(183)	[50]	ND	(3800)	[1000]	NA			NA		
Vinyl acetate	ND	(73.6)	[50]	ND	(1530)	[1000]	NA			NA		
Xylene (total)	776	(291)	[50]	57300	(6040)	[1000]	NA			NA		
cis-1,3-Dichloropropene	ND	(110)	[50]	ND	(2290)	[1000]	NA			NA		

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PARAMETER	9 A2 KRF-A2-U1618D 16 - 18				9 A2 KRF-A2-U2022 20 - 22				9 A2 KRF-A2-U2628 26 - 28	9 E1 KRF-E1-U0002 0 - 2
SW8240 - Volatile Organics, cont. (ug/kg)										
trans-1,2-Dichloroethene	ND		(106)	[50]	ND		(2200)	[1000]	NA	NA
trans-1,3-Dichloropropene	ND		(119)	[50]	ND		(2460)	[1000]	NA	NA
SW8270 - Semivolatile Organics (ug/g)										
1,2,4-Trichlorobenzene	ND		(0.0553)	[1]	24.5		(5.48)	[10]	NA	NA
1,2-Dichlorobenzene	0.0827		(0.0772)	[1]	989		(7.66)	[10]	NA	NA
1,3-Dichlorobenzene	0.228		(0.0702)	[1]	58.8		(0.697)	[1]	NA	NA
1,4-Dichlorobenzene	1.14		(0.0919)	[1]	118		(0.912)	[1]	NA	NA
2,4,5-Trichlorophenol	ND		(0.0691)	[1]	ND		(0.686)	[1]	NA	NA
2,4,6-Trichlorophenol	ND		(0.0823)	[1]	ND		(0.817)	[1]	NA	NA
2,4-Dichlorophenol	ND		(0.109)	[1]	ND		(1.08)	[1]	NA	NA
2,4-Dimethylphenol	ND		(0.101)	[1]	46.7		(1.01)	[1]	NA	NA
2,4-Dinitrophenol	ND		(0.141)	[1]	ND		(1.4)	[1]	NA	NA
2,4-Dinitrotoluene	ND		(0.0859)	[1]	ND		(0.852)	[1]	NA	NA
2,6-Dinitrotoluene	ND		(0.0936)	[1]	ND		(0.929)	[1]	NA	NA
2-Chloronaphthalene	ND		(0.0826)	[1]	ND		(0.819)	[1]	NA	NA
2-Chlorophenol	ND		(0.0711)	[1]	ND		(0.705)	[1]	NA	NA
2-Methylnaphthalene	1.02		(0.073)	[1]	31.4		(0.724)	[1]	NA	NA
2-Methylphenol	ND		(0.0395)	[1]	7.4		(0.392)	[1]	NA	NA
2-Nitroaniline	ND		(0.0928)	[1]	ND		(0.92)	[1]	NA	NA
2-Nitrophenol	ND		(0.0932)	[1]	ND		(0.924)	[1]	NA	NA
3,3'-Dichlorobenzidine	ND		(0.112)	[1]	ND		(1.12)	[1]	NA	NA
3-Nitroaniline	ND		(0.0979)	[1]	ND		(0.971)	[1]	NA	NA
4,6-Dinitro-2-methylphenol	ND		(0.123)	[1]	ND		(1.22)	[1]	NA	NA
4-Bromophenyl phenyl ether	ND		(0.0527)	[1]	ND		(0.523)	[1]	NA	NA
4-Chloro-3-methylphenol	ND		(0.0503)	[1]	ND		(0.499)	[1]	NA	NA
4-Chlorophenyl phenyl ether	ND		(0.0588)	[1]	ND		(0.583)	[1]	NA	NA
4-Methylphenol/3-Methylphenol	ND		(0.0458)	[1]	23.2	F	(0.455)	[1]	NA	NA
4-Nitroaniline	ND		(0.137)	[1]	ND		(1.36)	[1]	NA	NA
4-Nitrophenol	ND		(0.146)	[1]	ND		(1.45)	[1]	NA	NA
Acenaphthene	ND		(0.0803)	[1]	ND		(0.797)	[1]	NA	NA
Acenaphthylene	< DL		(0.0796)	[1]	ND		(0.789)	[1]	NA	NA
Anthracene	ND		(0.0959)	[1]	ND		(0.951)	[1]	NA	NA
Benzo(a)anthracene	0.0907		(0.0747)	[1]	ND		(0.741)	[1]	NA	NA
Benzo(a)pyrene	< DL		(0.0999)	[1]	ND		(0.991)	[1]	NA	NA
Benzo(b)fluoranthene	0.199	F	(0.132)	[1]	ND		(1.31)	[1]	NA	NA

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PARAMETER	9 A2 KRF-A2-U1618D 16 - 18			9 A2 KRF-A2-U2022 20 - 22			9 A2 KRF-A2-U2628 26 - 28			9 E1 KRF-E1-U0002 0 - 2		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Benzo(g,h,i)perylene	ND	(0.142)	[1]	ND	(1.41)	[1]	NA			NA		
Benzo(k)fluoranthene	0.199 F	(0.138)	[1]	ND	(1.37)	[1]	NA			NA		
Benzoic acid	ND	(3.28)	[1]	ND	(32.5)	[1]	NA			NA		
Benzyl alcohol	ND	(0.0676)	[1]	ND	(0.671)	[1]	NA			NA		
Butylbenzylphthalate	ND	(0.229)	[1]	ND	(2.27)	[1]	NA			NA		
Chrysene	< DL	(0.125)	[1]	ND	(1.24)	[1]	NA			NA		
Di-n-octylphthalate	ND	(0.0648)	[1]	ND	(0.642)	[1]	NA			NA		
Dibenz(a,h)anthracene	ND	(0.126)	[1]	ND	(1.25)	[1]	NA			NA		
Dibenzofuran	0.0843	(0.0696)	[1]	0.699	(0.691)	[1]	NA			NA		
Dibutylphthalate	< DL	(0.0621)	[1]	ND	(0.616)	[1]	NA			NA		
Diethylphthalate	ND	(0.0319)	[1]	ND	(0.316)	[1]	NA			NA		
Dimethylphthalate	ND	(0.0563)	[1]	ND	(0.558)	[1]	NA			NA		
Diphenylamine	ND	(0.113)	[1]	ND	(1.12)	[1]	NA			NA		
Fluoranthene	0.308	(0.0741)	[1]	1.15	(0.735)	[1]	NA			NA		
Fluorene	0.171	(0.0577)	[1]	0.762	(0.572)	[1]	NA			NA		
Hexachlorobenzene	ND	(0.0692)	[1]	ND	(0.687)	[1]	NA			NA		
Hexachlorobutadiene	ND	(0.13)	[1]	ND	(1.28)	[1]	NA			NA		
Hexachlorocyclopentadiene	ND	(0.149)	[1]	ND	(1.48)	[1]	NA			NA		
Hexachloroethane	ND	(0.0694)	[1]	ND	(0.688)	[1]	NA			NA		
Indeno(1,2,3-cd)pyrene	ND	(0.111)	[1]	ND	(1.1)	[1]	NA			NA		
Isophorone	ND	(0.0406)	[1]	ND	(0.403)	[1]	NA			NA		
N-Nitroso-di-n-propylamine	ND	(0.0775)	[1]	ND	(0.768)	[1]	NA			NA		
Naphthalene	0.337	(0.097)	[1]	23.4	(0.962)	[1]	NA			NA		
Nitrobenzene	ND	(0.0552)	[1]	ND	(0.547)	[1]	NA			NA		
Pentachlorophenol	ND	(0.12)	[1]	ND	(1.19)	[1]	NA			NA		
Phenanthrene	0.352	(0.0829)	[1]	1.04	(0.823)	[1]	NA			NA		
Phenol	ND	(0.0468)	[1]	1.19	(0.464)	[1]	NA			NA		
Pyrene	0.213	(0.0889)	[1]	< DL	(0.882)	[1]	NA			NA		
bis(2-Chloroethoxy)methane	ND	(0.0795)	[1]	ND	(0.788)	[1]	NA			NA		
bis(2-Chloroethyl)ether	ND	(0.0613)	[1]	ND	(0.608)	[1]	NA			NA		
bis(2-Chloroisopropyl)ether	ND	(0.0557)	[1]	ND	(0.552)	[1]	NA			NA		
bis(2-Ethylhexyl)phthalate	8.73	(0.334)	[1]	4.08	(3.31)	[1]	NA			NA		
p-Chloroaniline	ND	(0.118)	[1]	ND	(1.17)	[1]	NA			NA		
SW846 - Percent Moisture (percent)												
Percent moisture	20.1	(0)	[1]	22.9	(0)	[1]	9	(0)	[1]	18.9	(0)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 E1 KRF-E1-U1012 10 - 12			9 E1 KRF-E1-U1618 16 - 18			9 E1 KRF-E1-U1618D 16 - 18			9 E1 KRF-E1-U2425 24 - 25		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	3350	(285)	[10]	~~21300~~ 22,000 SB	(536)	[20]	22900	(536)	[20]	4690	(132)	[5]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	NA			ND	(532)	[500]	ND	(530)	[500]	ND	(1050)	[1000]
1,1,2,2-Tetrachloroethane	NA			ND	(692)	[500]	ND	(690)	[500]	ND	(1370)	[1000]
1,1,2-Trichloroethane	NA			ND	(525)	[500]	ND	(524)	[500]	ND	(1040)	[1000]
1,1-Dichloroethane	NA			ND	(417)	[500]	ND	(416)	[500]	ND	(825)	[1000]
1,1-Dichloroethene	NA			ND	(1030)	[500]	ND	(1030)	[500]	ND	(2040)	[1000]
1,2-Dichloroethane	NA			ND	(762)	[500]	ND	(760)	[500]	ND	(1510)	[1000]
1,2-Dichloropropane	NA			ND	(1440)	[500]	ND	(1430)	[500]	ND	(2850)	[1000]
2-Chloroethyl vinyl ether	NA			ND	(762)	[500]	ND	(760)	[500]	ND	(1510)	[1000]
2-Hexanone	NA			ND	(842)	[500]	ND	(840)	[500]	ND	(1670)	[1000]
4-Methyl-2-Pentanone(MIBK)	NA			ND	(569)	[500]	ND	(567)	[500]	ND	(1130)	[1000]
Acetone	NA			< DL	(3150)	[500]	< DL	(3140)	[500]	< DL	(6230)	[1000]
Benzene	NA			923	(352)	[500]	1590	(352)	[500]	< DL	(698)	[1000]
Bromodichloromethane	NA			ND	(1930)	[500]	ND	(1920)	[500]	ND	(3810)	[1000]
Bromomethane	NA			ND	(992)	[500]	ND	(990)	[500]	ND	(1960)	[1000]
Carbon disulfide	NA			ND	(789)	[500]	ND	(787)	[500]	ND	(1560)	[1000]
Carbon tetrachloride	NA			ND	(778)	[500]	ND	(776)	[500]	ND	(1540)	[1000]
Chlorobenzene	NA			55500	(542)	[500]	70500	(541)	[500]	94900	(1070)	[1000]
Chloroethane	NA			ND	(724)	[500]	ND	(722)	[500]	ND	(1430)	[1000]
Chloroform	NA			ND	(323)	[500]	ND	(322)	[500]	ND	(639)	[1000]
Chloromethane	NA			ND	(524)	[500]	< DL	(522)	[500]	ND	(1040)	[1000]
Dibromochloromethane	NA			ND	(380)	[500]	ND	(379)	[500]	ND	(753)	[1000]
Ethyl benzene	NA			ND	(590)	[500]	ND	(589)	[500]	< DL	(1170)	[1000]
Methyl ethyl ketone	NA			1720 B	(1480)	[500]	1720 B	(1480)	[500]	3550 B	(2930)	[1000]
Methylene Chloride	NA			3440	(992)	[500]	1170	(990)	[500]	2430	(1960)	[1000]
Styrene	NA			ND	(579)	[500]	ND	(578)	[500]	ND	(1150)	[1000]
Tetrachloroethene	NA			ND	(783)	[500]	ND	(781)	[500]	ND	(1550)	[1000]
Toluene	NA			ND	(432)	[500]	ND	(431)	[500]	4690	(855)	[1000]
Tribromomethane(Bromoform)	NA			ND	(260)	[500]	ND	(259)	[500]	ND	(514)	[1000]
Trichloroethene	NA			ND	(837)	[500]	ND	(835)	[500]	ND	(1660)	[1000]
Vinyl Chloride	NA			ND	(660)	[500]	ND	(658)	[500]	ND	(1310)	[1000]
Vinyl acetate	NA			ND	(440)	[500]	ND	(439)	[500]	ND	(871)	[1000]
Xylene (total)	NA			ND	(1360)	[500]	ND	(1360)	[500]	7260	(2700)	[1000]
cis-1,3-Dichloropropene	NA			ND	(291)	[500]	ND	(290)	[500]	ND	(576)	[1000]

Compiled: 22 June 1994   () = Detection Limit   [] = Dilution Factor   ND = Not Detected   NA = Not Applicable   * - Value considered suspect, Refer to QC Report

PARAMETER	9 E1 KRF-E1-U1012 10 - 12	9 E1 KRF-E1-U1618 16 - 18				9 E1 KRF-E1-U1618D 16 - 18				9 E1 KRF-E1-U2425 24 - 25		

SW8240 - Volatile Organics, cont. (ug/kg)												
trans-1,2-Dichloroethene	NA	ND		(896)	[500]	ND		(894)	[500]	ND	(1770)	[1000]
trans-1,3-Dichloropropene	NA	ND		(789)	[500]	ND		(787)	[500]	ND	(1560)	[1000]
SW8270 - Semivolatile Organics (ug/g)												
1,2,4-Trichlorobenzene	NA	ND		(0.0466)	[1]	ND		(0.0475)	[1]	3.23	(0.437)	[1]
1,2-Dichlorobenzene	NA	0.258		(0.0651)	[1]	0.344		(0.0663)	[1]	112	(0.611)	[1]
1,3-Dichlorobenzene	NA	0.587		(0.0592)	[1]	0.68		(0.0603)	[1]	7.29	(0.556)	[1]
1,4-Dichlorobenzene	NA	1.03		(0.0775)	[1]	1.15		(0.0789)	[1]	17.5	(0.727)	[1]
2,4,5-Trichlorophenol	NA	ND	X	(0.0583)	[1]	ND	X	(0.0593)	[1]	ND	(0.547)	[1]
2,4,6-Trichlorophenol	NA	ND	X	(0.0694)	[1]	ND	X	(0.0707)	[1]	ND	(0.651)	[1]
2,4-Dichlorophenol	NA	ND		(0.0922)	[1]	ND		(0.0939)	[1]	ND	(0.865)	[1]
2,4-Dimethylphenol	NA	ND		(0.0855)	[1]	ND		(0.087)	[1]	ND	(0.802)	[1]
2,4-Dinitrophenol	NA	ND	X	(0.119)	[1]	ND	X	(0.121)	[1]	ND	(1.11)	[1]
2,4-Dinitrotoluene	NA	ND	X	(0.0724)	[1]	ND	X	(0.0738)	[1]	ND	(0.68)	[1]
2,6-Dinitrotoluene	NA	ND	X	(0.0789)	[1]	ND	X	(0.0804)	[1]	ND	(0.741)	[1]
2-Chloronaphthalene	NA	ND	X	(0.0696)	[1]	ND	X	(0.0709)	[1]	ND	(0.653)	[1]
2-Chlorophenol	NA	ND		(0.0599)	[1]	ND		(0.0611)	[1]	ND	(0.563)	[1]
2-Methylnaphthalene	NA	15.7		(0.0615)	[1]	20.7		(0.313)	[5]	6.1	(0.577)	[1]
2-Methylphenol	NA	ND		(0.0333)	[1]	ND		(0.0339)	[1]	ND	(0.312)	[1]
2-Nitroaniline	NA	ND	X	(0.0782)	[1]	ND	X	(0.0797)	[1]	ND	(0.734)	[1]
2-Nitrophenol	NA	ND		(0.0785)	[1]	ND		(0.08)	[1]	ND	(0.737)	[1]
3,3'-Dichlorobenzidine	NA	ND		(0.0948)	[1]	ND		(0.0966)	[1]	ND	(0.89)	[1]
3-Nitroaniline	NA	ND	X	(0.0825)	[1]	ND	X	(0.084)	[1]	ND	(0.774)	[1]
4,6-Dinitro-2-methylphenol	NA	ND		(0.104)	[1]	ND		(0.106)	[1]	ND	(0.976)	[1]
4-Bromophenyl phenyl ether	NA	ND		(0.0444)	[1]	ND		(0.0452)	[1]	ND	(0.417)	[1]
4-Chloro-3-methylphenol	NA	ND		(0.0424)	[1]	ND		(0.0432)	[1]	ND	(0.398)	[1]
4-Chlorophenyl phenyl ether	NA	ND	X	(0.0496)	[1]	ND	X	(0.0505)	[1]	ND	(0.465)	[1]
4-Methylphenol/3-Methylphenol	NA	ND		(0.0386)	[1]	ND		(0.0393)	[1]	ND	(0.363)	[1]
4-Nitroaniline	NA	ND	X	(0.115)	[1]	ND	X	(0.118)	[1]	ND	(1.08)	[1]
4-Nitrophenol	NA	ND	X	(0.123)	[1]	ND	X	(0.125)	[1]	ND	(1.15)	[1]
Acenaphthene	NA	ND	X	(0.0677)	[1]	ND	X	(0.069)	[1]	ND	(0.635)	[1]
Acenaphthylene	NA	ND	X	(0.0671)	[1]	ND	X	(0.0683)	[1]	ND	(0.629)	[1]
Anthracene	NA	0.0856		(0.0808)	[1]	0.0895		(0.0823)	[1]	ND	(0.759)	[1]
Benzo(a)anthracene	NA	0.114		(0.063)	[1]	0.111		(0.0642)	[1]	ND	(0.591)	[1]
Benzo(a)pyrene	NA	ND		(0.0842)	[1]	ND	X	(0.0858)	[1]	ND	(0.79)	[1]
Benzo(b)fluoranthene	NA	0.216	F	(0.111)	[1]	0.305	XF	(0.113)	[1]	ND	(1.04)	[1]

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PARAMETER	9 E1 KRF-E1-U1012 10 - 12				9 E1 KRF-E1-U1618 16 - 18				9 E1 KRF-E1-U1618D 16 - 18				9 E1 KRF-E1-U2425 24 - 25			
SW8270 - Semivolatile Organics, cont. (ug/g)																
Benzo(g,h,i)perylene	NA				ND		(0.12)	[1]	ND	X	(0.122)	[1]	ND		(1.12)	[1]
Benzo(k)fluoranthene	NA				0.216	F	(0.117)	[1]	0.305	XF	(0.119)	[1]	ND		(1.09)	[1]
Benzoic acid	NA				ND		(2.76)	[1]	ND		(2.81)	[1]	ND		(25.9)	[1]
Benzyl alcohol	NA				ND		(0.057)	[1]	ND		(0.0581)	[1]	ND		(0.535)	[1]
Butylbenzylphthalate	NA				ND		(0.193)	[1]	< DL		(0.197)	[1]	ND		(1.81)	[1]
Chrysene	NA				0.203		(0.105)	[1]	0.233		(0.107)	[1]	ND		(0.985)	[1]
Di-n-octylphthalate	NA				ND		(0.0546)	[1]	ND	X	(0.0556)	[1]	ND		(0.512)	[1]
Dibenz(a,h)anthracene	NA				ND		(0.106)	[1]	ND	X	(0.108)	[1]	ND		(0.995)	[1]
Dibenzofuran	NA				ND	X	(0.0587)	[1]	ND	X	(0.0598)	[1]	ND		(0.551)	[1]
Dibutylphthalate	NA				0.612		(0.0524)	[1]	0.677		(0.0534)	[1]	ND		(0.492)	[1]
Diethylphthalate	NA				ND	X	(0.0269)	[1]	ND	X	(0.0274)	[1]	ND		(0.252)	[1]
Dimethylphthalate	NA				ND	X	(0.0475)	[1]	ND	X	(0.0483)	[1]	ND		(0.445)	[1]
Diphenylamine	NA				ND		(0.0953)	[1]	ND		(0.0971)	[1]	ND		(0.894)	[1]
Fluoranthene	NA				3.1		(0.0625)	[1]	3.84		(0.0636)	[1]	0.664		(0.586)	[1]
Fluorene	NA				ND	X	(0.0486)	[1]	ND	X	(0.0495)	[1]	ND		(0.456)	[1]
Hexachlorobenzene	NA				0.171		(0.0584)	[1]	ND		(0.0595)	[1]	ND		(0.548)	[1]
Hexachlorobutadiene	NA				ND		(0.109)	[1]	ND		(0.111)	[1]	ND		(1.02)	[1]
Hexachlorocyclopentadiene	NA				ND	X	(0.126)	[1]	ND	X	(0.128)	[1]	ND		(1.18)	[1]
Hexachloroethane	NA				ND		(0.0585)	[1]	ND		(0.0596)	[1]	ND		(0.549)	[1]
Indeno(1,2,3-cd)pyrene	NA				ND		(0.0935)	[1]	ND	X	(0.0953)	[1]	ND		(0.878)	[1]
Isophorone	NA				ND		(0.0342)	[1]	ND		(0.0349)	[1]	ND		(0.321)	[1]
N-Nitroso-di-n-propylamine	NA				ND		(0.0653)	[1]	ND		(0.0665)	[1]	ND		(0.613)	[1]
Naphthalene	NA				ND		(0.0818)	[1]	ND		(0.0833)	[1]	2.97		(0.767)	[1]
Nitrobenzene	NA				ND		(0.0465)	[1]	ND		(0.0474)	[1]	ND		(0.436)	[1]
Pentachlorophenol	NA				ND		(0.101)	[1]	ND		(0.103)	[1]	ND		(0.947)	[1]
Phenanthrene	NA				1.46		(0.0699)	[1]	1.63		(0.0712)	[1]	ND		(0.656)	[1]
Phenol	NA				ND		(0.0395)	[1]	ND		(0.0402)	[1]	ND		(0.37)	[1]
Pyrene	NA				0.736		(0.075)	[1]	0.785		(0.0763)	[1]	ND		(0.703)	[1]
bis(2-Chloroethoxy)methane	NA				ND		(0.067)	[1]	ND		(0.0682)	[1]	ND		(0.629)	[1]
bis(2-Chloroethyl)ether	NA				ND		(0.0517)	[1]	ND		(0.0526)	[1]	ND		(0.485)	[1]
bis(2-Chloroisopropyl)ether	NA				ND		(0.0469)	[1]	ND		(0.0478)	[1]	ND		(0.44)	[1]
bis(2-Ethylhexyl)phthalate	NA				25.9		(1.41)	[5]	26.1		(1.43)	[5]	3.61		(2.64)	[1]
p-Chloroaniline	NA				ND		(0.0995)	[1]	ND		(0.101)	[1]	ND		(0.934)	[1]
SW846 - Percent Moisture (percent)																
Percent moisture	12.5		(0)	[1]	6.89		(0)	[1]	7.13		(0)	[1]	6.01		(0)	[1]

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PARAMETER	9 E2 KRF-E2-U0002 0 - 2			9 E2 KRF-E2-U1012 10 - 12			9 E2 KRF-E2-U2628 26 - 28			9 E3 KRF-E3-U1416 14 - 16		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	1730	(32)	[1]	141	(33.7)	[1]	4440	(147)	[5]	1210	(32.1)	[1]
SW846 - Percent Moisture (percent)												
Percent moisture	22.1	(0)	[1]	26.2	(0)	[1]	15.1	(0)	[1]	22.3	(0)	[1]

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PARAMETER	9			9			9			9		
	E3			E3			E3			E4		
	KRF-E3-U1618			KRF-E3-U2022			KRF-E3-U2829			KRF-E4-U0709		
	16 - 18			20 - 22			28 - 29			7 - 9		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	7410	(157)	[5]	1360	(33.3)	[1]	325	(26.5)	[1]	1310	(29.7)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(125)	[100]	ND	(13100)	[10000]	NA			NA		
1,1,2,2-Tetrachloroethane	ND	(163)	[100]	ND	(17100)	[10000]	NA			NA		
1,1,2-Trichloroethane	ND	(123)	[100]	ND	(13000)	[10000]	NA			NA		
1,1-Dichloroethane	ND	(98)	[100]	ND	(10300)	[10000]	NA			NA		
1,1-Dichloroethene	ND	(242)	[100]	ND	(25500)	[10000]	NA			NA		
1,2-Dichloroethane	ND	(179)	[100]	ND	(18800)	[10000]	NA			NA		
1,2-Dichloropropane	ND	(338)	[100]	ND	(35500)	[10000]	NA			NA		
2-Chloroethyl vinyl ether	ND	(179)	[100]	ND	(18800)	[10000]	NA			NA		
2-Hexanone	ND	(198)	[100]	ND	(20800)	[10000]	NA			NA		
4-Methyl-2-Pentanone(MIBK)	ND	(134)	[100]	ND	(14100)	[10000]	NA			NA		
Acetone	< DL	(740)	[100]	ND	(77900)	[10000]	NA			NA		
Benzene	ND	(82.8)	[100]	ND	(8710)	[10000]	NA			NA		
Bromodichloromethane	ND	(453)	[100]	ND	(47600)	[10000]	NA			NA		
Bromomethane	ND	(233)	[100]	ND	(24500)	[10000]	NA			NA		
Carbon disulfide	ND	(185)	[100]	ND	(19500)	[10000]	NA			NA		
Carbon tetrachloride	ND	(183)	[100]	ND	(19200)	[10000]	NA			NA		
Chlorobenzene	8440	(127)	[100]	< DL	(13400)	[10000]	NA			NA		
Chloroethane	ND	(170)	[100]	ND	(17900)	[10000]	NA			NA		
Chloroform	ND	(75.9)	[100]	ND	(7980)	[10000]	NA			NA		
Chloromethane	ND	(123)	[100]	< DL	(12900)	[10000]	NA			NA		
Dibromochloromethane	ND	(89.4)	[100]	ND	(9400)	[10000]	NA			NA		
Ethyl benzene	< DL	(139)	[100]	< DL	(14600)	[10000]	NA			NA		
Methyl ethyl ketone	467 B	(348)	[100]	ND	(36600)	[10000]	NA			NA		
Methylene Chloride	339	(233)	[100]	35100	(24500)	[10000]	NA			NA		
Styrene	ND	(136)	[100]	ND	(14300)	[10000]	NA			NA		
Tetrachloroethene	ND	(184)	[100]	ND	(19400)	[10000]	NA			NA		
Toluene	ND	(102)	[100]	80600	(10700)	[10000]	NA			NA		
Tribromomethane(Bromoform)	ND	(61)	[100]	ND	(6420)	[10000]	NA			NA		
Trichloroethene	ND	(197)	[100]	ND	(20700)	[10000]	NA			NA		
Vinyl Chloride	ND	(155)	[100]	ND	(16300)	[10000]	NA			NA		
Vinyl acetate	ND	(103)	[100]	ND	(10900)	[10000]	NA			NA		
Xylene (total)	ND	(320)	[100]	89900	(33700)	[10000]	NA			NA		
cis-1,3-Dichloropropene	ND	(68.3)	[100]	ND	(7190)	[10000]	NA			NA		

Compiled: 22 Jun 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 E3 KRF-E3-U1618 16 - 18			9 E3 KRF-E3-U2022 20 - 22			9 E3 KRF-E3-U2829 28 - 29	9 E4 KRF-E4-U0709 7 - 9
SW8240 - Volatile Organics, cont. (ug/kg)								
trans-1,2-Dichloroethene	ND	(211)	[100]	ND	(22100)	[10000]	NA	NA
trans-1,3-Dichloropropene	ND	(185)	[100]	ND	(19500)	[10000]	NA	NA
SW8270 - Semivolatile Organics (ug/g)								
1,2,4-Trichlorobenzene	ND	(0.107)	[1]	11.5	(1.06)	[1]	NA	NA
1,2-Dichlorobenzene	< DL	(0.0908)	[1]	192	(0.896)	[1]	NA	NA
1,3-Dichlorobenzene	0.334	(0.0552)	[1]	14.2	(0.545)	[1]	NA	NA
1,4-Dichlorobenzene	2.42	(0.0865)	[1]	132	(0.853)	[1]	NA	NA
2,4,5-Trichlorophenol	ND	(0.0861)	[1]	ND	(0.85)	[1]	NA	NA
2,4,6-Trichlorophenol	ND	(0.0619)	[1]	ND	(0.611)	[1]	NA	NA
2,4-Dichlorophenol	ND	(0.0277)	[1]	ND	(0.274)	[1]	NA	NA
2,4-Dimethylphenol	ND	(0.108)	[1]	82.3	(1.07)	[1]	NA	NA
2,4-Dinitrophenol	ND	(0.343)	[1]	ND	(3.39)	[1]	NA	NA
2,4-Dinitrotoluene	ND	(0.0616)	[1]	ND	(0.608)	[1]	NA	NA
2,6-Dinitrotoluene	ND	(0.097)	[1]	ND	(0.958)	[1]	NA	NA
2-Chloronaphthalene	ND	(0.141)	[1]	ND	(1.39)	[1]	NA	NA
2-Chlorophenol	ND	(0.083)	[1]	ND	(0.82)	[1]	NA	NA
2-Methylnaphthalene	0.772	(0.0894)	[1]	152	(0.882)	[1]	NA	NA
2-Methylphenol	ND	(0.078)	[1]	21.7	(0.77)	[1]	NA	NA
2-Nitroaniline	ND	(0.141)	[1]	ND	(1.39)	[1]	NA	NA
2-Nitrophenol	ND	(0.0848)	[1]	ND	(0.836)	[1]	NA	NA
3,3'-Dichlorobenzidine	ND	(0.0661)	[1]	ND	(0.652)	[1]	NA	NA
3-Nitroaniline	ND	(0.105)	[1]	ND	(1.04)	[1]	NA	NA
4,6-Dinitro-2-methylphenol	ND	(0.12)	[1]	ND	(1.18)	[1]	NA	NA
4-Bromophenyl phenyl ether	ND	(0.108)	[1]	ND	(1.07)	[1]	NA	NA
4-Chloro-3-methylphenol	ND	(0.0816)	[1]	ND	(0.805)	[1]	NA	NA
4-Chlorophenyl phenyl ether	ND	(0.0704)	[1]	ND	(0.695)	[1]	NA	NA
4-Methylphenol/3-Methylphenol	ND	(0.0537)	[1]	70.2 F	(0.53)	[1]	NA	NA
4-Nitroaniline	ND	(0.134)	[1]	ND	(1.32)	[1]	NA	NA
4-Nitrophenol	ND	(0.342)	[1]	ND	(3.38)	[1]	NA	NA
Acenaphthene	ND	(0.0892)	[1]	1.27	(0.88)	[1]	NA	NA
Acenaphthylene	ND	(0.0778)	[1]	ND	(0.767)	[1]	NA	NA
Anthracene	ND	(0.0721)	[1]	ND	(0.712)	[1]	NA	NA
Benzo(a)anthracene	< DL	(0.0676)	[1]	< DL	(0.667)	[1]	NA	NA
Benzo(a)pyrene	ND	(0.0854)	[1]	< DL	(0.843)	[1]	NA	NA
Benzo(b)fluoranthene	0.0895 F	(0.0862)	[1]	< DL	(0.851)	[1]	NA	NA

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PARAMETER	9 E3 KRF-E3-U1618 16 - 18			9 E3 KRF-E3-U2022 20 - 22			9 E3 KRF-E3-U2829 28 - 29			9 E4 KRF-E4-U0709 7 - 9		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Benzo(g,h,i)perylene	ND	(0.083)	[1]	< DL	(0.82)	[1]	NA			NA		
Benzo(k)fluoranthene	< DL	(0.108)	[1]	< DL	(1.07)	[1]	NA			NA		
Benzoic acid	ND	(0.74)	[1]	ND	(7.3)	[1]	NA			NA		
Benzyl alcohol	ND	(0.0746)	[1]	ND	(0.736)	[1]	NA			NA		
Butylbenzylphthalate	ND	(0.217)	[1]	< DL	(2.14)	[1]	NA			NA		
Chrysene	< DL	(0.0894)	[1]	< DL	(0.882)	[1]	NA			NA		
Di-n-octylphthalate	ND	(0.0979)	[1]	ND	(0.966)	[1]	NA			NA		
Dibenz(a,h)anthracene	ND	(0.0898)	[1]	ND	(0.886)	[1]	NA			NA		
Dibenzofuran	ND	(0.0682)	[1]	ND	(0.673)	[1]	NA			NA		
Dibutylphthalate	ND	(0.0714)	[1]	2.86	(0.705)	[1]	NA			NA		
Diethylphthalate	ND	(0.0467)	[1]	ND	(0.461)	[1]	NA			NA		
Dimethylphthalate	ND	(0.0488)	[1]	ND	(0.482)	[1]	NA			NA		
Diphenylamine	ND	(0.114)	[1]	ND	(1.12)	[1]	NA			NA		
Fluoranthene	0.278	(0.0769)	[1]	26.2	(0.759)	[1]	NA			NA		
Fluorene	0.128	(0.0638)	[1]	3.27	(0.629)	[1]	NA			NA		
Hexachlorobenzene	ND	(0.0865)	[1]	2.76	(0.853)	[1]	NA			NA		
Hexachlorobutadiene	ND	(0.0904)	[1]	ND	(0.892)	[1]	NA			NA		
Hexachlorocyclopentadiene	ND	(0.261)	[1]	ND	(2.58)	[1]	NA			NA		
Hexachloroethane	ND	(0.103)	[1]	ND	(1.02)	[1]	NA			NA		
Indeno(1,2,3-cd)pyrene	ND	(0.0651)	[1]	< DL	(0.643)	[1]	NA			NA		
Isophorone	ND	(0.0938)	[1]	ND	(0.926)	[1]	NA			NA		
N-Nitroso-di-n-propylamine	ND	(0.0529)	[1]	ND	(0.522)	[1]	NA			NA		
Naphthalene	0.207	(0.0778)	[1]	53.3	(0.767)	[1]	NA			NA		
Nitrobenzene	ND	(0.14)	[1]	ND	(1.38)	[1]	NA			NA		
Pentachlorophenol	ND	(0.13)	[1]	ND	(1.28)	[1]	NA			NA		
Phenanthrene	0.336	(0.0999)	[1]	4.79	(0.985)	[1]	NA			NA		
Phenol	ND	(0.0408)	[1]	4.2	(0.403)	[1]	NA			NA		
Pyrene	0.113	(0.0547)	[1]	1.59	(0.54)	[1]	NA			NA		
bis(2-Chloroethoxy)methane	ND	(0.103)	[1]	ND	(1.01)	[1]	NA			NA		
bis(2-Chloroethyl)ether	ND	(0.113)	[1]	ND	(1.12)	[1]	NA			NA		
bis(2-Chloroisopropyl)ether	ND	(0.14)	[1]	ND	(1.38)	[1]	NA			NA		
bis(2-Ethylhexyl)phthalate	15.2 B	(0.183)	[1]	132 B	(1.8)	[1]	NA			NA		
p-Chloroaniline	ND	(0.109)	[1]	ND	(1.08)	[1]	NA			NA		
SW846 - Percent Moisture (percent)												
Percent moisture	20.7	(0)	[1]	24.9	(0)	[1]	5.94	(0)	[1]	16	(0)	[1]

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PARAMETER	9 E4 KRF-E4-U0911 9 - 11			9 E4 KRF-E4-U2426 24 - 26			9 E5 KRF-E5-U0406 4 - 6			9 E5 KRF-E5-U0608 6 - 8		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	729	(29.3)	[1]	3660	(54)	[2]	2710	(59.9)	[2]	1530	(29.6)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(1.83)	[1]	ND	(1070)	[1000]	ND	(1.86)	[1]	ND	(1.85)	[1]
1,1,2,2-Tetrachloroethane	ND	(4.96)	[1]	ND	(1400)	[1000]	ND	(5.06)	[1]	ND	(5.03)	[1]
1,1,2-Trichloroethane	ND	(1.49)	[1]	ND	(1060)	[1000]	ND	(1.52)	[1]	ND	(1.51)	[1]
1,1-Dichloroethane	ND	(1.68)	[1]	ND	(841)	[1000]	ND	(1.71)	[1]	ND	(1.7)	[1]
1,1-Dichloroethene	ND	(2.51)	[1]	ND	(2080)	[1000]	ND	(2.56)	[1]	ND	(2.55)	[1]
1,2-Dichloroethane	ND	(1.7)	[1]	ND	(1540)	[1000]	ND	(1.73)	[1]	ND	(1.72)	[1]
1,2-Dichloropropane	ND	(2.56)	[1]	ND	(2900)	[1000]	ND	(2.62)	[1]	ND	(2.6)	[1]
2-Chloroethyl vinyl ether	ND	(2.8)	[1]	ND	(1540)	[1000]	ND	(2.85)	[1]	ND	(2.84)	[1]
2-Hexanone	ND	(0.937)	[1]	ND	(1700)	[1000]	ND	(0.956)	[1]	ND	(0.951)	[1]
4-Methyl-2-Pentanone(MIBK)	ND	(0.894)	[1]	ND	(1150)	[1000]	ND	(0.913)	[1]	ND	(0.908)	[1]
Acetone	194 B	(1.47)	[1]	< DL	(6350)	[1000]	24.8 B	(1.5)	[1]	13 B	(1.49)	[1]
Benzene	< DL	(1.69)	[1]	823	(711)	[1000]	< DL	(1.72)	[1]	< DL	(1.71)	[1]
Bromodichloromethane	ND	(1.59)	[1]	ND	(3890)	[1000]	ND	(1.63)	[1]	ND	(1.62)	[1]
Bromomethane	ND	(1.96)	[1]	ND	(2000)	[1000]	ND	(2)	[1]	ND	(1.99)	[1]
Carbon disulfide	ND	(2.53)	[1]	ND	(1590)	[1000]	ND	(2.58)	[1]	ND	(2.57)	[1]
Carbon tetrachloride	ND	(1.95)	[1]	ND	(1570)	[1000]	ND	(1.99)	[1]	ND	(1.98)	[1]
Chlorobenzene	6.77	(4.54)	[1]	239000	(4720)	[2000]	7.41	(4.63)	[1]	12.6	(4.61)	[1]
Chloroethane	ND	(2)	[1]	ND	(1460)	[1000]	ND	(2.04)	[1]	ND	(2.03)	[1]
Chloroform	ND	(2.04)	[1]	ND	(652)	[1000]	ND	(2.09)	[1]	ND	(2.08)	[1]
Chloromethane	ND	(2.38)	[1]	1350	(1060)	[1000]	ND	(2.43)	[1]	ND	(2.42)	[1]
Dibromochloromethane	ND	(1.79)	[1]	ND	(767)	[1000]	ND	(1.83)	[1]	ND	(1.82)	[1]
Ethyl benzene	ND	(1.62)	[1]	1360	(1190)	[1000]	ND	(1.65)	[1]	ND	(1.64)	[1]
Methyl ethyl ketone	48.1 B	(1.49)	[1]	4370 B	(2990)	[1000]	9.61 B	(1.52)	[1]	8.13 B	(1.51)	[1]
Methylene Chloride	3.28	(2.55)	[1]	3100	(2000)	[1000]	8.68	(2.61)	[1]	4.33	(2.59)	[1]
Styrene	ND	(1.58)	[1]	ND	(1170)	[1000]	ND	(1.62)	[1]	ND	(1.61)	[1]
Tetrachloroethene	ND	(4.64)	[1]	ND	(1580)	[1000]	ND	(4.74)	[1]	ND	(4.72)	[1]
Toluene	2.54	(1.66)	[1]	< DL	(871)	[1000]	3.57	(1.7)	[1]	2.57	(1.69)	[1]
Tribromomethane(Bromoform)	ND	(1.48)	[1]	ND	(524)	[1000]	ND	(1.51)	[1]	ND	(1.5)	[1]
Trichloroethene	ND	(4.75)	[1]	ND	(1690)	[1000]	ND	(4.85)	[1]	ND	(4.82)	[1]
Vinyl Chloride	ND	(2.02)	[1]	ND	(1330)	[1000]	ND	(2.06)	[1]	ND	(2.05)	[1]
Vinyl acetate	ND	(10.7)	[1]	ND	(887)	[1000]	ND	(10.9)	[1]	ND	(10.9)	[1]
Xylene (total)	ND	(3.56)	[1]	10300	(2750)	[1000]	ND	(3.63)	[1]	ND	(3.61)	[1]
cis-1,3-Dichloropropene	ND	(1.57)	[1]	ND	(587)	[1000]	ND	(1.6)	[1]	ND	(1.6)	[1]

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PARAMETER	9 E4 KRF-E4-U0911 9 - 11			9 E4 KRF-E4-U2426 24 - 26			9 E5 KRF-E5-U0406 4 - 6			9 E5 KRF-E5-U0608 6 - 8		
SW8240 - Volatile Organics, cont. (ug/kg)												
trans-1,2-Dichloroethene	ND	(2.28)	[1]	ND	(1810)	[1000]	ND	(2.32)	[1]	ND	(2.31)	[1]
trans-1,3-Dichloropropene	ND	(1.7)	[1]	ND	(1590)	[1000]	ND	(1.73)	[1]	ND	(1.72)	[1]
SW8270 - Semivolatile Organics (ug/g)												
1,2,4-Trichlorobenzene	ND XY	(0.0865)	[5]	0.248	(0.0927)	[1]	ND	(0.0348)	[1]	ND	(0.0345)	[1]
1,2-Dichlorobenzene	ND XY	(0.121)	[5]	1.24	(0.0784)	[1]	ND	(0.0295)	[1]	0.045	(0.0292)	[1]
1,3-Dichlorobenzene	ND XY	(0.11)	[5]	2.63	(0.0477)	[1]	ND	(0.0179)	[1]	ND	(0.0177)	[1]
1,4-Dichlorobenzene	ND XY	(0.144)	[5]	17.9	(0.149)	[2]	ND	(0.0281)	[1]	ND	(0.0278)	[1]
2,4,5-Trichlorophenol	ND XY	(0.108)	[5]	ND	(0.0743)	[1]	ND	(0.028)	[1]	ND	(0.0277)	[1]
2,4,6-Trichlorophenol	ND XY	(0.129)	[5]	ND	(0.0535)	[1]	ND	(0.0201)	[1]	ND	(0.0199)	[1]
2,4-Dichlorophenol	ND XY	(0.171)	[5]	ND	(0.0239)	[1]	ND	(0.009)	[1]	ND	(0.00891)	[1]
2,4-Dimethylphenol	ND XY	(0.159)	[5]	ND	(0.0934)	[1]	ND	(0.0351)	[1]	ND	(0.0348)	[1]
2,4-Dinitrophenol	ND XY	(0.22)	[5]	ND	(0.297)	[1]	ND	(0.111)	[1]	ND	(0.11)	[1]
2,4-Dinitrotoluene	ND XY	(0.134)	[5]	ND	(0.0532)	[1]	ND	(0.02)	[1]	ND	(0.0198)	[1]
2,6-Dinitrotoluene	ND XY	(0.147)	[5]	ND	(0.0838)	[1]	ND	(0.0315)	[1]	ND	(0.0312)	[1]
2-Chloronaphthalene	ND XY	(0.129)	[5]	ND	(0.122)	[1]	ND	(0.0458)	[1]	ND	(0.0454)	[1]
2-Chlorophenol	ND XY	(0.111)	[5]	ND	(0.0717)	[1]	ND	(0.027)	[1]	ND	(0.0267)	[1]
2-Methylnaphthalene	ND XY	(0.114)	[5]	6.13	(0.0772)	[1]	ND	(0.029)	[1]	< DL	(0.0288)	[1]
2-Methylphenol	ND XY	(0.0618)	[5]	ND	(0.0673)	[1]	ND	(0.0253)	[1]	ND	(0.0251)	[1]
2-Nitroaniline	ND XY	(0.145)	[5]	ND	(0.122)	[1]	ND	(0.0458)	[1]	ND	(0.0454)	[1]
2-Nitrophenol	ND XY	(0.146)	[5]	ND	(0.0732)	[1]	ND	(0.0275)	[1]	ND	(0.0273)	[1]
3,3'-Dichlorobenzidine	ND XY	(0.176)	[5]	ND	(0.0571)	[1]	ND	(0.0215)	[1]	ND	(0.0213)	[1]
3-Nitroaniline	ND XY	(0.153)	[5]	ND	(0.0911)	[1]	ND	(0.0342)	[1]	ND	(0.0339)	[1]
4,6-Dinitro-2-methylphenol	ND XY	(0.193)	[5]	ND	(0.103)	[1]	ND	(0.0389)	[1]	ND	(0.0385)	[1]
4-Bromophenyl phenyl ether	ND XY	(0.0824)	[5]	ND	(0.0933)	[1]	ND	(0.0351)	[1]	ND	(0.0347)	[1]
4-Chloro-3-methylphenol	ND XY	(0.0787)	[5]	ND	(0.0704)	[1]	ND	(0.0265)	[1]	ND	(0.0262)	[1]
4-Chlorophenyl phenyl ether	ND XY	(0.092)	[5]	ND	(0.0608)	[1]	ND	(0.0229)	[1]	ND	(0.0226)	[1]
4-Methylphenol/3-Methylphenol	ND XY	(0.0717)	[5]	ND	(0.0464)	[1]	ND	(0.0174)	[1]	ND	(0.0173)	[1]
4-Nitroaniline	ND XY	(0.214)	[5]	ND	(0.115)	[1]	ND	(0.0434)	[1]	ND	(0.043)	[1]
4-Nitrophenol	ND XY	(0.228)	[5]	ND	(0.295)	[1]	ND	(0.111)	[1]	ND	(0.11)	[1]
Acenaphthene	ND XY	(0.126)	[5]	ND	(0.077)	[1]	ND	(0.0289)	[1]	0.0603	(0.0287)	[1]
Acenaphthylene	ND XY	(0.125)	[5]	ND	(0.0671)	[1]	ND	(0.0252)	[1]	ND	(0.025)	[1]
Anthracene	< DL XY	(0.15)	[5]	< DL	(0.0623)	[1]	0.0297	(0.0234)	[1]	0.144	(0.0232)	[1]
Benzo(a)anthracene	0.151 XY	(0.117)	[5]	< DL	(0.0583)	[1]	0.0836	(0.0219)	[1]	0.344	(0.0217)	[1]
Benzo(a)pyrene	< DL XY	(0.156)	[5]	ND	(0.0737)	[1]	0.102	(0.0277)	[1]	0.329	(0.0274)	[1]
Benzo(b)fluoranthene	< DL XY	(0.207)	[5]	ND	(0.0744)	[1]	0.244 F	(0.028)	[1]	0.735 F	(0.0277)	[1]

ompiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9				9				9				9			
	E4				E4				E5				E5			
	KRF-E4-U0911				KRF-E4-U2426				KRF-E5-U0406				KRF-E5-U0608			
	9 - 11				24 - 26				4 - 6				6 - 8			
SW8270 - Semivolatile Organics, cont. (ug/g)																
Benzo(g,h,i)perylene	ND	XY	(0.222)	[5]	< DL		(0.0717)	[1]	0.0406		(0.027)	[1]	0.0883		(0.0267)	[1]
Benzo(k)fluoranthene	< DL	XY	(0.216)	[5]	ND		(0.0936)	[1]	0.244	F	(0.0352)	[1]	0.735	F	(0.0349)	[1]
Benzoic acid	ND	XY	(5.13)	[5]	ND		(0.639)	[1]	ND		(0.24)	[1]	ND		(0.238)	[1]
Benzyl alcohol	ND	XY	(0.106)	[5]	ND		(0.0644)	[1]	ND		(0.0242)	[1]	ND		(0.024)	[1]
Butylbenzylphthalate	ND	XY	(0.359)	[5]	ND		(0.187)	[1]	ND		(0.0705)	[1]	0.0698		(0.0598)	[1]
Chrysene	< DL	XY	(0.195)	[5]	< DL		(0.0772)	[1]	0.133		(0.029)	[1]	0.388		(0.0288)	[1]
Di-n-octylphthalate	ND	XY	(0.101)	[5]	ND		(0.0845)	[1]	< DL		(0.0318)	[1]	0.034		(0.0315)	[1]
Dibenz(a,h)anthracene	ND	XY	(0.197)	[5]	ND		(0.0775)	[1]	ND		(0.0291)	[1]	< DL		(0.0289)	[1]
Dibenzofuran	ND	XY	(0.109)	[5]	ND		(0.0589)	[1]	ND		(0.0221)	[1]	0.038		(0.0219)	[1]
Dibutylphthalate	ND	XY	(0.0973)	[5]	0.158		(0.0616)	[1]	0.0323		(0.0232)	[1]	ND		(0.023)	[1]
Diethylphthalate	ND	XY	(0.0499)	[5]	ND		(0.0403)	[1]	ND		(0.0152)	[1]	ND		(0.015)	[1]
Dimethylphthalate	ND	XY	(0.0881)	[5]	ND		(0.0421)	[1]	ND		(0.0158)	[1]	ND		(0.0157)	[1]
Diphenylamine	ND	XY	(0.177)	[5]	ND		(0.0981)	[1]	ND		(0.0369)	[1]	ND		(0.0365)	[1]
Fluoranthene	0.265	XY	(0.116)	[5]	0.703		(0.0664)	[1]	0.203		(0.025)	[1]	0.872		(0.0247)	[1]
Fluorene	ND	XY	(0.0902)	[5]	0.179		(0.0551)	[1]	< DL		(0.0207)	[1]	0.0572		(0.0205)	[1]
Hexachlorobenzene	ND	XY	(0.108)	[5]	ND		(0.0747)	[1]	ND		(0.0281)	[1]	ND		(0.0278)	[1]
Hexachlorobutadiene	ND	XY	(0.203)	[5]	ND		(0.078)	[1]	ND		(0.0293)	[1]	ND		(0.0291)	[1]
Hexachlorocyclopentadiene	ND	XY	(0.234)	[5]	ND		(0.226)	[1]	ND		(0.0848)	[1]	ND		(0.084)	[1]
Hexachloroethane	ND	XY	(0.109)	[5]	ND		(0.0893)	[1]	ND		(0.0336)	[1]	ND		(0.0332)	[1]
Indeno(1,2,3-cd)pyrene	ND	XY	(0.174)	[5]	ND		(0.0562)	[1]	0.0605		(0.0211)	[1]	0.106		(0.0209)	[1]
Isophorone	ND	XY	(0.0635)	[5]	ND		(0.081)	[1]	ND		(0.0305)	[1]	ND		(0.0302)	[1]
N-Nitroso-di-n-propylamine	ND	XY	(0.121)	[5]	ND		(0.0456)	[1]	ND		(0.0172)	[1]	ND		(0.017)	[1]
Naphthalene	ND	XY	(0.152)	[5]	3.51		(0.0671)	[1]	ND		(0.0252)	[1]	0.0271		(0.025)	[1]
Nitrobenzene	ND	XY	(0.0863)	[5]	ND		(0.121)	[1]	ND		(0.0454)	[1]	ND		(0.045)	[1]
Pentachlorophenol	ND	XY	(0.187)	[5]	ND		(0.112)	[1]	ND		(0.0422)	[1]	ND		(0.0418)	[1]
Phenanthrene	0.226	XY	(0.13)	[5]	0.271		(0.0862)	[1]	0.128		(0.0324)	[1]	0.581		(0.0321)	[1]
Phenol	ND	XY	(0.0733)	[5]	ND		(0.0353)	[1]	ND		(0.0133)	[1]	ND		(0.0131)	[1]
Pyrene	0.228	XY	(0.139)	[5]	0.0941		(0.0472)	[1]	0.194		(0.0178)	[1]	0.591		(0.0176)	[1]
bis(2-Chloroethoxy)methane	ND	XY	(0.124)	[5]	ND		(0.0887)	[1]	ND		(0.0334)	[1]	ND		(0.0331)	[1]
bis(2-Chloroethyl)ether	ND	XY	(0.0959)	[5]	ND		(0.0978)	[1]	ND		(0.0368)	[1]	ND		(0.0364)	[1]
bis(2-Chloroisopropyl)ether	ND	XY	(0.0871)	[5]	ND		(0.121)	[1]	ND		(0.0454)	[1]	ND		(0.045)	[1]
bis(2-Ethylhexyl)phthalate	ND	XY	(0.522)	[5]	2.73	B	(0.158)	[1]	0.908	B	(0.0593)	[1]	0.725	B	(0.0588)	[1]
p-Chloroaniline	ND	XY	(0.185)	[5]	ND		(0.0941)	[1]	ND		(0.0354)	[1]	ND		(0.0351)	[1]
SW846 - Percent Moisture (percent)																
Percent moisture	14.8		(0)	[1]	7.6		(0)	[1]	16.7		(0)	[1]	15.6		(0)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 E5 KRF-E5-U1012 10 - 12			9 E5 KRF-E5-U1214 12 - 14			9 E5 KRF-E5-U1820 18 - 20			9 E5 KRF-E5-U2022 20 - 22		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	668	(30.4)	[1]	739	(31.7)	[1]	105000	(1630)	[50]	43500	(1680)	[50]
SW846 - Percent Moisture (percent)												
Percent moisture	18	(0)	[1]	21.2	(0)	[1]	23.3	(0)	[1]	25.6	(0)	[1]

Compiled: 22 J 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9			9			9			9		
	E6			E6			E6			E6		
	KRF-E6-U0810			KRF-E6-U1618			KRF-E6-U1618D			KRF-E6-U2022		
	8 - 10			16 - 18			16 - 18			20 - 22		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	1860	(149)	[5]	3160	(165)	[5]	233	(32.4)	[1]	22700	(615)	[20]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(3.75)	[1]	ND	(41.6)	[20]	ND	(41)	[20]	ND	(2430)	[2000]
1,1,2,2-Tetrachloroethane	ND	(10.2)	[1]	ND	(85.1)	[20]	ND	(83.8)	[20]	ND	(3170)	[2000]
1,1,2-Trichloroethane	ND	(3.06)	[1]	ND	(50.8)	[20]	ND	(50)	[20]	ND	(2400)	[2000]
1,1-Dichloroethane	ND	(3.44)	[1]	ND	(48.7)	[20]	ND	(48)	[20]	ND	(1910)	[2000]
1,1-Dichloroethene	ND	(5.15)	[1]	ND	(68.7)	[20]	ND	(67.7)	[20]	ND	(4710)	[2000]
1,2-Dichloroethane	ND	(3.49)	[1]	ND	(72.4)	[20]	ND	(71.3)	[20]	ND	(3480)	[2000]
1,2-Dichloropropane	ND	(5.27)	[1]	ND	(45.3)	[20]	ND	(44.6)	[20]	ND	(6580)	[2000]
2-Chloroethyl vinyl ether	ND	(5.75)	[1]	ND	(26.3)	[20]	ND	(25.9)	[20]	ND	(3480)	[2000]
2-Hexanone	ND	(1.93)	[1]	ND	(81.4)	[20]	ND	(80.1)	[20]	ND	(3850)	[2000]
4-Methyl-2-Pentanone(MIBK)	ND	(1.84)	[1]	ND	(70.3)	[20]	ND	(69.2)	[20]	ND	(2600)	[2000]
Acetone	335 B	(3.02)	[1]	ND	(110)	[20]	ND	(108)	[20]	< DL	(14400)	[2000]
Benzene	ND	(3.47)	[1]	ND	(94.8)	[20]	ND	(93.3)	[20]	13100	(1610)	[2000]
Bromodichloromethane	ND	(3.28)	[1]	ND	(60.3)	[20]	ND	(59.4)	[20]	ND	(8810)	[2000]
Bromomethane	ND	(4.04)	[1]	ND	(96.7)	[20]	ND	(95.2)	[20]	ND	(4540)	[2000]
Carbon disulfide	ND	(5.2)	[1]	ND	(89)	[20]	ND	(87.6)	[20]	ND	(3610)	[2000]
Carbon tetrachloride	ND	(4.01)	[1]	ND	(71.9)	[20]	ND	(70.8)	[20]	ND	(3560)	[2000]
Chlorobenzene	12.4	(9.33)	[1]	2310	(57.4)	[20]	1180	(56.5)	[20]	203000	(2480)	[2000]
Chloroethane	ND	(4.11)	[1]	ND	(86.4)	[20]	ND	(85.1)	[20]	ND	(3310)	[2000]
Chloroform	ND	(4.2)	[1]	ND	(38.2)	[20]	ND	(37.6)	[20]	ND	(1480)	[2000]
Chloromethane	ND	(4.89)	[1]	ND	(73.5)	[20]	ND	(72.3)	[20]	ND	(2390)	[2000]
Dibromochloromethane	ND	(3.68)	[1]	ND	(42.9)	[20]	ND	(42.3)	[20]	ND	(1740)	[2000]
Ethyl benzene	ND	(3.33)	[1]	< DL	(62.9)	[20]	< DL	(62)	[20]	< DL	(2700)	[2000]
Methyl ethyl ketone	76.4 B	(3.06)	[1]	ND	(107)	[20]	ND	(105)	[20]	9100 B	(6770)	[2000]
Methylene Chloride	< DL	(5.25)	[1]	ND	(106)	[20]	ND	(104)	[20]	5910	(4540)	[2000]
Styrene	ND	(3.25)	[1]	ND	(45)	[20]	ND	(44.3)	[20]	ND	(2650)	[2000]
Tetrachloroethene	ND	(9.55)	[1]	ND	(68)	[20]	ND	(66.9)	[20]	ND	(3580)	[2000]
Toluene	< DL	(3.42)	[1]	127	(39.5)	[20]	63.5	(38.9)	[20]	ND	(1980)	[2000]
Tribromomethane(Bromoform)	ND	(3.04)	[1]	ND	(53.7)	[20]	ND	(52.9)	[20]	ND	(1190)	[2000]
Trichloroethene	ND	(9.76)	[1]	ND	(51.1)	[20]	ND	(50.3)	[20]	ND	(3830)	[2000]
Vinyl Chloride	ND	(4.16)	[1]	ND	(77.2)	[20]	ND	(76)	[20]	ND	(3020)	[2000]
Vinyl acetate	ND	(22)	[1]	ND	(31.1)	[20]	ND	(30.6)	[20]	ND	(2010)	[2000]
Xylene (total)	ND	(7.32)	[1]	228	(123)	[20]	< DL	(121)	[20]	ND	(6230)	[2000]
cis-1,3-Dichloropropene	ND	(3.23)	[1]	ND	(46.6)	[20]	ND	(45.9)	[20]	ND	(1330)	[2000]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 E6 KRF-E6-U0810 8 - 10			9 E6 KRF-E6-U1618 16 - 18			9 E6 KRF-E6-U1618D 16 - 18			9 E6 KRF-E6-U2022 20 - 22		
SW8240 - Volatile Organics, cont. (ug/kg)												
trans-1,2-Dichloroethene	ND	(4.68)	[1]	ND	(44.8)	[20]	ND	(44.1)	[20]	ND	(4100)	[2000]
trans-1,3-Dichloropropene	ND	(3.49)	[1]	ND	(50)	[20]	ND	(49.3)	[20]	ND	(3610)	[2000]
SW8270 - Semivolatile Organics (ug/g)												
1,2,4-Trichlorobenzene	ND	(0.0522)	[1]	ND	(0.0582)	[1]	ND	(0.0573)	[1]	ND	(0.516)	[1]
1,2-Dichlorobenzene	ND	(0.0729)	[1]	0.166	(0.0813)	[1]	ND	(0.0801)	[1]	ND	(0.721)	[1]
1,3-Dichlorobenzene	ND	(0.0663)	[1]	0.143	(0.0739)	[1]	ND	(0.0728)	[1]	ND	(0.656)	[1]
1,4-Dichlorobenzene	ND	(0.0867)	[1]	1.04	(0.0967)	[1]	0.106	(0.0953)	[1]	ND	(0.858)	[1]
2,4,5-Trichlorophenol	ND	(0.0652)	[1]	ND	(0.0727)	[1]	ND	(0.0717)	[1]	ND	(0.646)	[1]
2,4,6-Trichlorophenol	ND	(0.0777)	[1]	ND	(0.0866)	[1]	ND	(0.0854)	[1]	ND	(0.769)	[1]
2,4-Dichlorophenol	ND	(0.103)	[1]	ND	(0.115)	[1]	ND	(0.113)	[1]	ND	(1.02)	[1]
2,4-Dimethylphenol	ND	(0.0957)	[1]	0.241	(0.107)	[1]	ND	(0.105)	[1]	ND	(0.947)	[1]
2,4-Dinitrophenol	ND	(0.133)	[1]	ND	(0.148)	[1]	ND	(0.146)	[1]	ND	(1.31)	[1]
2,4-Dinitrotoluene	ND	(0.0811)	[1]	ND	(0.0904)	[1]	ND	(0.0891)	[1]	ND	(0.803)	[1]
2,6-Dinitrotoluene	ND	(0.0884)	[1]	ND	(0.0986)	[1]	ND	(0.0971)	[1]	ND	(0.875)	[1]
2-Chloronaphthalene	ND	(0.0779)	[1]	ND	(0.0869)	[1]	ND	(0.0856)	[1]	ND	(0.771)	[1]
2-Chlorophenol	ND	(0.0671)	[1]	ND	(0.0748)	[1]	ND	(0.0737)	[1]	ND	(0.664)	[1]
2-Methylnaphthalene	ND	(0.0689)	[1]	0.582	(0.0768)	[1]	ND	(0.0757)	[1]	1.85	(0.682)	[1]
2-Methylphenol	ND	(0.0373)	[1]	ND	(0.0415)	[1]	ND	(0.0409)	[1]	ND	(0.369)	[1]
2-Nitroaniline	ND	(0.0876)	[1]	ND	(0.0976)	[1]	ND	(0.0962)	[1]	ND	(0.867)	[1]
2-Nitrophenol	ND	(0.0879)	[1]	ND	(0.098)	[1]	ND	(0.0966)	[1]	ND	(0.87)	[1]
3,3'-Dichlorobenzidine	ND	(0.106)	[1]	ND	(0.118)	[1]	ND	(0.117)	[1]	ND	(1.05)	[1]
3-Nitroaniline	ND	(0.0924)	[1]	ND	(0.103)	[1]	ND	(0.102)	[1]	ND	(0.914)	[1]
4,6-Dinitro-2-methylphenol	ND	(0.116)	[1]	ND	(0.13)	[1]	ND	(0.128)	[1]	ND	(1.15)	[1]
4-Bromophenyl phenyl ether	ND	(0.0497)	[1]	ND	(0.0554)	[1]	ND	(0.0546)	[1]	ND	(0.492)	[1]
4-Chloro-3-methylphenol	ND	(0.0475)	[1]	ND	(0.0529)	[1]	ND	(0.0522)	[1]	ND	(0.47)	[1]
4-Chlorophenyl phenyl ether	ND	(0.0555)	[1]	ND	(0.0619)	[1]	ND	(0.061)	[1]	ND	(0.549)	[1]
4-Methylphenol/3-Methylphenol	ND	(0.0432)	[1]	ND	(0.0482)	[1]	ND	(0.0475)	[1]	ND	(0.428)	[1]
4-Nitroaniline	ND	(0.129)	[1]	ND	(0.144)	[1]	ND	(0.142)	[1]	ND	(1.28)	[1]
4-Nitrophenol	ND	(0.137)	[1]	ND	(0.153)	[1]	ND	(0.151)	[1]	ND	(1.36)	[1]
Acenaphthene	< DL	(0.0758)	[1]	ND	(0.0845)	[1]	ND	(0.0833)	[1]	ND	(0.75)	[1]
Acenaphthylene	ND	(0.0751)	[1]	ND	(0.0837)	[1]	ND	(0.0825)	[1]	ND	(0.743)	[1]
Anthracene	< DL	(0.0905)	[1]	ND	(0.101)	[1]	ND	(0.0994)	[1]	ND	(0.896)	[1]
Benzo(a)anthracene	0.4	(0.0705)	[1]	ND	(0.0786)	[1]	ND	(0.0775)	[1]	ND	(0.698)	[1]
Benzo(a)pyrene	0.436	(0.0942)	[1]	ND	(0.105)	[1]	ND	(0.104)	[1]	ND	(0.933)	[1]
Benzo(b)fluoranthene	1.04 F	(0.125)	[1]	ND	(0.139)	[1]	ND	(0.137)	[1]	ND	(1.23)	[1]

	9			9			9			9		
	E6			E6			E6			E6		
	KRF-E6-U0810			KRF-E6-U1618			KRF-E6-U1618D			KRF-E6-U2022		
PARAMETER	8 - 10			16 - 18			16 - 18			20 - 22		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Benzo(g,h,i)perylene	0.17	(0.134)	[1]	ND	(0.149)	[1]	ND	(0.147)	[1]	ND	(1.33)	[1]
Benzo(k)fluoranthene	1.04 F	(0.13)	[1]	ND	(0.145)	[1]	ND	(0.143)	[1]	ND	(1.29)	[1]
Benzoic acid	ND	(3.09)	[1]	ND	(3.45)	[1]	ND	(3.4)	[1]	ND	(30.6)	[1]
Benzyl alcohol	ND	(0.0638)	[1]	ND	(0.0712)	[1]	ND	(0.0701)	[1]	ND	(0.632)	[1]
Butylbenzylphthalate	< DL	(0.216)	[1]	ND	(0.241)	[1]	ND	(0.238)	[1]	ND	(2.14)	[1]
Chrysene	0.65	(0.118)	[1]	ND	(0.131)	[1]	ND	(0.129)	[1]	ND	(1.16)	[1]
Di-n-octylphthalate	ND	(0.0611)	[1]	ND	(0.0681)	[1]	ND	(0.0672)	[1]	ND	(0.605)	[1]
Dibenz(a,h)anthracene	ND	(0.119)	[1]	ND	(0.132)	[1]	ND	(0.13)	[1]	ND	(1.17)	[1]
Dibenzofuran	< DL	(0.0657)	[1]	ND	(0.0733)	[1]	ND	(0.0722)	[1]	ND	(0.65)	[1]
Dibutylphthalate	ND	(0.0586)	[1]	ND	(0.0654)	[1]	ND	(0.0644)	[1]	0.679	(0.58)	[1]
Diethylphthalate	ND	(0.0301)	[1]	ND	(0.0335)	[1]	ND	(0.0331)	[1]	ND	(0.298)	[1]
Dimethylphthalate	ND	(0.0531)	[1]	ND	(0.0592)	[1]	ND	(0.0584)	[1]	ND	(0.526)	[1]
Diphenylamine	ND	(0.107)	[1]	ND	(0.119)	[1]	ND	(0.117)	[1]	ND	(1.06)	[1]
Fluoranthene	1.03	(0.0699)	[1]	0.104	(0.078)	[1]	ND	(0.0768)	[1]	2.19	(0.692)	[1]
Fluorene	0.0699	(0.0544)	[1]	ND	(0.0607)	[1]	ND	(0.0598)	[1]	ND	(0.539)	[1]
Hexachlorobenzene	ND	(0.0653)	[1]	ND	(0.0729)	[1]	ND	(0.0718)	[1]	ND	(0.647)	[1]
Hexachlorobutadiene	ND	(0.122)	[1]	ND	(0.136)	[1]	ND	(0.134)	[1]	ND	(1.21)	[1]
Hexachlorocyclopentadiene	ND	(0.141)	[1]	ND	(0.157)	[1]	ND	(0.155)	[1]	ND	(1.4)	[1]
Hexachloroethane	ND	(0.0655)	[1]	ND	(0.073)	[1]	ND	(0.0719)	[1]	ND	(0.648)	[1]
Indeno(1,2,3-cd)pyrene	0.168	(0.105)	[1]	ND	(0.117)	[1]	ND	(0.115)	[1]	ND	(1.04)	[1]
Isophorone	ND	(0.0383)	[1]	ND	(0.0427)	[1]	ND	(0.0421)	[1]	ND	(0.379)	[1]
N-Nitroso-di-n-propylamine	ND	(0.0731)	[1]	ND	(0.0815)	[1]	ND	(0.0803)	[1]	ND	(0.724)	[1]
Naphthalene	ND	(0.0915)	[1]	0.47	(0.102)	[1]	ND	(0.101)	[1]	1.16	(0.906)	[1]
Nitrobenzene	ND	(0.0521)	[1]	ND	(0.0581)	[1]	ND	(0.0572)	[1]	ND	(0.515)	[1]
Pentachlorophenol	ND	(0.113)	[1]	ND	(0.126)	[1]	ND	(0.124)	[1]	ND	(1.12)	[1]
Phenanthrene	0.336	(0.0783)	[1]	0.126	(0.0873)	[1]	ND	(0.086)	[1]	< DL	(0.775)	[1]
Phenol	ND	(0.0442)	[1]	ND	(0.0493)	[1]	ND	(0.0486)	[1]	ND	(0.437)	[1]
Pyrene	0.946	(0.0839)	[1]	< DL	(0.0936)	[1]	ND	(0.0922)	[1]	< DL	(0.831)	[1]
bis(2-Chloroethoxy)methane	ND	(0.075)	[1]	ND	(0.0836)	[1]	ND	(0.0824)	[1]	ND	(0.742)	[1]
bis(2-Chloroethyl)ether	ND	(0.0578)	[1]	ND	(0.0645)	[1]	ND	(0.0635)	[1]	ND	(0.572)	[1]
bis(2-Chloroisopropyl)ether	ND	(0.0525)	[1]	ND	(0.0586)	[1]	ND	(0.0577)	[1]	ND	(0.52)	[1]
bis(2-Ethylhexyl)phthalate	< DL	(0.315)	[1]	3.18	(0.351)	[1]	< DL	(0.346)	[1]	18.1	(3.12)	[1]
p-Chloroaniline	ND	(0.111)	[1]	ND	(0.124)	[1]	ND	(0.122)	[1]	ND	(1.1)	[1]
SW846 - Percent Moisture (percent)												
Percent moisture	16	(0)	[1]	24.3	(0)	[1]	23.1	(0)	[1]	18.9	(0)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 E7 KRF-E7-U0204 2 - 4				9 E7 KRF-E7-U1214 12 - 14				9 E8 KRF-E8-U0608 6 - 8				9 E8 KRF-E8-U2426 24 - 26			
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)																
Hydrocarbons	492		(29.7)	[1]	1400		(32.9)	[1]	655		(30.8)	[1]	10100		(144)	[5]
SW8240 - Volatile Organics (ug/kg)																
1,1,1-Trichloroethane	ND		(1.87)	[1]	NA				ND		(1.93)	[1]	NA			
1,1,2,2-Tetrachloroethane	ND		(5.09)	[1]	NA				ND		(5.25)	[1]	NA			
1,1,2-Trichloroethane	ND		(1.53)	[1]	NA				ND		(1.58)	[1]	NA			
1,1-Dichloroethane	ND		(1.72)	[1]	NA				ND		(1.77)	[1]	NA			
1,1-Dichloroethene	ND		(2.57)	[1]	NA				ND		(2.65)	[1]	NA			
1,2-Dichloroethane	ND		(1.74)	[1]	NA				ND		(1.8)	[1]	NA			
1,2-Dichloropropane	ND		(2.63)	[1]	NA				ND		(2.72)	[1]	NA			
2-Chloroethyl vinyl ether	ND		(2.87)	[1]	NA				ND		(2.96)	[1]	NA			
2-Hexanone	ND		(0.962)	[1]	NA				ND		(0.992)	[1]	NA			
4-Methyl-2-Pentanone(MIBK)	ND		(0.918)	[1]	NA				ND		(0.947)	[1]	NA			
Acetone	7.3	B	(1.51)	[1]	NA				27.4	B	(1.55)	[1]	NA			
Benzene	< DL		(1.73)	[1]	NA				< DL		(1.79)	[1]	NA			
Bromodichloromethane	ND		(1.64)	[1]	NA				ND		(1.69)	[1]	NA			
Bromomethane	ND		(2.02)	[1]	NA				ND		(2.08)	[1]	NA			
Carbon disulfide	ND		(2.6)	[1]	NA				ND		(2.68)	[1]	NA			
Carbon tetrachloride	ND		(2)	[1]	NA				ND		(2.07)	[1]	NA			
Chlorobenzene	7.85		(4.66)	[1]	NA				8		(4.81)	[1]	NA			
Chloroethane	ND		(2.05)	[1]	NA				ND		(2.12)	[1]	NA			
Chloroform	ND		(2.1)	[1]	NA				ND		(2.17)	[1]	NA			
Chloromethane	ND		(2.44)	[1]	NA				ND		(2.52)	[1]	NA			
Dibromochloromethane	ND		(1.84)	[1]	NA				ND		(1.9)	[1]	NA			
Ethyl benzene	ND		(1.66)	[1]	NA				ND		(1.71)	[1]	NA			
Methyl ethyl ketone	11.5	B	(1.53)	[1]	NA				14.8	B	(1.58)	[1]	NA			
Methylene Chloride	< DL		(2.62)	[1]	NA				< DL		(2.7)	[1]	NA			
Styrene	ND		(1.62)	[1]	NA				ND		(1.68)	[1]	NA			
Tetrachloroethene	ND		(4.77)	[1]	NA				ND		(4.92)	[1]	NA			
Toluene	1.94		(1.71)	[1]	NA				2.5		(1.76)	[1]	NA			
Tribromomethane(Bromoform)	ND		(1.52)	[1]	NA				ND		(1.57)	[1]	NA			
Trichloroethene	ND		(4.87)	[1]	NA				ND		(5.03)	[1]	NA			
Vinyl Chloride	ND		(2.08)	[1]	NA				ND		(2.14)	[1]	NA			
Vinyl acetate	ND		(11)	[1]	NA				ND		(11.3)	[1]	NA			
Xylene (total)	ND		(3.65)	[1]	NA				ND		(3.77)	[1]	NA			
cis-1,3-Dichloropropene	ND		(1.61)	[1]	NA				ND		(1.66)	[1]	NA			

Compiled: 22 Jı 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer t [illegible] Report

PARAMETER	9 E7 KRF-E7-U0204 2 - 4				9 E7 KRF-E7-U1214 12 - 14	9 E8 KRF-E8-U0608 6 - 8				9 E8 KRF-E8-U2426 24 - 26
SW8240 - Volatile Organics, cont. (ug/kg)										
trans-1,2-Dichloroethene	ND		(2.34)	[1]	NA	ND		(2.41)	[1]	NA
trans-1,3-Dichloropropene	ND		(1.74)	[1]	NA	ND		(1.8)	[1]	NA
SW8270 - Semivolatile Organics (ug/g)										
1,2,4-Trichlorobenzene	ND		(0.0176)	[1]	NA	ND		(0.0357)	[1]	NA
1,2-Dichlorobenzene	ND		(0.0245)	[1]	NA	< DL		(0.0302)	[1]	NA
1,3-Dichlorobenzene	ND		(0.0223)	[1]	NA	ND		(0.0183)	[1]	NA
1,4-Dichlorobenzene	ND		(0.0292)	[1]	NA	ND		(0.0287)	[1]	NA
2,4,5-Trichlorophenol	ND		(0.022)	[1]	NA	ND		(0.0286)	[1]	NA
2,4,6-Trichlorophenol	ND		(0.0262)	[1]	NA	ND		(0.0206)	[1]	NA
2,4-Dichlorophenol	ND		(0.0347)	[1]	NA	ND		(0.00922)	[1]	NA
2,4-Dimethylphenol	ND		(0.0322)	[1]	NA	ND		(0.036)	[1]	NA
2,4-Dinitrophenol	ND		(0.0447)	[1]	NA	ND		(0.114)	[1]	NA
2,4-Dinitrotoluene	ND		(0.0273)	[1]	NA	ND		(0.0205)	[1]	NA
2,6-Dinitrotoluene	ND		(0.0298)	[1]	NA	ND		(0.0323)	[1]	NA
2-Chloronaphthalene	ND		(0.0262)	[1]	NA	ND		(0.0469)	[1]	NA
2-Chlorophenol	ND		(0.0226)	[1]	NA	ND		(0.0276)	[1]	NA
2-Methylnaphthalene	ND		(0.0232)	[1]	NA	ND		(0.0297)	[1]	NA
2-Methylphenol	ND		(0.0125)	[1]	NA	ND		(0.0259)	[1]	NA
2-Nitroaniline	ND		(0.0295)	[1]	NA	ND		(0.0469)	[1]	NA
2-Nitrophenol	ND		(0.0296)	[1]	NA	ND		(0.0282)	[1]	NA
3,3'-Dichlorobenzidine	ND		(0.0357)	[1]	NA	ND		(0.022)	[1]	NA
3-Nitroaniline	ND		(0.0311)	[1]	NA	ND		(0.0351)	[1]	NA
4,6-Dinitro-2-methylphenol	ND		(0.0392)	[1]	NA	ND		(0.0398)	[1]	NA
4-Bromophenyl phenyl ether	ND		(0.0167)	[1]	NA	ND		(0.0359)	[1]	NA
4-Chloro-3-methylphenol	ND		(0.016)	[1]	NA	ND		(0.0271)	[1]	NA
4-Chlorophenyl phenyl ether	ND		(0.0187)	[1]	NA	ND		(0.0234)	[1]	NA
4-Methylphenol/3-Methylphenol	ND		(0.0146)	[1]	NA	ND		(0.0179)	[1]	NA
4-Nitroaniline	ND		(0.0435)	[1]	NA	ND		(0.0444)	[1]	NA
4-Nitrophenol	ND		(0.0463)	[1]	NA	ND		(0.114)	[1]	NA
Acenaphthene	ND		(0.0255)	[1]	NA	ND		(0.0296)	[1]	NA
Acenaphthylene	ND		(0.0253)	[1]	NA	ND		(0.0259)	[1]	NA
Anthracene	ND		(0.0305)	[1]	NA	ND		(0.024)	[1]	NA
Benzo(a)anthracene	0.0787		(0.0237)	[1]	NA	0.0309		(0.0225)	[1]	NA
Benzo(a)pyrene	0.0831		(0.0317)	[1]	NA	0.0385		(0.0284)	[1]	NA
Benzo(b)fluoranthene	0.169	F	(0.0419)	[1]	NA	0.0987	F	(0.0287)	[1]	NA

Compiled: 22 June 1994   () = Detection Limit   [] = Dilution Factor   ND = Not Detected   NA = Not Applicable   * - Value considered suspect, Refer to QC Report

PARAMETER	9 E7 KRF-E7-U0204 2 - 4			9 E7 KRF-E7-U1214 12 - 14			9 E8 KRF-E8-U0608 6 - 8			9 E8 KRF-E8-U2426 24 - 26		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Benzo(g,h,i)perylene	< DL	(0.0451)	[1]	NA			< DL	(0.0276)	[1]	NA		
Benzo(k)fluoranthene	0.169 F	(0.0439)	[1]	NA			0.0987 F	(0.036)	[1]	NA		
Benzoic acid	ND	(1.04)	[1]	NA			ND	(0.246)	[1]	NA		
Benzyl alcohol	ND	(0.0215)	[1]	NA			ND	(0.0248)	[1]	NA		
Butylbenzylphthalate	ND	(0.0728)	[1]	NA			ND	(0.0722)	[1]	NA		
Chrysene	0.0791	(0.0396)	[1]	NA			0.0473	(0.0297)	[1]	NA		
Di-n-octylphthalate	ND	(0.0206)	[1]	NA			1.03	(0.0325)	[1]	NA		
Dibenz(a,h)anthracene	ND	(0.04)	[1]	NA			ND	(0.0298)	[1]	NA		
Dibenzofuran	ND	(0.0221)	[1]	NA			ND	(0.0227)	[1]	NA		
Dibutylphthalate	ND	(0.0197)	[1]	NA			ND	(0.0237)	[1]	NA		
Diethylphthalate	ND	(0.0101)	[1]	NA			ND	(0.0155)	[1]	NA		
Dimethylphthalate	ND	(0.0179)	[1]	NA			ND	(0.0162)	[1]	NA		
Diphenylamine	ND	(0.0359)	[1]	NA			ND	(0.0378)	[1]	NA		
Fluoranthene	0.129	(0.0235)	[1]	NA			0.0497	(0.0256)	[1]	NA		
Fluorene	ND	(0.0183)	[1]	NA			ND	(0.0212)	[1]	NA		
Hexachlorobenzene	ND	(0.022)	[1]	NA			ND	(0.0287)	[1]	NA		
Hexachlorobutadiene	ND	(0.0411)	[1]	NA			ND	(0.0301)	[1]	NA		
Hexachlorocyclopentadiene	ND	(0.0475)	[1]	NA			ND	(0.0868)	[1]	NA		
Hexachloroethane	ND	(0.022)	[1]	NA			ND	(0.0344)	[1]	NA		
Indeno(1,2,3-cd)pyrene	< DL	(0.0352)	[1]	NA			ND	(0.0217)	[1]	NA		
Isophorone	ND	(0.0129)	[1]	NA			ND	(0.0312)	[1]	NA		
N-Nitroso-di-n-propylamine	ND	(0.0246)	[1]	NA			ND	(0.0176)	[1]	NA		
Naphthalene	ND	(0.0308)	[1]	NA			ND	(0.0259)	[1]	NA		
Nitrobenzene	ND	(0.0175)	[1]	NA			ND	(0.0465)	[1]	NA		
Pentachlorophenol	ND	(0.038)	[1]	NA			ND	(0.0432)	[1]	NA		
Phenanthrene	0.0325	(0.0263)	[1]	NA			< DL	(0.0332)	[1]	NA		
Phenol	ND	(0.0149)	[1]	NA			ND	(0.0136)	[1]	NA		
Pyrene	0.112	(0.0282)	[1]	NA			0.0432	(0.0182)	[1]	NA		
bis(2-Chloroethoxy)methane	ND	(0.0252)	[1]	NA			ND	(0.0342)	[1]	NA		
bis(2-Chloroethyl)ether	ND	(0.0195)	[1]	NA			ND	(0.0377)	[1]	NA		
bis(2-Chloroisopropyl)ether	ND	(0.0177)	[1]	NA			ND	(0.0465)	[1]	NA		
bis(2-Ethylhexyl)phthalate	ND	(0.106)	[1]	NA			128 B	(1.22)	[20]	NA		
p-Chloroaniline	ND	(0.0375)	[1]	NA			ND	(0.0362)	[1]	NA		
SW846 - Percent Moisture (percent)												
Percent moisture	16	(0)	[1]	24.1	(0)	[1]	18.9	(0)	[1]	13.4	(0)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 E8 KRF-E8-U2628 26 - 28			9 F1 KRF-F1-U0406 4 - 6			9 F1 KRF-F1-U1012 10 - 12			9 F1 KRF-F1-U1820 18 - 20		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	2060	(27.5)	[1]	6910	(147)	[5]	1240	(33.6)	[1]	5440	(158)	[5]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	NA			ND	(1.83)	[1]	NA			NA		
1,1,2,2-Tetrachloroethane	NA			ND	(4.98)	[1]	NA			NA		
1,1,2-Trichloroethane	NA			ND	(1.5)	[1]	NA			NA		
1,1-Dichloroethane	NA			ND	(1.68)	[1]	NA			NA		
1,1-Dichloroethene	NA			ND	(2.52)	[1]	NA			NA		
1,2-Dichloroethane	NA			ND	(1.7)	[1]	NA			NA		
1,2-Dichloropropane	NA			ND	(2.57)	[1]	NA			NA		
2-Chloroethyl vinyl ether	NA			ND	(2.81)	[1]	NA			NA		
2-Hexanone	NA			ND	(0.941)	[1]	NA			NA		
4-Methyl-2-Pentanone(MIBK)	NA			ND	(0.898)	[1]	NA			NA		
Acetone	NA			13.7 B	(1.47)	[1]	NA			NA		
Benzene	NA			ND	(1.69)	[1]	NA			NA		
Bromodichloromethane	NA			ND	(1.6)	[1]	NA			NA		
Bromomethane	NA			ND	(1.97)	[1]	NA			NA		
Carbon disulfide	NA			ND	(2.54)	[1]	NA			NA		
Carbon tetrachloride	NA			ND	(1.96)	[1]	NA			NA		
Chlorobenzene	NA			9.95	(4.56)	[1]	NA			NA		
Chloroethane	NA			ND	(2.01)	[1]	NA			NA		
Chloroform	NA			ND	(2.05)	[1]	NA			NA		
Chloromethane	NA			ND	(2.39)	[1]	NA			NA		
Dibromochloromethane	NA			ND	(1.8)	[1]	NA			NA		
Ethyl benzene	NA			ND	(1.62)	[1]	NA			NA		
Methyl ethyl ketone	NA			8.07 B	(1.5)	[1]	NA			NA		
Methylene Chloride	NA			4.92	(2.56)	[1]	NA			NA		
Styrene	NA			ND	(1.59)	[1]	NA			NA		
Tetrachloroethene	NA			ND	(4.66)	[1]	NA			NA		
Toluene	NA			2.93	(1.67)	[1]	NA			NA		
Tribromomethane(Bromoform)	NA			ND	(1.48)	[1]	NA			NA		
Trichloroethene	NA			ND	(4.77)	[1]	NA			NA		
Vinyl Chloride	NA			ND	(2.03)	[1]	NA			NA		
Vinyl acetate	NA			ND	(10.8)	[1]	NA			NA		
Xylene (total)	NA			ND	(3.57)	[1]	NA			NA		
cis-1,3-Dichloropropene	NA			ND	(1.58)	[1]	NA			NA		

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 E8 KRF-E8-U2628 26 - 28	9 F1 KRF-F1-U0406 4 - 6				9 F1 KRF-F1-U1012 10 - 12	9 F1 KRF-F1-U1820 18 - 20
SW8240 - Volatile Organics, cont. (ug/kg)							
trans-1,2-Dichloroethene	NA	ND		(2.28)	[1]	NA	NA
trans-1,3-Dichloropropene	NA	ND		(1.7)	[1]	NA	NA
SW8270 - Semivolatile Organics (ug/g)							
1,2,4-Trichlorobenzene	NA	ND		(0.0339)	[1]	NA	NA
1,2-Dichlorobenzene	NA	ND		(0.0287)	[1]	NA	NA
1,3-Dichlorobenzene	NA	0.0356		(0.0174)	[1]	NA	NA
1,4-Dichlorobenzene	NA	0.207		(0.0273)	[1]	NA	NA
2,4,5-Trichlorophenol	NA	ND		(0.0272)	[1]	NA	NA
2,4,6-Trichlorophenol	NA	ND		(0.0196)	[1]	NA	NA
2,4-Dichlorophenol	NA	ND		(0.00875)	[1]	NA	NA
2,4-Dimethylphenol	NA	ND		(0.0342)	[1]	NA	NA
2,4-Dinitrophenol	NA	ND		(0.108)	[1]	NA	NA
2,4-Dinitrotoluene	NA	ND		(0.0194)	[1]	NA	NA
2,6-Dinitrotoluene	NA	ND		(0.0306)	[1]	NA	NA
2-Chloronaphthalene	NA	ND		(0.0445)	[1]	NA	NA
2-Chlorophenol	NA	ND		(0.0262)	[1]	NA	NA
2-Methylnaphthalene	NA	0.327		(0.0282)	[1]	NA	NA
2-Methylphenol	NA	ND		(0.0246)	[1]	NA	NA
2-Nitroaniline	NA	ND		(0.0445)	[1]	NA	NA
2-Nitrophenol	NA	ND		(0.0268)	[1]	NA	NA
3,3'-Dichlorobenzidine	NA	ND		(0.0209)	[1]	NA	NA
3-Nitroaniline	NA	ND		(0.0333)	[1]	NA	NA
4,6-Dinitro-2-methylphenol	NA	ND		(0.0378)	[1]	NA	NA
4-Bromophenyl phenyl ether	NA	ND		(0.0341)	[1]	NA	NA
4-Chloro-3-methylphenol	NA	ND		(0.0258)	[1]	NA	NA
4-Chlorophenyl phenyl ether	NA	ND		(0.0222)	[1]	NA	NA
4-Methylphenol/3-Methylphenol	NA	ND		(0.017)	[1]	NA	NA
4-Nitroaniline	NA	ND		(0.0422)	[1]	NA	NA
4-Nitrophenol	NA	ND		(0.108)	[1]	NA	NA
Acenaphthene	NA	0.157		(0.0282)	[1]	NA	NA
Acenaphthylene	NA	ND		(0.0246)	[1]	NA	NA
Anthracene	NA	0.351		(0.0228)	[1]	NA	NA
Benzo(a)anthracene	NA	0.221		(0.0213)	[1]	NA	NA
Benzo(a)pyrene	NA	0.24	X	(0.027)	[1]	NA	NA
Benzo(b)fluoranthene	NA	0.517	XF	(0.0272)	[1]	NA	NA

PARAMETER	9 E8 KRF-E8-U2628 26 - 28				9 F1 KRF-F1-U0406 4 - 6				9 F1 KRF-F1-U1012 10 - 12				9 F1 KRF-F1-U1820 18 - 20			
SW8270 - Semivolatile Organics, cont.	(ug/g)															
Benzo(g,h,i)perylene	NA				0.119	X	(0.0262)	[1]	NA				NA			
Benzo(k)fluoranthene	NA				0.517	XF	(0.0342)	[1]	NA				NA			
Benzoic acid	NA				ND		(0.234)	[1]	NA				NA			
Benzyl alcohol	NA				ND		(0.0236)	[1]	NA				NA			
Butylbenzylphthalate	NA				0.127		(0.0686)	[1]	NA				NA			
Chrysene	NA				0.382		(0.0282)	[1]	NA				NA			
Di-n-octylphthalate	NA				ND	X	(0.0309)	[1]	NA				NA			
Dibenz(a,h)anthracene	NA				ND	X	(0.0284)	[1]	NA				NA			
Dibenzofuran	NA				0.146		(0.0215)	[1]	NA				NA			
Dibutylphthalate	NA				ND		(0.0225)	[1]	NA				NA			
Diethylphthalate	NA				ND		(0.0148)	[1]	NA				NA			
Dimethylphthalate	NA				ND		(0.0154)	[1]	NA				NA			
Diphenylamine	NA				ND		(0.0359)	[1]	NA				NA			
Fluoranthene	NA				0.55		(0.0243)	[1]	NA				NA			
Fluorene	NA				ND		(0.0201)	[1]	NA				NA			
Hexachlorobenzene	NA				ND		(0.0273)	[1]	NA				NA			
Hexachlorobutadiene	NA				ND		(0.0285)	[1]	NA				NA			
Hexachlorocyclopentadiene	NA				ND		(0.0825)	[1]	NA				NA			
Hexachloroethane	NA				ND		(0.0327)	[1]	NA				NA			
Indeno(1,2,3-cd)pyrene	NA				0.0895	X	(0.0206)	[1]	NA				NA			
Isophorone	NA				ND		(0.0296)	[1]	NA				NA			
N-Nitroso-di-n-propylamine	NA				ND		(0.0167)	[1]	NA				NA			
Naphthalene	NA				0.0538		(0.0246)	[1]	NA				NA			
Nitrobenzene	NA				ND		(0.0442)	[1]	NA				NA			
Pentachlorophenol	NA				ND		(0.0411)	[1]	NA				NA			
Phenanthrene	NA				1.58		(0.0315)	[1]	NA				NA			
Phenol	NA				ND		(0.0129)	[1]	NA				NA			
Pyrene	NA				1.45		(0.0173)	[1]	NA				NA			
bis(2-Chloroethoxy)methane	NA				ND		(0.0325)	[1]	NA				NA			
bis(2-Chloroethyl)ether	NA				ND		(0.0358)	[1]	NA				NA			
bis(2-Chloroisopropyl)ether	NA				ND		(0.0442)	[1]	NA				NA			
bis(2-Ethylhexyl)phthalate	NA				0.452	B	(0.0577)	[1]	NA				NA			
p-Chloroaniline	NA				ND		(0.0344)	[1]	NA				NA			
SW846 - Percent Moisture (percent)																
Percent moisture	9.44		(0)	[1]	14.8		(0)	[1]	25.6		(0)	[1]	21		(0)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 F2 KRF-F2-U1416 14 - 16				9 F2 KRF-F2-U2628 26 - 28				9 F3 KRF-F3-U0406 4 - 6			9 F3 KRF-F3-U1012 10 - 12		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)														
Hydrocarbons	3250		(71.6)	[2]	4440		(141)	[5]	4920	(299)	[10]	336	(31.3)	[1]
SW8240 - Volatile Organics (ug/kg)														
1,1,1-Trichloroethane	ND		(141)	[100]	ND		(1110)	[1000]	NA			NA		
1,1,2,2-Tetrachloroethane	ND		(183)	[100]	ND		(1450)	[1000]	NA			NA		
1,1,2-Trichloroethane	ND		(139)	[100]	ND		(1100)	[1000]	NA			NA		
1,1-Dichloroethane	ND		(110)	[100]	ND		(874)	[1000]	NA			NA		
1,1-Dichloroethene	ND		(273)	[100]	ND		(2160)	[1000]	NA			NA		
1,2-Dichloroethane	ND		(202)	[100]	ND		(1600)	[1000]	NA			NA		
1,2-Dichloropropane	ND		(381)	[100]	ND		(3010)	[1000]	NA			NA		
2-Chloroethyl vinyl ether	ND		(202)	[100]	ND		(1600)	[1000]	NA			NA		
2-Hexanone	ND		(223)	[100]	ND		(1770)	[1000]	NA			NA		
4-Methyl-2-Pentanone(MIBK)	ND		(151)	[100]	ND		(1190)	[1000]	NA			NA		
Acetone	< DL		(833)	[100]	< DL		(6600)	[1000]	NA			NA		
Benzene	ND		(93.3)	[100]	< DL		(739)	[1000]	NA			NA		
Bromodichloromethane	ND		(510)	[100]	ND		(4040)	[1000]	NA			NA		
Bromomethane	ND		(263)	[100]	ND		(2080)	[1000]	NA			NA		
Carbon disulfide	ND		(209)	[100]	ND		(1650)	[1000]	NA			NA		
Carbon tetrachloride	ND		(206)	[100]	ND		(1630)	[1000]	NA			NA		
Chlorobenzene	312		(143)	[100]	75500		(1140)	[1000]	NA			NA		
Chloroethane	ND		(192)	[100]	ND		(1520)	[1000]	NA			NA		
Chloroform	ND		(85.5)	[100]	ND		(677)	[1000]	NA			NA		
Chloromethane	192		(139)	[100]	< DL		(1100)	[1000]	NA			NA		
Dibromochloromethane	ND		(101)	[100]	ND		(797)	[1000]	NA			NA		
Ethyl benzene	ND		(156)	[100]	< DL		(1240)	[1000]	NA			NA		
Methyl ethyl ketone	548	B	(392)	[100]	4340	B	(3100)	[1000]	NA			NA		
Methylene Chloride	420		(263)	[100]	2880		(2080)	[1000]	NA			NA		
Styrene	ND		(153)	[100]	ND		(1210)	[1000]	NA			NA		
Tetrachloroethene	ND		(207)	[100]	ND		(1640)	[1000]	NA			NA		
Toluene	< DL		(114)	[100]	5440		(905)	[1000]	NA			NA		
Tribromomethane(Bromoform)	ND		(68.7)	[100]	ND		(544)	[1000]	NA			NA		
Trichloroethene	ND		(222)	[100]	ND		(1750)	[1000]	NA			NA		
Vinyl Chloride	ND		(175)	[100]	ND		(1380)	[1000]	NA			NA		
Vinyl acetate	ND		(116)	[100]	ND		(922)	[1000]	NA			NA		
Xylene (total)	ND		(361)	[100]	7840		(2860)	[1000]	NA			NA		
cis-1,3-Dichloropropene	ND		(77)	[100]	ND		(609)	[1000]	NA			NA		

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PARAMETER	9 F2 KRF-F2-U1416 14 - 16			9 F2 KRF-F2-U2628 26 - 28			9 F3 KRF-F3-U0406 4 - 6			9 F3 KRF-F3-U1012 10 - 12		
SW8240 - Volatile Organics, cont. (ug/kg)												
trans-1,2-Dichloroethene	ND	(237)	[100]	ND	(1880)	[1000]	NA			NA		
trans-1,3-Dichloropropene	ND	(209)	[100]	ND	(1650)	[1000]	NA			NA		
SW8270 - Semivolatile Organics (ug/g)												
1,2,4-Trichlorobenzene	ND	(0.125)	[1]	1.28	(0.792)	[1]	NA			NA		
1,2-Dichlorobenzene	ND	(0.106)	[1]	46	(0.67)	[1]	NA			NA		
1,3-Dichlorobenzene	ND	(0.0643)	[1]	2.75	(0.407)	[1]	NA			NA		
1,4-Dichlorobenzene	ND	(0.101)	[1]	6.81	(0.638)	[1]	NA			NA		
2,4,5-Trichlorophenol	ND	(0.1)	[1]	ND	(0.635)	[1]	NA			NA		
2,4,6-Trichlorophenol	ND	(0.0721)	[1]	ND	(0.457)	[1]	NA			NA		
2,4-Dichlorophenol	ND	(0.0323)	[1]	ND	(0.205)	[1]	NA			NA		
2,4-Dimethylphenol	ND	(0.126)	[1]	1.01	(0.798)	[1]	NA			NA		
2,4-Dinitrophenol	ND	(0.4)	[1]	ND	(2.53)	[1]	NA			NA		
2,4-Dinitrotoluene	ND	(0.0717)	[1]	ND	(0.454)	[1]	NA			NA		
2,6-Dinitrotoluene	ND	(0.113)	[1]	ND	(0.716)	[1]	NA			NA		
2-Chloronaphthalene	ND	(0.164)	[1]	ND	(1.04)	[1]	NA			NA		
2-Chlorophenol	ND	(0.0967)	[1]	ND	(0.613)	[1]	NA			NA		
2-Methylnaphthalene	0.139	(0.104)	[1]	3.48	(0.66)	[1]	NA			NA		
2-Methylphenol	ND	(0.0908)	[1]	ND	(0.576)	[1]	NA			NA		
2-Nitroaniline	ND	(0.164)	[1]	ND	(1.04)	[1]	NA			NA		
2-Nitrophenol	ND	(0.0987)	[1]	ND	(0.625)	[1]	NA			NA		
3,3'-Dichlorobenzidine	ND	(0.077)	[1]	ND	(0.488)	[1]	NA			NA		
3-Nitroaniline	ND	(0.123)	[1]	ND	(0.778)	[1]	NA			NA		
4,6-Dinitro-2-methylphenol	ND	(0.139)	[1]	ND	(0.883)	[1]	NA			NA		
4-Bromophenyl phenyl ether	ND	(0.126)	[1]	ND	(0.797)	[1]	NA			NA		
4-Chloro-3-methylphenol	ND	(0.095)	[1]	ND	(0.602)	[1]	NA			NA		
4-Chlorophenyl phenyl ether	ND	(0.082)	[1]	ND	(0.519)	[1]	NA			NA		
4-Methylphenol/3-Methylphenol	ND	(0.0626)	[1]	ND	(0.396)	[1]	NA			NA		
4-Nitroaniline	ND	(0.156)	[1]	ND	(0.986)	[1]	NA			NA		
4-Nitrophenol	ND	(0.399)	[1]	ND	(2.52)	[1]	NA			NA		
Acenaphthene	ND	(0.104)	[1]	ND	(0.658)	[1]	NA			NA		
Acenaphthylene	ND	(0.0906)	[1]	ND	(0.574)	[1]	NA			NA		
Anthracene	ND	(0.084)	[1]	ND	(0.532)	[1]	NA			NA		
Benzo(a)anthracene	ND	(0.0787)	[1]	ND	(0.499)	[1]	NA			NA		
Benzo(a)pyrene	ND	(0.0994)	[1]	ND	(0.63)	[1]	NA			NA		
Benzo(b)fluoranthene	< DL	(0.1)	[1]	ND	(0.636)	[1]	NA			NA		

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PARAMETER	9 F2 KRF-F2-U1416 14 - 16			9 F2 KRF-F2-U2628 26 - 28			9 F3 KRF-F3-U0406 4 - 6			9 F3 KRF-F3-U1012 10 - 12		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Benzo(g,h,i)perylene	ND	(0.0967)	[1]	ND	(0.613)	[1]	NA			NA		
Benzo(k)fluoranthene	< DL	(0.126)	[1]	ND	(0.8)	[1]	NA			NA		
Benzoic acid	ND	(0.861)	[1]	ND	(5.46)	[1]	NA			NA		
Benzyl alcohol	ND	(0.0868)	[1]	ND	(0.55)	[1]	NA			NA		
Butylbenzylphthalate	< DL	(0.253)	[1]	ND	(1.6)	[1]	NA			NA		
Chrysene	ND	(0.104)	[1]	ND	(0.66)	[1]	NA			NA		
Di-n-octylphthalate	ND	(0.114)	[1]	ND	(0.722)	[1]	NA			NA		
Dibenz(a,h)anthracene	ND	(0.105)	[1]	ND	(0.662)	[1]	NA			NA		
Dibenzofuran	ND	(0.0794)	[1]	ND	(0.503)	[1]	NA			NA		
Dibutylphthalate	ND	(0.0831)	[1]	ND	(0.527)	[1]	NA			NA		
Diethylphthalate	ND	(0.0544)	[1]	ND	(0.345)	[1]	NA			NA		
Dimethylphthalate	ND	(0.0568)	[1]	ND	(0.36)	[1]	NA			NA		
Diphenylamine	ND	(0.132)	[1]	ND	(0.838)	[1]	NA			NA		
Fluoranthene	< DL	(0.0896)	[1]	< DL	(0.567)	[1]	NA			NA		
Fluorene	ND	(0.0743)	[1]	ND	(0.471)	[1]	NA			NA		
Hexachlorobenzene	ND	(0.101)	[1]	ND	(0.638)	[1]	NA			NA		
Hexachlorobutadiene	ND	(0.105)	[1]	ND	(0.667)	[1]	NA			NA		
Hexachlorocyclopentadiene	ND	(0.304)	[1]	ND	(1.93)	[1]	NA			NA		
Hexachloroethane	ND	(0.12)	[1]	ND	(0.763)	[1]	NA			NA		
Indeno(1,2,3-cd)pyrene	ND	(0.0758)	[1]	ND	(0.481)	[1]	NA			NA		
Isophorone	ND	(0.109)	[1]	ND	(0.692)	[1]	NA			NA		
N-Nitroso-di-n-propylamine	ND	(0.0616)	[1]	ND	(0.39)	[1]	NA			NA		
Naphthalene	ND	(0.0906)	[1]	1.55	(0.574)	[1]	NA			NA		
Nitrobenzene	ND	(0.163)	[1]	ND	(1.03)	[1]	NA			NA		
Pentachlorophenol	ND	(0.151)	[1]	ND	(0.959)	[1]	NA			NA		
Phenanthrene	0.274	(0.116)	[1]	< DL	(0.737)	[1]	NA			NA		
Phenol	ND	(0.0476)	[1]	ND	(0.301)	[1]	NA			NA		
Pyrene	< DL	(0.0637)	[1]	< DL	(0.404)	[1]	NA			NA		
bis(2-Chloroethoxy)methane	ND	(0.12)	[1]	ND	(0.758)	[1]	NA			NA		
bis(2-Chloroethyl)ether	ND	(0.132)	[1]	ND	(0.836)	[1]	NA			NA		
bis(2-Chloroisopropyl)ether	ND	(0.163)	[1]	ND	(1.03)	[1]	NA			NA		
bis(2-Ethylhexyl)phthalate	< DL B	(0.213)	[1]	3.05 B	(1.35)	[1]	NA			NA		
p-Chloroaniline	ND	(0.127)	[1]	ND	(0.805)	[1]	NA			NA		
SW846 - Percent Moisture (percent)												
Percent moisture	30.2	(0)	[1]	11.6	(0)	[1]	16.6	(0)	[1]	20.5	(0)	[1]

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PARAMETER	9			9			9			9		
	F4			F4			F4			F4		
	KRF-F4-U0002			KRF-F4-U1214			KRF-F4-U1618			KRF-F4-U2829		
	0 - 2			12 - 14			16 - 18			28 - 29		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	1220	(31)	[1]	1790	(33)	[1]	1090	(34)	[1]	1670	(27.3)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(1.93)	[1]	NA			NA			ND	(1070)	[1000]
1,1,2,2-Tetrachloroethane	ND	(5.23)	[1]	NA			NA			ND	(1400)	[1000]
1,1,2-Trichloroethane	ND	(1.57)	[1]	NA			NA			ND	(1060)	[1000]
1,1-Dichloroethane	ND	(1.77)	[1]	NA			NA			ND	(842)	[1000]
1,1-Dichloroethene	ND	(2.65)	[1]	NA			NA			ND	(2080)	[1000]
1,2-Dichloroethane	ND	(1.79)	[1]	NA			NA			ND	(1540)	[1000]
1,2-Dichloropropane	ND	(2.71)	[1]	NA			NA			ND	(2900)	[1000]
2-Chloroethyl vinyl ether	ND	(2.95)	[1]	NA			NA			ND	(1540)	[1000]
2-Hexanone	ND	(0.99)	[1]	NA			NA			ND	(1700)	[1000]
4-Methyl-2-Pentanone(MIBK)	ND	(0.944)	[1]	NA			NA			ND	(1150)	[1000]
Acetone	5.22 B	(1.55)	[1]	NA			NA			< DL	(6360)	[1000]
Benzene	< DL	(1.78)	[1]	NA			NA			ND	(712)	[1000]
Bromodichloromethane	ND	(1.68)	[1]	NA			NA			ND	(3890)	[1000]
Bromomethane	ND	(2.07)	[1]	NA			NA			ND	(2000)	[1000]
Carbon disulfide	ND	(2.67)	[1]	NA			NA			ND	(1590)	[1000]
Carbon tetrachloride	ND	(2.06)	[1]	NA			NA			ND	(1570)	[1000]
Chlorobenzene	24.2	(4.8)	[1]	NA			NA			111000	(1090)	[1000]
Chloroethane	ND	(2.11)	[1]	NA			NA			ND	(1460)	[1000]
Chloroform	ND	(2.16)	[1]	NA			NA			ND	(652)	[1000]
Chloromethane	ND	(2.51)	[1]	NA			NA			ND	(1060)	[1000]
Dibromochloromethane	ND	(1.89)	[1]	NA			NA			ND	(768)	[1000]
Ethyl benzene	ND	(1.71)	[1]	NA			NA			< DL	(1190)	[1000]
Methyl ethyl ketone	10.3 B	(1.57)	[1]	NA			NA			3770 B	(2990)	[1000]
Methylene Chloride	3.92	(2.7)	[1]	NA			NA			2340	(2000)	[1000]
Styrene	ND	(1.67)	[1]	NA			NA			ND	(1170)	[1000]
Tetrachloroethene	ND	(4.91)	[1]	NA			NA			ND	(1580)	[1000]
Toluene	2.89	(1.76)	[1]	NA			NA			ND	(872)	[1000]
Tribromomethane(Bromoform)	ND	(1.56)	[1]	NA			NA			ND	(524)	[1000]
Trichloroethene	ND	(5.02)	[1]	NA			NA			ND	(1690)	[1000]
Vinyl Chloride	ND	(2.14)	[1]	NA			NA			ND	(1330)	[1000]
Vinyl acetate	ND	(11.3)	[1]	NA			NA			ND	(888)	[1000]
Xylene (total)	ND	(3.76)	[1]	NA			NA			4300	(2750)	[1000]
cis-1,3-Dichloropropene	ND	(1.66)	[1]	NA			NA			ND	(587)	[1000]

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PARAMETER	9 F4 KRF-F4-U0002 0 - 2			9 F4 KRF-F4-U1214 12 - 14	9 F4 KRF-F4-U1618 16 - 18	9 F4 KRF-F4-U2829 28 - 29		
SW8240 - Volatile Organics, cont. (ug/kg)								
trans-1,2-Dichloroethene	ND	(2.4)	[1]	NA	NA	ND	(1810)	[1000]
trans-1,3-Dichloropropene	ND	(1.79)	[1]	NA	NA	ND	(1590)	[1000]
SW8270 - Semivolatile Organics (ug/g)								
1,2,4-Trichlorobenzene	ND	(0.0183)	[1]	NA	NA	ND	(0.0485)	[1]
1,2-Dichlorobenzene	ND	(0.0256)	[1]	NA	NA	0.412	(0.0678)	[1]
1,3-Dichlorobenzene	ND	(0.0233)	[1]	NA	NA	0.295	(0.0616)	[1]
1,4-Dichlorobenzene	ND	(0.0305)	[1]	NA	NA	3.08	(0.0807)	[1]
2,4,5-Trichlorophenol	ND	(0.0229)	[1]	NA	NA	ND	(0.0607)	[1]
2,4,6-Trichlorophenol	ND	(0.0273)	[1]	NA	NA	ND	(0.0722)	[1]
2,4-Dichlorophenol	ND	(0.0363)	[1]	NA	NA	ND	(0.096)	[1]
2,4-Dimethylphenol	ND	(0.0336)	[1]	NA	NA	ND	(0.089)	[1]
2,4-Dinitrophenol	ND	(0.0467)	[1]	NA	NA	ND	(0.123)	[1]
2,4-Dinitrotoluene	ND	(0.0285)	[1]	NA	NA	ND	(0.0754)	[1]
2,6-Dinitrotoluene	ND	(0.0311)	[1]	NA	NA	ND	(0.0822)	[1]
2-Chloronaphthalene	ND	(0.0274)	[1]	NA	NA	ND	(0.0725)	[1]
2-Chlorophenol	ND	(0.0236)	[1]	NA	NA	0.105	(0.0624)	[1]
2-Methylnaphthalene	0.0288	(0.0242)	[1]	NA	NA	1.71	(0.064)	[1]
2-Methylphenol	ND	(0.0131)	[1]	NA	NA	ND	(0.0346)	[1]
2-Nitroaniline	ND	(0.0308)	[1]	NA	NA	ND	(0.0814)	[1]
2-Nitrophenol	ND	(0.0309)	[1]	NA	NA	ND	(0.0817)	[1]
3,3'-Dichlorobenzidine	ND	(0.0373)	[1]	NA	NA	ND	(0.0987)	[1]
3-Nitroaniline	ND	(0.0325)	[1]	NA	NA	ND	(0.0859)	[1]
4,6-Dinitro-2-methylphenol	ND	(0.041)	[1]	NA	NA	ND	(0.108)	[1]
4-Bromophenyl phenyl ether	ND	(0.0175)	[1]	NA	NA	ND	(0.0462)	[1]
4-Chloro-3-methylphenol	ND	(0.0167)	[1]	NA	NA	ND	(0.0442)	[1]
4-Chlorophenyl phenyl ether	ND	(0.0195)	[1]	NA	NA	ND	(0.0516)	[1]
4-Methylphenol/3-Methylphenol	ND	(0.0152)	[1]	NA	NA	ND	(0.0402)	[1]
4-Nitroaniline	ND	(0.0455)	[1]	NA	NA	ND	(0.12)	[1]
4-Nitrophenol	ND	(0.0484)	[1]	NA	NA	ND	(0.128)	[1]
Acenaphthene	0.05	(0.0267)	[1]	NA	NA	ND	(0.0705)	[1]
Acenaphthylene	ND	(0.0264)	[1]	NA	NA	ND	(0.0698)	[1]
Anthracene	0.0955	(0.0318)	[1]	NA	NA	ND	(0.0842)	[1]
Benzo(a)anthracene	1.09	(0.0248)	[1]	NA	NA	ND	(0.0656)	[1]
Benzo(a)pyrene	1.53	(0.0331)	[1]	NA	NA	ND	(0.0876)	[1]
Benzo(b)fluoranthene	3.09 F	(0.0458)	[1]	NA	NA	ND	(0.116)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 F4 KRF-F4-U0002 0 - 2			9 F4 KRF-F4-U1214 12 - 14			9 F4 KRF-F4-U1618 16 - 18			9 F4 KRF-F4-U2829 28 - 29		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Benzo(g,h,i)perylene	0.563	(0.0471)	[1]	NA			NA			ND	(0.125)	[1]
Benzo(k)fluoranthene	3.09 F	(0.0459)	[1]	NA			NA			ND	(0.121)	[1]
Benzoic acid	ND	(1.09)	[1]	NA			NA			ND	(2.87)	[1]
Benzyl alcohol	ND	(0.0224)	[1]	NA			NA			ND	(0.0593)	[1]
Butylbenzylphthalate	ND	(0.076)	[1]	NA			NA			ND	(0.201)	[1]
Chrysene	1.23	(0.0413)	[1]	NA			NA			ND	(0.109)	[1]
Di-n-octylphthalate	ND	(0.0215)	[1]	NA			NA			ND	(0.0568)	[1]
Dibenz(a,h)anthracene	0.229	(0.0417)	[1]	NA			NA			ND	(0.11)	[1]
Dibenzofuran	0.0417	(0.0231)	[1]	NA			NA			ND	(0.0611)	[1]
Dibutylphthalate	0.123	(0.0206)	[1]	NA			NA			ND	(0.0545)	[1]
Diethylphthalate	ND	(0.0106)	[1]	NA			NA			ND	(0.028)	[1]
Dimethylphthalate	ND	(0.0187)	[1]	NA			NA			ND	(0.0494)	[1]
Diphenylamine	ND	(0.0375)	[1]	NA			NA			ND	(0.0992)	[1]
Fluoranthene	1.64	(0.0246)	[1]	NA			NA			0.225	(0.065)	[1]
Fluorene	0.0455	(0.0191)	[1]	NA			NA			< DL	(0.0506)	[1]
Hexachlorobenzene	ND	(0.023)	[1]	NA			NA			ND	(0.0608)	[1]
Hexachlorobutadiene	ND	(0.043)	[1]	NA			NA			ND	(0.114)	[1]
Hexachlorocyclopentadiene	ND	(0.0496)	[1]	NA			NA			ND	(0.131)	[1]
Hexachloroethane	ND	(0.023)	[1]	NA			NA			ND	(0.0609)	[1]
Indeno(1,2,3-cd)pyrene	0.619	(0.0368)	[1]	NA			NA			ND	(0.0974)	[1]
Isophorone	ND	(0.0135)	[1]	NA			NA			ND	(0.0356)	[1]
N-Nitroso-di-n-propylamine	ND	(0.0257)	[1]	NA			NA			ND	(0.068)	[1]
Naphthalene	< DL	(0.0322)	[1]	NA			NA			0.913	(0.0851)	[1]
Nitrobenzene	ND	(0.0183)	[1]	NA			NA			ND	(0.0484)	[1]
Pentachlorophenol	ND	(0.0397)	[1]	NA			NA			ND	(0.105)	[1]
Phenanthrene	0.448	(0.0275)	[1]	NA			NA			0.0784	(0.0728)	[1]
Phenol	ND	(0.0155)	[1]	NA			NA			ND	(0.0411)	[1]
Pyrene	1.52	(0.0295)	[1]	NA			NA			< DL	(0.078)	[1]
bis(2-Chloroethoxy)methane	ND	(0.0264)	[1]	NA			NA			ND	(0.0697)	[1]
bis(2-Chloroethyl)ether	ND	(0.0203)	[1]	NA			NA			ND	(0.0538)	[1]
bis(2-Chloroisopropyl)ether	ND	(0.0185)	[1]	NA			NA			ND	(0.0489)	[1]
bis(2-Ethylhexyl)phthalate	3.76	(0.111)	[1]	NA			NA			1.04	(0.293)	[1]
p-Chloroaniline	ND	(0.0392)	[1]	NA			NA			ND	(0.104)	[1]
SW846 - Percent Moisture (percent)												
Percent moisture	19.5	(0)	[1]	24.5	(0)	[1]	26.7	(0)	[1]	8.5	(0)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 F5 KRF-F5-U1214 12 - 14			9 F5 KRF-F5-U1618 16 - 18			9 F5 KRF-F5-U1820 18 - 20			9 F5 KRF-F5-U2324 23 - 24		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	1220	(32.9)	[1]	22100	(1560)	[50]	35000	(658)	[20]	10300	(282)	[10]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	NA			ND	(123)	[100]	ND	(1290)	[1000]	NA		
1,1,2,2-Tetrachloroethane	NA			ND	(161)	[100]	ND	(1680)	[1000]	NA		
1,1,2-Trichloroethane	NA			ND	(122)	[100]	ND	(1280)	[1000]	NA		
1,1-Dichloroethane	NA			ND	(96.8)	[100]	ND	(1010)	[1000]	NA		
1,1-Dichloroethene	NA			ND	(239)	[100]	ND	(2500)	[1000]	NA		
1,2-Dichloroethane	NA			ND	(177)	[100]	ND	(1850)	[1000]	NA		
1,2-Dichloropropane	NA			ND	(334)	[100]	ND	(3490)	[1000]	NA		
2-Chloroethyl vinyl ether	NA			ND	(177)	[100]	ND	(1850)	[1000]	NA		
2-Hexanone	NA			ND	(196)	[100]	ND	(2050)	[1000]	NA		
4-Methyl-2-Pentanone(MIBK)	NA			ND	(132)	[100]	ND	(1380)	[1000]	NA		
Acetone	NA			ND	(731)	[100]	< DL	(7650)	[1000]	NA		
Benzene	NA			< DL	(81.8)	[100]	< DL	(857)	[1000]	NA		
Bromodichloromethane	NA			ND	(447)	[100]	ND	(4680)	[1000]	NA		
Bromomethane	NA			ND	(230)	[100]	ND	(2410)	[1000]	NA		
Carbon disulfide	NA			ND	(183)	[100]	ND	(1920)	[1000]	NA		
Carbon tetrachloride	NA			ND	(181)	[100]	ND	(1890)	[1000]	NA		
Chlorobenzene	NA			4960	(126)	[100]	7390	(1320)	[1000]	NA		
Chloroethane	NA			ND	(168)	[100]	ND	(1760)	[1000]	NA		
Chloroform	NA			ND	(75)	[100]	ND	(785)	[1000]	NA		
Chloromethane	NA			< DL	(122)	[100]	1530	(1270)	[1000]	NA		
Dibromochloromethane	NA			ND	(88.3)	[100]	ND	(925)	[1000]	NA		
Ethyl benzene	NA			699	(137)	[100]	4320	(1430)	[1000]	NA		
Methyl ethyl ketone	NA			485 B	(344)	[100]	ND	(3600)	[1000]	NA		
Methylene Chloride	NA			309	(230)	[100]	3600	(2410)	[1000]	NA		
Styrene	NA			ND	(135)	[100]	ND	(1410)	[1000]	NA		
Tetrachloroethene	NA			ND	(182)	[100]	ND	(1900)	[1000]	NA		
Toluene	NA			448	(100)	[100]	30700	(1050)	[1000]	NA		
Tribromomethane(Bromoform)	NA			ND	(60.3)	[100]	ND	(631)	[1000]	NA		
Trichloroethene	NA			ND	(194)	[100]	ND	(2030)	[1000]	NA		
Vinyl Chloride	NA			ND	(153)	[100]	ND	(1600)	[1000]	NA		
Vinyl acetate	NA			ND	(102)	[100]	ND	(1070)	[1000]	NA		
Xylene (total)	NA			5730	(316)	[100]	32600	(3310)	[1000]	NA		
cis-1,3-Dichloropropene	NA			ND	(67.5)	[100]	ND	(707)	[1000]	NA		

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PARAMETER	9 F5 KRF-F5-U1214 12 - 14	9 F5 KRF-F5-U1618 16 - 18			9 F5 KRF-F5-U1820 18 - 20			9 F5 KRF-F5-U2324 23 - 24
SW8240 - Volatile Organics, cont. (ug/kg)								
trans-1,2-Dichloroethene	NA	ND	(208)	[100]	ND	(2180)	[1000]	NA
trans-1,3-Dichloropropene	NA	ND	(183)	[100]	ND	(1920)	[1000]	NA
SW8270 - Semivolatile Organics (ug/g)								
1,2,4-Trichlorobenzene	NA	ND	(0.102)	[1]	1.18	(1.09)	[1]	NA
1,2-Dichlorobenzene	NA	0.289	(0.0861)	[1]	15.8	(0.919)	[1]	NA
1,3-Dichlorobenzene	NA	0.257	(0.0524)	[1]	1.01	(0.559)	[1]	NA
1,4-Dichlorobenzene	NA	1.03	(0.082)	[1]	5.19	(0.875)	[1]	NA
2,4,5-Trichlorophenol	NA	ND	(0.0817)	[1]	ND	(0.871)	[1]	NA
2,4,6-Trichlorophenol	NA	ND	(0.0588)	[1]	ND	(0.627)	[1]	NA
2,4-Dichlorophenol	NA	ND	(0.0263)	[1]	ND	(0.281)	[1]	NA
2,4-Dimethylphenol	NA	ND	(0.103)	[1]	4.59	(1.09)	[1]	NA
2,4-Dinitrophenol	NA	ND	(0.326)	[1]	ND	(3.48)	[1]	NA
2,4-Dinitrotoluene	NA	ND	(0.0584)	[1]	ND	(0.623)	[1]	NA
2,6-Dinitrotoluene	NA	ND	(0.092)	[1]	ND	(0.982)	[1]	NA
2-Chloronaphthalene	NA	ND	(0.134)	[1]	ND	(1.43)	[1]	NA
2-Chlorophenol	NA	ND	(0.0788)	[1]	ND	(0.84)	[1]	NA
2-Methylnaphthalene	NA	1.47	(0.0848)	[1]	28.5	(0.905)	[1]	NA
2-Methylphenol	NA	ND	(0.074)	[1]	ND	(0.789)	[1]	NA
2-Nitroaniline	NA	ND	(0.134)	[1]	ND	(1.43)	[1]	NA
2-Nitrophenol	NA	ND	(0.0804)	[1]	ND	(0.858)	[1]	NA
3,3'-Dichlorobenzidine	NA	ND	(0.0627)	[1]	ND	(0.669)	[1]	NA
3-Nitroaniline	NA	ND	(0.1)	[1]	ND	(1.07)	[1]	NA
4,6-Dinitro-2-methylphenol	NA	ND	(0.114)	[1]	ND	(1.21)	[1]	NA
4-Bromophenyl phenyl ether	NA	ND	(0.103)	[1]	ND	(1.09)	[1]	NA
4-Chloro-3-methylphenol	NA	ND	(0.0774)	[1]	ND	(0.825)	[1]	NA
4-Chlorophenyl phenyl ether	NA	ND	(0.0668)	[1]	ND	(0.713)	[1]	NA
4-Methylphenol/3-Methylphenol	NA	ND	(0.051)	[1]	2.89 F	(0.544)	[1]	NA
4-Nitroaniline	NA	ND	(0.127)	[1]	ND	(1.35)	[1]	NA
4-Nitrophenol	NA	ND	(0.325)	[1]	ND	(3.46)	[1]	NA
Acenaphthene	NA	ND	(0.0846)	[1]	ND	(0.902)	[1]	NA
Acenaphthylene	NA	ND	(0.0738)	[1]	ND	(0.787)	[1]	NA
Anthracene	NA	ND	(0.0684)	[1]	ND	(0.73)	[1]	NA
Benzo(a)anthracene	NA	0.0956	(0.0641)	[1]	< DL	(0.684)	[1]	NA
Benzo(a)pyrene	NA	0.0825	(0.081)	[1]	ND	(0.864)	[1]	NA
Benzo(b)fluoranthene	NA	0.289 F	(0.0818)	[1]	ND	(0.873)	[1]	NA

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PARAMETER	9 F5 KRF-F5-U1214 12 - 14			9 F5 KRF-F5-U1618 16 - 18			9 F5 KRF-F5-U1820 18 - 20			9 F5 KRF-F5-U2324 23 - 24		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Benzo(g,h,i)perylene	NA			< DL	(0.0788)	[1]	ND	(0.84)	[1]	NA		
Benzo(k)fluoranthene	NA			0.289 F	(0.103)	[1]	ND	(1.1)	[1]	NA		
Benzoic acid	NA			ND	(0.702)	[1]	ND	(7.49)	[1]	NA		
Benzyl alcohol	NA			ND	(0.0707)	[1]	ND	(0.755)	[1]	NA		
Butylbenzylphthalate	NA			ND	(0.206)	[1]	ND	(2.2)	[1]	NA		
Chrysene	NA			0.187	(0.0848)	[1]	< DL	(0.905)	[1]	NA		
Di-n-octylphthalate	NA			ND	(0.0928)	[1]	ND	(0.991)	[1]	NA		
Dibenz(a,h)anthracene	NA			ND	(0.0852)	[1]	ND	(0.909)	[1]	NA		
Dibenzofuran	NA			ND	(0.0647)	[1]	ND	(0.69)	[1]	NA		
Dibutylphthalate	NA			0.169	(0.0677)	[1]	1.85	(0.722)	[1]	NA		
Diethylphthalate	NA			ND	(0.0443)	[1]	ND	(0.473)	[1]	NA		
Dimethylphthalate	NA			ND	(0.0463)	[1]	ND	(0.494)	[1]	NA		
Diphenylamine	NA			ND	(0.108)	[1]	ND	(1.15)	[1]	NA		
Fluoranthene	NA			0.462	(0.073)	[1]	4.21	(0.778)	[1]	NA		
Fluorene	NA			0.179	(0.0605)	[1]	1.3	(0.645)	[1]	NA		
Hexachlorobenzene	NA			ND	(0.082)	[1]	ND	(0.875)	[1]	NA		
Hexachlorobutadiene	NA			ND	(0.0858)	[1]	ND	(0.915)	[1]	NA		
Hexachlorocyclopentadiene	NA			ND	(0.248)	[1]	ND	(2.64)	[1]	NA		
Hexachloroethane	NA			ND	(0.0981)	[1]	ND	(1.05)	[1]	NA		
Indeno(1,2,3-cd)pyrene	NA			0.0911	(0.0618)	[1]	ND	(0.659)	[1]	NA		
Isophorone	NA			ND	(0.089)	[1]	ND	(0.95)	[1]	NA		
N-Nitroso-di-n-propylamine	NA			ND	(0.0501)	[1]	ND	(0.535)	[1]	NA		
Naphthalene	NA			0.671	(0.0738)	[1]	8.78	(0.787)	[1]	NA		
Nitrobenzene	NA			ND	(0.133)	[1]	ND	(1.42)	[1]	NA		
Pentachlorophenol	NA			ND	(0.123)	[1]	ND	(1.32)	[1]	NA		
Phenanthrene	NA			0.607	(0.0947)	[1]	2.17	(1.01)	[1]	NA		
Phenol	NA			ND	(0.0307)	[1]	ND	(0.413)	[1]	NA		
Pyrene	NA			0.249	(0.0519)	[1]	0.647	(0.554)	[1]	NA		
bis(2-Chloroethoxy)methane	NA			ND	(0.0975)	[1]	ND	(1.04)	[1]	NA		
bis(2-Chloroethyl)ether	NA			ND	(0.108)	[1]	ND	(1.15)	[1]	NA		
bis(2-Chloroisopropyl)ether	NA			ND	(0.133)	[1]	ND	(1.42)	[1]	NA		
bis(2-Ethylhexyl)phthalate	NA			20.4 EXB	(0.173)	[1]	15.6 B	(1.85)	[1]	NA		
p-Chloroaniline	NA			ND	(0.103)	[1]	ND	(1.1)	[1]	NA		
SW846 - Percent Moisture (percent)												
Percent moisture	24.2	(0)	[1]	20.2	(0)	[1]	24	(0)	[1]	11.3	(0)	[1]

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PARAMETER	9 TD3 KRF-TD3-U0406 4 - 6			9 TD3 KRF-TD3-U1416 14 - 16			9 TD3 KRF-TD3-U2426 24 - 26			9 TD3 KRF-TD3-U2426D 24 - 26		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	1420	(30.8)	[1]	122	(34.3)	[1]	5700	(142)	[5]	6430	(145)	[5]
SW846 - Percent Moisture (percent)												
Percent moisture	19.2	(0)	[1]	27.4	(0)	[1]	12.3	(0)	[1]	13.9	(0)	[1]

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PARAMETER	9			9			9			9		
	TD5			TD5			TD5			TD6		
	KRF-TD5-U0406			KRF-TD5-U1416			KRF-TD5-U2425			KRF-TD6-U0406		
---------	4 - 6			14 - 16			24 - 25			4 - 6		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	445	(31.9)	[1]	31300	(588)	[20]	2080	(136)	[5]	538	(29.3)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(4.04)	[1]	NA			ND	(3440)	[2000]	ND	(1.84)	[1]
1,1,2,2-Tetrachloroethane	ND	(11)	[1]	NA			ND	(7030)	[2000]	ND	(4.99)	[1]
1,1,2-Trichloroethane	ND	(3.29)	[1]	NA			ND	(4200)	[2000]	ND	(1.5)	[1]
1,1-Dichloroethane	ND	(3.7)	[1]	NA			ND	(4030)	[2000]	ND	(1.69)	[1]
1,1-Dichloroethene	ND	(5.54)	[1]	NA			ND	(5680)	[2000]	ND	(2.52)	[1]
1,2-Dichloroethane	ND	(3.75)	[1]	NA			ND	(5990)	[2000]	ND	(1.71)	[1]
1,2-Dichloropropane	ND	(5.67)	[1]	NA			ND	(3740)	[2000]	ND	(2.58)	[1]
2-Chloroethyl vinyl ether	ND	(6.18)	[1]	NA			ND	(2180)	[2000]	ND	(2.81)	[1]
2-Hexanone	ND	(2.07)	[1]	NA			ND	(6720)	[2000]	ND	(0.942)	[1]
4-Methyl-2-Pentanone(MIBK)	ND	(1.98)	[1]	NA			ND	(5810)	[2000]	ND	(0.899)	[1]
Acetone	272 B	(3.24)	[1]	NA			ND	(9080)	[2000]	2.86 B	(1.48)	[1]
Benzene	< DL	(3.73)	[1]	NA			ND	(7830)	[2000]	< DL	(1.7)	[1]
Bromodichloromethane	ND	(3.52)	[1]	NA			ND	(4980)	[2000]	ND	(1.6)	[1]
Bromomethane	ND	(4.34)	[1]	NA			ND	(7990)	[2000]	ND	(1.98)	[1]
Carbon disulfide	ND	(5.59)	[1]	NA			ND	(7360)	[2000]	ND	(2.54)	[1]
Carbon tetrachloride	ND	(4.32)	[1]	NA			ND	(5940)	[2000]	ND	(1.96)	[1]
Chlorobenzene	< DL	(10)	[1]	NA			27200	(4740)	[2000]	6.81	(4.57)	[1]
Chloroethane	ND	(4.42)	[1]	NA			ND	(7140)	[2000]	ND	(2.01)	[1]
Chloroform	ND	(4.52)	[1]	NA			ND	(3160)	[2000]	ND	(2.06)	[1]
Chloromethane	ND	(5.26)	[1]	NA			ND	(6070)	[2000]	ND	(2.39)	[1]
Dibromochloromethane	ND	(3.96)	[1]	NA			ND	(3550)	[2000]	ND	(1.8)	[1]
Ethyl benzene	ND	(3.58)	[1]	NA			ND	(5200)	[2000]	ND	(1.63)	[1]
Methyl ethyl ketone	72.1 B	(3.29)	[1]	NA			ND	(8840)	[2000]	3.75 B	(1.5)	[1]
Methylene Chloride	< DL	(5.64)	[1]	NA			ND	(8750)	[2000]	5.62	(2.57)	[1]
Styrene	ND	(3.5)	[1]	NA			ND	(3720)	[2000]	ND	(1.59)	[1]
Tetrachloroethene	ND	(10.3)	[1]	NA			ND	(5620)	[2000]	ND	(4.67)	[1]
Toluene	< DL	(3.68)	[1]	NA			ND	(3260)	[2000]	2.58	(1.67)	[1]
Tribromomethane(Bromoform)	ND	(3.27)	[1]	NA			ND	(4440)	[2000]	ND	(1.49)	[1]
Trichloroethene	ND	(10.5)	[1]	NA			ND	(4220)	[2000]	ND	(4.78)	[1]
Vinyl Chloride	ND	(4.47)	[1]	NA			ND	(6380)	[2000]	ND	(2.03)	[1]
Vinyl acetate	ND	(23.7)	[1]	NA			ND	(2570)	[2000]	ND	(10.8)	[1]
Xylene (total)	ND	(7.87)	[1]	NA			< DL	(10100)	[2000]	ND	(3.58)	[1]
cis-1,3-Dichloropropene	ND	(3.47)	[1]	NA			ND	(3850)	[2000]	ND	(1.58)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9				9	9				9			
	TD5				TD5	TD5				TD6			
	KRF-TD5-U0406				KRF-TD5-U1416	KRF-TD5-U2425				KRF-TD6-U0406			
	4 - 6				14 - 16	24 - 25				4 - 6			
SW8240 - Volatile Organics, cont. (ug/kg)													
trans-1,2-Dichloroethene	ND		(5.03)	[1]	NA	ND		(3700)	[2000]	ND		(2.29)	[1]
trans-1,3-Dichloropropene	ND		(3.75)	[1]	NA	ND		(4140)	[2000]	ND		(1.71)	[1]
SW8270 - Semivolatile Organics (ug/g)													
1,2,4-Trichlorobenzene	ND		(0.037)	[1]	NA	ND		(0.719)	[1]	ND		(0.0342)	[1]
1,2-Dichlorobenzene	ND		(0.0313)	[1]	NA	ND		(0.608)	[1]	ND		(0.029)	[1]
1,3-Dichlorobenzene	ND		(0.019)	[1]	NA	ND		(0.37)	[1]	ND		(0.0176)	[1]
1,4-Dichlorobenzene	ND		(0.0298)	[1]	NA	ND		(0.579)	[1]	ND		(0.0276)	[1]
2,4,5-Trichlorophenol	ND		(0.0297)	[1]	NA	ND		(0.577)	[1]	ND		(0.0275)	[1]
2,4,6-Trichlorophenol	ND		(0.0214)	[1]	NA	ND		(0.415)	[1]	ND		(0.0198)	[1]
2,4-Dichlorophenol	ND		(0.00956)	[1]	NA	ND		(0.186)	[1]	ND		(0.00884)	[1]
2,4-Dimethylphenol	ND		(0.0373)	[1]	NA	ND		(0.725)	[1]	ND		(0.0345)	[1]
2,4-Dinitrophenol	ND		(0.119)	[1]	NA	ND		(2.3)	[1]	ND		(0.11)	[1]
2,4-Dinitrotoluene	ND		(0.0212)	[1]	NA	ND		(0.412)	[1]	ND		(0.0196)	[1]
2,6-Dinitrotoluene	ND		(0.0335)	[1]	NA	ND		(0.65)	[1]	ND		(0.0309)	[1]
2-Chloronaphthalene	ND		(0.0487)	[1]	NA	ND		(0.945)	[1]	ND		(0.045)	[1]
2-Chlorophenol	ND		(0.0287)	[1]	NA	ND		(0.556)	[1]	ND		(0.0265)	[1]
2-Methylnaphthalene	ND		(0.0309)	[1]	NA	1.58		(0.599)	[1]	ND		(0.0285)	[1]
2-Methylphenol	ND		(0.0269)	[1]	NA	ND		(0.522)	[1]	ND		(0.0249)	[1]
2-Nitroaniline	ND		(0.0487)	[1]	NA	ND		(0.945)	[1]	ND		(0.045)	[1]
2-Nitrophenol	ND		(0.0292)	[1]	NA	ND		(0.568)	[1]	ND		(0.027)	[1]
3,3'-Dichlorobenzidine	ND		(0.0228)	[1]	NA	ND		(0.443)	[1]	ND		(0.0211)	[1]
3-Nitroaniline	ND		(0.0364)	[1]	NA	ND		(0.706)	[1]	ND		(0.0336)	[1]
4,6-Dinitro-2-methylphenol	ND		(0.0413)	[1]	NA	ND		(0.802)	[1]	ND		(0.0382)	[1]
4-Bromophenyl phenyl ether	ND		(0.0373)	[1]	NA	ND		(0.724)	[1]	ND		(0.0345)	[1]
4-Chloro-3-methylphenol	ND		(0.0281)	[1]	NA	ND		(0.546)	[1]	ND		(0.026)	[1]
4-Chlorophenyl phenyl ether	ND		(0.0243)	[1]	NA	ND		(0.472)	[1]	ND		(0.0225)	[1]
4-Methylphenol/3-Methylphenol	ND		(0.0185)	[1]	NA	ND		(0.36)	[1]	ND		(0.0171)	[1]
4-Nitroaniline	ND		(0.0461)	[1]	NA	ND		(0.895)	[1]	ND		(0.0426)	[1]
4-Nitrophenol	ND		(0.118)	[1]	NA	ND		(2.29)	[1]	ND		(0.109)	[1]
Acenaphthene	ND		(0.0308)	[1]	NA	ND		(0.597)	[1]	ND		(0.0284)	[1]
Acenaphthylene	ND		(0.0268)	[1]	NA	ND		(0.521)	[1]	ND		(0.0240)	[1]
Anthracene	ND		(0.0249)	[1]	NA	ND		(0.483)	[1]	0.025		(0.023)	[1]
Benzo(a)anthracene	0.0334		(0.0233)	[1]	NA	ND		(0.453)	[1]	0.115		(0.0216)	[1]
Benzo(a)pyrene	0.0609		(0.0295)	[1]	NA	ND		(0.572)	[1]	0.112		(0.0272)	[1]
Benzo(b)fluoranthene	0.151	F	(0.0298)	[1]	NA	ND		(0.577)	[1]	0.241	F	(0.0275)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 TD5 KRF-TD5-U0406 4 - 6				9 TD5 KRF-TD5-U1416 14 - 16				9 TD5 KRF-TD5-U2425 24 - 25				9 TD6 KRF-TD6-U0406 4 - 6			
SW8270 - Semivolatile Organics, cont. (ug/g)																
Benzo(g,h,i)perylene	< DL		(0.0287)	[1]	NA				ND		(0.556)	[1]	0.0379		(0.0265)	[1]
Benzo(k)fluoranthene	0.151	F	(0.0374)	[1]	NA				ND		(0.726)	[1]	0.241	F	(0.0346)	[1]
Benzoic acid	ND		(0.255)	[1]	NA				ND		(4.95)	[1]	ND		(0.236)	[1]
Benzyl alcohol	ND		(0.0257)	[1]	NA				ND		(0.499)	[1]	ND		(0.0238)	[1]
Butylbenzylphthalate	ND		(0.0749)	[1]	NA				ND		(1.45)	[1]	ND		(0.0692)	[1]
Chrysene	0.0741		(0.0309)	[1]	NA				ND		(0.599)	[1]	0.113		(0.0285)	[1]
Di-n-octylphthalate	ND		(0.0338)	[1]	NA				ND		(0.656)	[1]	ND		(0.0312)	[1]
Dibenz(a,h)anthracene	ND		(0.031)	[1]	NA				ND		(0.601)	[1]	ND		(0.0286)	[1]
Dibenzofuran	ND		(0.0235)	[1]	NA				ND		(0.457)	[1]	ND		(0.0218)	[1]
Dibutylphthalate	ND		(0.0246)	[1]	NA				ND		(0.478)	[1]	ND		(0.0228)	[1]
Diethylphthalate	ND		(0.0161)	[1]	NA				ND		(0.313)	[1]	ND		(0.0149)	[1]
Dimethylphthalate	ND		(0.0168)	[1]	NA				ND		(0.327)	[1]	ND		(0.0156)	[1]
Diphenylamine	ND		(0.0392)	[1]	NA				ND		(0.761)	[1]	ND		(0.0362)	[1]
Fluoranthene	0.0961		(0.0265)	[1]	NA				0.674		(0.515)	[1]	0.218		(0.0245)	[1]
Fluorene	ND		(0.022)	[1]	NA				ND		(0.427)	[1]	ND		(0.0203)	[1]
Hexachlorobenzene	ND		(0.0298)	[1]	NA				ND		(0.579)	[1]	ND		(0.0276)	[1]
Hexachlorobutadiene	ND		(0.0312)	[1]	NA				ND		(0.605)	[1]	ND		(0.0288)	[1]
Hexachlorocyclopentadiene	ND		(0.0902)	[1]	NA				ND		(1.75)	[1]	ND		(0.0833)	[1]
Hexachloroethane	ND		(0.0357)	[1]	NA				ND		(0.692)	[1]	ND		(0.033)	[1]
Indeno(1,2,3-cd)pyrene	< DL		(0.0225)	[1]	NA				ND		(0.436)	[1]	0.0477		(0.0208)	[1]
Isophorone	ND		(0.0324)	[1]	NA				ND		(0.628)	[1]	ND		(0.0299)	[1]
N-Nitroso-di-n-propylamine	ND		(0.0182)	[1]	NA				ND		(0.354)	[1]	ND		(0.0169)	[1]
Naphthalene	ND		(0.0268)	[1]	NA				< DL		(0.521)	[1]	ND		(0.0248)	[1]
Nitrobenzene	ND		(0.0482)	[1]	NA				ND		(0.936)	[1]	ND		(0.0446)	[1]
Pentachlorophenol	ND		(0.0449)	[1]	NA				ND		(0.871)	[1]	ND		(0.0415)	[1]
Phenanthrene	< DL		(0.0345)	[1]	NA				< DL		(0.669)	[1]	0.0743		(0.0318)	[1]
Phenol	ND		(0.0141)	[1]	NA				ND		(0.274)	[1]	ND		(0.013)	[1]
Pyrene	0.0762		(0.0189)	[1]	NA				ND		(0.366)	[1]	0.16		(0.0174)	[1]
bis(2-Chloroethoxy)methane	ND		(0.0355)	[1]	NA				ND		(0.688)	[1]	ND		(0.0328)	[1]
bis(2-Chloroethyl)ether	ND		(0.0391)	[1]	NA				ND		(0.759)	[1]	ND		(0.0361)	[1]
bis(2-Chloroisopropyl)ether	ND		(0.0482)	[1]	NA				ND		(0.936)	[1]	ND		(0.0446)	[1]
bis(2-Ethylhexyl)phthalate	6.69	B	(0.0631)	[1]	NA				2.18	B	(1.22)	[1]	0.309	B	(0.0583)	[1]
p-Chloroaniline	ND		(0.0376)	[1]	NA				ND		(0.73)	[1]	ND		(0.0348)	[1]
SW846 - Percent Moisture (percent)																
Percent moisture	22		(0)	[1]	15		(0)	[1]	8.47		(0)	[1]	14.8		(0)	[1]

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 TD6 KRF-TD6-U1416 14 - 16			9 TD6 KRF-TD6-U2527 25 - 27				
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)								
Hydrocarbons	2980	(58.9)	[2]	2940	(54.6)	[2]	NA	NA
SW8240 - Volatile Organics (ug/kg)								
1,1,1-Trichloroethane	ND	(37.1)	[20]	NA			NA	NA
1,1,2,2-Tetrachloroethane	ND	(75.9)	[20]	NA			NA	NA
1,1,2-Trichloroethane	ND	(45.3)	[20]	NA			NA	NA
1,1-Dichloroethane	ND	(43.5)	[20]	NA			NA	NA
1,1-Dichloroethene	ND	(61.3)	[20]	NA			NA	NA
1,2-Dichloroethane	ND	(64.6)	[20]	NA			NA	NA
1,2-Dichloropropane	ND	(40.4)	[20]	NA			NA	NA
2-Chloroethyl vinyl ether	ND	(23.5)	[20]	NA			NA	NA
2-Hexanone	ND	(72.6)	[20]	NA			NA	NA
4-Methyl-2-Pentanone(MIBK)	ND	(62.7)	[20]	NA			NA	NA
Acetone	ND	(97.9)	[20]	NA			NA	NA
Benzene	ND	(84.6)	[20]	NA			NA	NA
Bromodichloromethane	ND	(53.8)	[20]	NA			NA	NA
Bromomethane	ND	(86.2)	[20]	NA			NA	NA
Carbon disulfide	ND	(79.4)	[20]	NA			NA	NA
Carbon tetrachloride	ND	(64.1)	[20]	NA			NA	NA
Chlorobenzene	411	(51.2)	[20]	NA			NA	NA
Chloroethane	ND	(77)	[20]	NA			NA	NA
Chloroform	ND	(34.1)	[20]	NA			NA	NA
Chloromethane	ND	(65.5)	[20]	NA			NA	NA
Dibromochloromethane	ND	(38.3)	[20]	NA			NA	NA
Ethyl benzene	ND	(56.1)	[20]	NA			NA	NA
Methyl ethyl ketone	ND	(95.4)	[20]	NA			NA	NA
Methylene Chloride	ND	(94.4)	[20]	NA			NA	NA
Styrene	ND	(40.2)	[20]	NA			NA	NA
Tetrachloroethene	ND	(60.6)	[20]	NA			NA	NA
Toluene	ND	(35.2)	[20]	NA			NA	NA
Tribromomethane(Bromoform)	ND	(47.9)	[20]	NA			NA	NA
Trichloroethene	ND	(45.6)	[20]	NA			NA	NA
Vinyl Chloride	ND	(68.8)	[20]	NA			NA	NA
Vinyl acetate	ND	(27.7)	[20]	NA			NA	NA
Xylene (total)	ND	(109)	[20]	NA			NA	NA
cis-1,3-Dichloropropene	ND	(41.6)	[20]	NA			NA	NA

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect. Refer to QC Report

PARAMETER	9 TD6 KRF-TD6-U1416 14 - 16			9 TD6 KRF-TD6-U2527 25 - 27		
SW8240 - Volatile Organics, cont. (ug/kg)						
trans-1,2-Dichloroethene	ND	(39.9)	[20]	NA	NA	NA
trans-1,3-Dichloropropene	ND	(44.6)	[20]	NA	NA	NA
SW8270 - Semivolatile Organics (ug/g)						
1,2,4-Trichlorobenzene	ND	(0.103)	[1]	NA	NA	NA
1,2-Dichlorobenzene	0.146	(0.0869)	[1]	NA	NA	NA
1,3-Dichlorobenzene	ND	(0.0528)	[1]	NA	NA	NA
1,4-Dichlorobenzene	0.133	(0.0828)	[1]	NA	NA	NA
2,4,5-Trichlorophenol	ND	(0.0824)	[1]	NA	NA	NA
2,4,6-Trichlorophenol	ND	(0.0593)	[1]	NA	NA	NA
2,4-Dichlorophenol	ND	(0.0265)	[1]	NA	NA	NA
2,4-Dimethylphenol	ND	(0.104)	[1]	NA	NA	NA
2,4-Dinitrophenol	ND	(0.329)	[1]	NA	NA	NA
2,4-Dinitrotoluene	ND	(0.059)	[1]	NA	NA	NA
2,6-Dinitrotoluene	ND	(0.0929)	[1]	NA	NA	NA
2-Chloronaphthalene	ND	(0.135)	[1]	NA	NA	NA
2-Chlorophenol	ND	(0.0795)	[1]	NA	NA	NA
2-Methylnaphthalene	< DL	(0.0856)	[1]	NA	NA	NA
2-Methylphenol	ND	(0.0747)	[1]	NA	NA	NA
2-Nitroaniline	ND	(0.135)	[1]	NA	NA	NA
2-Nitrophenol	ND	(0.0811)	[1]	NA	NA	NA
3,3'-Dichlorobenzidine	ND	(0.0633)	[1]	NA	NA	NA
3-Nitroaniline	ND	(0.101)	[1]	NA	NA	NA
4,6-Dinitro-2-methylphenol	ND	(0.115)	[1]	NA	NA	NA
4-Bromophenyl phenyl ether	ND	(0.103)	[1]	NA	NA	NA
4-Chloro-3-methylphenol	ND	(0.0781)	[1]	NA	NA	NA
4-Chlorophenyl phenyl ether	ND	(0.0674)	[1]	NA	NA	NA
4-Methylphenol/3-Methylphenol	ND	(0.0514)	[1]	NA	NA	NA
4-Nitroaniline	ND	(0.128)	[1]	NA	NA	NA
4-Nitrophenol	ND	(0.328)	[1]	NA	NA	NA
Acenaphthene	ND	(0.0854)	[1]	NA	NA	NA
Acenaphthylene	ND	(0.0745)	[1]	NA	NA	NA
Anthracene	ND	(0.069)	[1]	NA	NA	NA
Benzo(a)anthracene	ND	(0.0647)	[1]	NA	NA	NA
Benzo(a)pyrene	ND	(0.0817)	[1]	NA	NA	NA
Benzo(b)fluoranthene	< DL	(0.0826)	[1]	NA	NA	NA

PARAMETER	9 TD6 KRF-TD6-U1416 14 - 16				9 TD6 KRF-TD6-U2527 25 - 27				
SW8270 - Semivolatile Organics, cont. (ug/g)									
Benzo(g,h,i)perylene	ND		(0.0795)	[1]	NA			NA	NA
Benzo(k)fluoranthene	< DL		(0.104)	[1]	NA			NA	NA
Benzoic acid	ND		(0.708)	[1]	NA			NA	NA
Benzyl alcohol	ND		(0.0714)	[1]	NA			NA	NA
Butylbenzylphthalate	ND		(0.208)	[1]	NA			NA	NA
Chrysene	ND		(0.0856)	[1]	NA			NA	NA
Di-n-octylphthalate	ND		(0.0937)	[1]	NA			NA	NA
Dibenz(a,h)anthracene	ND		(0.086)	[1]	NA			NA	NA
Dibenzofuran	< DL		(0.0653)	[1]	NA			NA	NA
Dibutylphthalate	ND		(0.0683)	[1]	NA			NA	NA
Diethylphthalate	ND		(0.0447)	[1]	NA			NA	NA
Dimethylphthalate	ND		(0.0467)	[1]	NA			NA	NA
Diphenylamine	ND		(0.109)	[1]	NA			NA	NA
Fluoranthene	< DL		(0.0736)	[1]	NA			NA	NA
Fluorene	ND		(0.0611)	[1]	NA			NA	NA
Hexachlorobenzene	ND		(0.0828)	[1]	NA			NA	NA
Hexachlorobutadiene	ND		(0.0865)	[1]	NA			NA	NA
Hexachlorocyclopentadiene	ND		(0.25)	[1]	NA			NA	NA
Hexachloroethane	ND		(0.099)	[1]	NA			NA	NA
Indeno(1,2,3-cd)pyrene	ND		(0.0624)	[1]	NA			NA	NA
Isophorone	ND		(0.0898)	[1]	NA			NA	NA
N-Nitroso-di-n-propylamine	ND		(0.0506)	[1]	NA			NA	NA
Naphthalene	ND		(0.0745)	[1]	NA			NA	NA
Nitrobenzene	ND		(0.134)	[1]	NA			NA	NA
Pentachlorophenol	ND		(0.124)	[1]	NA			NA	NA
Phenanthrene	< DL		(0.0956)	[1]	NA			NA	NA
Phenol	ND		(0.0391)	[1]	NA			NA	NA
Pyrene	< DL		(0.0524)	[1]	NA			NA	NA
bis(2-Chloroethoxy)methane	ND		(0.0984)	[1]	NA			NA	NA
bis(2-Chloroethyl)ether	ND		(0.109)	[1]	NA			NA	NA
bis(2-Chloroisopropyl)ether	ND		(0.134)	[1]	NA			NA	NA
bis(2-Ethylhexyl)phthalate	1.55	B	(0.175)	[1]	NA			NA	NA
p-Chloroaniline	ND		(0.104)	[1]	NA			NA	NA
SW846 - Percent Moisture (percent)									
Percent moisture	15.1		(0)	[1]	8.73	(0)	[1]	NA	NA

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

TABLE A ALL RESULTS OF ORGANIC ANALYSES FOR WATER SAMPLES, SITE '*', RF Heating, Kelly AFB.

PARAMETER	SITE ID LOCATION ID SAMPLE ID									
	9 MW-9 KRF-09-GW118			9 MW-10 KRF-10-GW114			9 DW-02 KRF-DW02-GW119			
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/L)										
Hydrocarbons	0.834	(0.194)	[1]	4.92	(0.344)	[1]	267	(1.79)	[10]	NA
SW8240 - Volatile Organics (ug/L)										
1,1,1-Trichloroethane	ND	(1.58)	[1]	ND	(1.58)	[1]	ND	(590)	[500]	NA
1,1,2,2-Tetrachloroethane	ND	(3.23)	[1]	ND X	(3.23)	[1]	ND	(545)	[500]	NA
1,1,2-Trichloroethane	ND	(1.93)	[1]	ND X	(1.93)	[1]	ND	(323)	[500]	NA
1,1-Dichloroethane	ND	(1.85)	[1]	1.93	(1.85)	[1]	ND	(675)	[500]	NA
1,1-Dichloroethene	ND	(2.61)	[1]	ND	(2.61)	[1]	ND	(710)	[500]	NA
1,2-Dichloroethane	ND	(2.75)	[1]	ND	(2.75)	[1]	ND	(232)	[500]	NA
1,2-Dichloropropane	ND	(1.72)	[1]	ND	(1.72)	[1]	ND	(625)	[500]	NA
2-Chloroethyl vinyl ether	ND	(1)	[1]	ND	(1)	[1]	ND	(610)	[500]	NA
2-Hexanone	ND	(3.09)	[1]	ND X	(3.09)	[1]	ND	(1780)	[500]	NA
4-Methyl-2-Pentanone(MIBK)	4.95	(2.67)	[1]	11.5	(2.67)	[1]	ND	(1780)	[500]	NA
Acetone	10.3	(4.17)	[1]	61.9	(4.17)	[1]	< DL	(13300)	[500]	NA
Benzene	596	(65.7)	[100]	782	(32.8)	[50]	< DL	(1000)	[500]	NA
Bromodichloromethane	ND	(2.29)	[1]	ND	(2.29)	[1]	ND	(436)	[500]	NA
Bromomethane	ND	(3.67)	[1]	ND	(3.67)	[1]	ND	(880)	[500]	NA
Carbon disulfide	ND	(3.38)	[1]	ND	(3.38)	[1]	< DL B	(930)	[500]	NA
Carbon tetrachloride	ND	(2.73)	[1]	ND	(2.73)	[1]	ND	(595)	[500]	NA
Chlorobenzene	12000	(101)	[100]	25500	(288)	[250]	15700	(630)	[500]	NA
Chloroethane	ND	(3.28)	[1]	ND	(3.28)	[1]	ND	(735)	[500]	NA
Chloroform	ND	(1.45)	[1]	ND	(1.45)	[1]	ND	(600)	[500]	NA
Chloromethane	ND	(2.79)	[1]	ND	(2.79)	[1]	ND	(1060)	[500]	NA
Dibromochloromethane	ND	(1.63)	[1]	ND X	(1.63)	[1]	ND	(540)	[500]	NA
Ethyl benzene	91.9	(2.39)	[1]	101 X	(2.39)	[1]	ND	(304)	[500]	NA
Methyl ethyl ketone	ND	(4.06)	[1]	16.4	(4.06)	[1]	ND	(2290)	[500]	NA

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 MW-9 KRF-09-GW118			9 MW-10 KRF-10-GW114			9 DW-02 KRF-DW02-GW119			
SW8240 - Volatile Organics, cont. (ug/L)										
Methylene Chloride	ND	(4.02)	[1]	4.72	(4.02)	[1]	1260 B	(1100)	[500]	NA
Styrene	2.06	(1.71)	[1]	ND X	(1.71)	[1]	ND	(188)	[500]	NA
Tetrachloroethene	ND	(2.58)	[1]	ND X	(2.58)	[1]	ND	(625)	[500]	NA
Toluene	5.65	(1.5)	[1]	51.2	(1.5)	[1]	ND	(353)	[500]	NA
Tribromomethane(Bromoform)	ND	(2.04)	[1]	ND X	(2.04)	[1]	ND	(494)	[500]	NA
Trichloroethene	ND	(1.94)	[1]	ND	(1.94)	[1]	ND	(444)	[500]	NA
Vinyl Chloride	10.2	(2.93)	[1]	28	(2.93)	[1]	ND	(870)	[500]	NA
Vinyl acetate	ND	(1.18)	[1]	ND	(1.18)	[1]	ND	(705)	[500]	NA
Xylene (total)	12	(4.66)	[1]	276 X	(4.66)	[1]	ND	(825)	[500]	NA
cis-1,3-Dichloropropene	ND	(1.77)	[1]	ND	(1.77)	[1]	ND	(268)	[500]	NA
trans-1,2-Dichloroethene	< DL	(1.7)	[1]	14	(1.7)	[1]	ND	(540)	[500]	NA
trans-1,3-Dichloropropene	ND	(1.9)	[1]	ND	(1.9)	[1]	ND	(249)	[500]	NA
SW8270 - Semivolatile Organics (ug/L)										
1,2,4-Trichlorobenzene	ND	(1.01)	[1]	51.4	(1.67)	[1]	15.5	(0.875)	[1]	NA
1,2-Dichlorobenzene	163	(0.855)	[1]	11200	(46.6)	[20]	1820	(14.8)	[20]	NA
1,3-Dichlorobenzene	23.5	(0.52)	[1]	760	(42.4)	[20]	152	(9)	[20]	NA
1,4-Dichlorobenzene	183	(0.815)	[1]	2160	(55.5)	[20]	529	(14.1)	[20]	NA
2,4,5-Trichlorophenol	ND	(0.812)	[1]	ND	(2.09)	[1]	ND	(0.702)	[1]	NA
2,4,6-Trichlorophenol	ND	(0.584)	[1]	ND	(2.48)	[1]	ND	(0.505)	[1]	NA
2,4-Dichlorophenol	ND	(0.261)	[1]	36.3	(3.3)	[1]	ND	(0.226)	[1]	NA
2,4-Dimethylphenol	ND	(1.02)	[1]	3.45	(3.06)	[1]	ND	(0.882)	[1]	NA
2,4-Dinitrophenol	ND	(3.24)	[1]	ND	(4.25)	[1]	ND	(2.8)	[1]	NA
2,4-Dinitrotoluene	ND	(0.58)	[1]	ND	(2.59)	[1]	ND	(0.502)	[1]	NA
2,6-Dinitrotoluene	ND	(0.914)	[1]	ND	(2.83)	[1]	ND	(0.791)	[1]	NA
2-Chloronaphthalene	ND	(1.33)	[1]	ND	(2.49)	[1]	ND	(1.15)	[1]	NA
2-Chlorophenol	37.4	(0.783)	[1]	193	(2.15)	[1]	22.1	(0.677)	[1]	NA
2-Methylnaphthalene	59.2	(0.843)	[1]	16.2	(2.2)	[1]	124	(14.6)	[20]	NA
2-Methylphenol	ND	(0.735)	[1]	ND	(1.19)	[1]	ND	(0.636)	[1]	NA
2-Nitroaniline	ND	(1.33)	[1]	ND	(2.8)	[1]	ND	(1.15)	[1]	NA
2-Nitrophenol	ND	(0.799)	[1]	ND	(2.81)	[1]	ND	(0 691)	[1]	NA
3,3'-Dichlorobenzidine	ND	(0.623)	[1]	ND	(3.39)	[1]	ND	(0.539)	[1]	NA
3-Nitroaniline	ND	(0.994)	[1]	ND	(2.95)	[1]	ND	(0.86)	[1]	NA
4,6-Dinitro-2-methylphenol	ND	(1.13)	[1]	ND	(3.73)	[1]	ND	(0.976)	[1]	NA
4-Bromophenyl phenyl ether	ND	(1.02)	[1]	ND	(1.59)	[1]	ND	(0.381)	[1]	NA
4-Chloro-3-methylphenol	ND	(0.769)	[1]	ND	(1.52)	[1]	ND	(0.665)	[1]	NA

Compiled: 22 June 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable * - Value considered suspect, Refer to QC Report

PARAMETER	9 MW-9 KRF-09-GW118				9 MW-10 KRF-10-GW114				9 DW-02 KRF-DW02-GW119				
SW8270 - Semivolatile Organics, cont. (ug/L)													
4-Chlorophenyl phenyl ether	ND		(0.664)	[1]	ND		(1.77)	[1]	ND		(0.574)	[1]	NA
4-Methylphenol/3-Methylphenol	ND		(0.506)	[1]	5.9	F	(1.38)	[1]	ND		(0.438)	[1]	NA
4-Nitroaniline	ND		(1.26)	[1]	ND		(4.14)	[1]	ND		(1.09)	[1]	NA
4-Nitrophenol	ND		(3.23)	[1]	ND		(4.4)	[1]	ND		(2.79)	[1]	NA
Acenaphthene	< DL		(0.84)	[1]	ND		(2.42)	[1]	7.79		(0.727)	[1]	NA
Acenaphthylene	ND		(0.733)	[1]	ND		(2.4)	[1]	ND		(0.634)	[1]	NA
Anthracene	ND		(0.68)	[1]	ND		(2.89)	[1]	0.657		(0.588)	[1]	NA
Benzo(a)anthracene	ND		(0.637)	[1]	ND		(2.26)	[1]	0.599		(0.551)	[1]	NA
Benzo(a)pyrene	ND		(0.805)	[1]	ND		(3.02)	[1]	< DL		(0.696)	[1]	NA
Benzo(b)fluoranthene	ND		(0.813)	[1]	ND		(3.98)	[1]	0.91	F	(0.703)	[1]	NA
Benzo(g,h,i)perylene	ND		(0.783)	[1]	ND		(4.29)	[1]	< DL		(0.677)	[1]	NA
Benzo(k)fluoranthene	ND		(1.02)	[1]	ND		(4.17)	[1]	0.91	F	(0.884)	[1]	NA
Benzoic acid	ND		(6.97)	[1]	< DL		(98.9)	[1]	ND		(6.03)	[1]	NA
Benzyl alcohol	ND		(0.703)	[1]	ND		(2.04)	[1]	ND		(0.608)	[1]	NA
Butylbenzylphthalate	ND		(2.05)	[1]	ND		(6.92)	[1]	< DL		(1.77)	[1]	NA
Chrysene	ND		(0.843)	[1]	ND		(3.76)	[1]	0.913		(0.729)	[1]	NA
Di-n-octylphthalate	ND		(0.923)	[1]	ND		(1.95)	[1]	ND		(0.798)	[1]	NA
Dibenz(a,h)anthracene	ND		(0.846)	[1]	ND		(3.8)	[1]	ND		(0.732)	[1]	NA
Dibenzofuran	0.727		(0.643)	[1]	ND		(2.1)	[1]	3.2		(0.556)	[1]	NA
Dibutylphthalate	1.51		(0.673)	[1]	ND		(1.88)	[1]	5		(0.582)	[1]	NA
Diethylphthalate	1.77		(0.44)	[1]	2.5		(0.962)	[1]	2.23		(0.381)	[1]	NA
Dimethylphthalate	ND		(0.46)	[1]	ND		(1.7)	[1]	ND		(0.398)	[1]	NA
Diphenylamine	< DL	F	(1.07)	[1]	ND		(3.41)	[1]	ND		(0.926)	[1]	NA
Fluoranthene	ND		(0.725)	[1]	ND		(2.24)	[1]	29.3		(0.627)	[1]	NA
Fluorene	0.74		(0.601)	[1]	ND		(1.74)	[1]	7.51		(0.52)	[1]	NA
Hexachlorobenzene	ND		(0.815)	[1]	ND		(2.09)	[1]	1.17		(0.705)	[1]	NA
Hexachlorobutadiene	ND		(0.652)	[1]	ND		(3.91)	[1]	ND		(0.737)	[1]	NA
Hexachlorocyclopentadiene	ND		(2.46)	[1]	ND		(4.51)	[1]	ND		(2.13)	[1]	NA
Hexachloroethane	ND		(0.975)	[1]	ND		(2.09)	[1]	ND		(0.843)	[1]	NA
Indeno(1,2,3-cd)pyrene	ND		(0.614)	[1]	ND		(3.35)	[1]	< DL		(0.531)	[1]	NA
Isophorone	ND		(0.884)	[1]	ND		(1.23)	[1]	ND		(0.765)	[1]	NA
N-Nitroso-di-n-propylamine	ND		(0.498)	[1]	ND		(2.34)	[1]	ND		(0.431)	[1]	NA
Naphthalene	71.1		(0.733)	[1]	121		(2.93)	[1]	86.8		(0.634)	[1]	NA
Nitrobenzene	ND		(1.32)	[1]	ND		(1.67)	[1]	ND		(1.14)	[1]	NA
Pentachlorophenol	ND		(1.23)	[1]	ND		(3.61)	[1]	ND		(1.06)	[1]	NA
Phenanthrene	< DL		(0.941)	[1]	ND		(2.5)	[1]	7.17		(0.814)	[1]	NA

Compiled: 22 June 1994   () = Detection Limit   [] = Dilution Factor   ND = Not Detected   NA = Not Applicable   * - Value considered suspect, Refer to QC Report

PARAMETER	9 MW-9 KRF-09-GW118			9 MW-10 KRF-10-GW114			9 DW-02 KRF-DW02-GW119			
SW8270 - Semivolatile Organics, cont. (ug/L)										
Phenol	3.58	(0.385)	[1]	22.3	(1.41)	[1]	ND	(0.333)	[1]	NA
Pyrene	ND	(0.516)	[1]	ND	(2.68)	[1]	2.83	(0.446)	[1]	NA
bis(2-Chloroethoxy)methane	ND	(0.969)	[1]	ND	(2.4)	[1]	ND	(0.838)	[1]	NA
bis(2-Chloroethyl)ether	ND	(1.07)	[1]	ND	(1.85)	[1]	ND	(0.924)	[1]	NA
bis(2-Chloroisopropyl)ether	ND	(1.32)	[1]	ND	(1.68)	[1]	ND	(1.14)	[1]	NA
bis(2-Ethylhexyl)phthalate	< DL	(1.72)	[1]	ND	(10.1)	[1]	218	(29.8)	[20]	NA
p-Chloroaniline	ND	(1.03)	[1]	ND	(3.56)	[1]	ND	(0.889)	[1]	NA

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September 23, 1994

Cliff Blanchard
Brown & Root Environmental
800 Oak Ridge Turnpike, Suite A600
Oak Ridge, TN 37830

Re: EPA Contract No. 68-C0-0048, WA 0-44
SAIC Project No. 01-0832-07-1123-013

Dear Cliff:

Enclosed is a copy of the post-treatment soil analyses from Radian. These summary tables present preliminary TRPH, VOC and SVOC data from the July sampling event. The data are currently undergoing a complete QC check, and are not considered validated. A final data summary will be sent when the QC check is complete.

Per your request, I am also sending you a copy of the raw footage that was taken in March 1994. The video, which will be sent under separate cover from AVS Video, shows system installation, Visitor's Day, and background shots of Kelly AFB.

If you have any questions or comments, please call me at 513-723-2600, extension 2608.

Sincerely,

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

Peggy Groeber

Margaret M. Groeber
Work Assignment Manager

Encl.

cc. C. Dial, SAIC
L. Staley, EPA

s9a:cliff1.let

635 West Seventh Street, Suite 403, Cincinnati, Ohio 45203 • (513) 723-2600 • FAX: (513) 723-2605
Other SAIC Offices: Albuquerque, Colorado Springs, Dayton, Falls Church, Huntsville, Las Vegas, Los Altos, Los Angeles, McLean, Oak Ridge, Orlando, San Diego, Seattle, Tucson

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)												
	9			9			9			9		
	AIA			AIA			AIA			AIA		
	KRF-AIA-U0002			KRF-AIA-U1618			KRF-AIA-U1820			KRF-AIA-U2627		
PARAMETER	0 - 2			16 - 18			18 - 20			26 - 27		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	184 ✓	(6.77)	[1]	20800✓	(84.1)	[10]	28300✓	(167)	[20]	5880 ✓	(35.2)	[5]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(1.62)	[1]	NA			ND	(126)	[100]	ND	(106)	[100]
1,1,2,2-Tetrachloroethane	ND	(4.4)	[1]	NA			ND	(164)	[100]	ND	(139)	[100]
1,1,2-Trichloroethane	ND	(1.32)	[1]	NA			ND	(124)	[100]	ND	(105)	[100]
1,1-Dichloroethane	ND	(1.49)	[1]	NA			ND	(98.8)	[100]	ND	(83.5)	[100]
1,1-Dichloroethene	ND	(2.22)	[1]	NA			ND	(244)	[100]	ND	(206)	[100]
1,2-Dichloroethane	ND	(1.51)	[1]	NA			ND	(180)	[100]	ND	(153)	[100]
1,2-Dichloropropane	ND	(2.27)	[1]	NA			ND	(341)	[100]	ND	(288)	[100]
2-Chloroethyl vinyl ether	ND	(2.48)	[1]	NA			ND	(180)	[100]	ND	(153)	[100]
2-Hexanone	1230✓	(161)	[100]	NA			ND	(200)	[100]	ND	(169)	[100]
4-Methyl-2-Pentanone(MIBK)	354✓	(109)	[100]	NA			ND	(135)	[100]	ND	(114)	[100]
Acetone	1450✓	(604)	[100]	NA			1220✓	(746)	[100]	< DL	(630)	[100]
Benzene	< DL	(1.5)	[1]	NA			1220✓	(83.5)	[100]	321✓	(70.6)	[100]
Bromodichloromethane	ND	(1.41)	[1]	NA			ND	(456)	[100]	ND	(386)	[100]
Bromomethane	ND	(1.74)	[1]	NA			ND	(235)	[100]	ND	(199)	[100]
Carbon disulfide	ND	(2.24)	[1]	NA			ND	(187)	[100]	ND	(158)	[100]
Carbon tetrachloride	ND	(1.73)	[1]	NA			ND	(184)	[100]	ND	(156)	[100]
Chlorobenzene	4.57✓	(4.03)	[1]	NA			30100✓	(642)	[500]	213000✓	(5420)	[5000]
Chloroethane	ND	(1.77)	[1]	NA			ND	(172)	[100]	ND	(145)	[100]
Chloroform	ND	(1.81)	[1]	NA			ND	(76.5)	[100]	ND	(64.7)	[100]
Chloromethane	ND	(2.11)	[1]	NA			ND	(124)	[100]	ND	(105)	[100]
Dibromochloromethane	ND	(1.59)	[1]	NA			ND	(90.1)	[100]	ND	(76.2)	[100]
Ethyl benzene	ND	(1.43)	[1]	NA			1130✓	(140)	[100]	1140✓	(118)	[100]
Methyl ethyl ketone	1610 ✓	(284)	[100]	NA			ND	(351)	[100]	ND	(296)	[100]
Methylene Chloride	3.12 ✓	(2.26)	[1]	NA			ND	(235)	[100]	ND	(199)	[100]
Styrene	ND	(1.4)	[1]	NA			ND	(137)	[100]	ND	(116)	[100]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9				9	9				9		
	A1A				A1A	A1A				A1A		
	KRF-A1A-U0002				KRF-A1A-U1618	KRF-A1A-U1820				KRF-A1A-U2627		
	0 - 2				16 - 18	18 - 20				26 - 27		
SW8240 - Volatile Organics, cont. (ug/kg)												
Tetrachloroethene	ND		(4.12)	[1]	NA	ND		(186)	[100]	ND	(157)	[100]
Toluene	ND		(1.48)	[1]	NA	839✓		(102)	[100]	549✓	(86.5)	[100]
Tribromomethane(Bromoform)	ND		(1.31)	[1]	NA	ND		(61.5)	[100]	ND	(52)	[100]
Trichloroethene	ND		(4.21)	[1]	NA	ND		(198)	[100]	ND	(168)	[100]
Vinyl Chloride	ND		(1.79)	[1]	NA	ND		(156)	[100]	ND	(132)	[100]
Vinyl acetate	ND		(9.5)	[1]	NA	ND		(104)	[100]	ND	(88.1)	[100]
Xylene (total)	ND		(3.16)	[1]	NA	4010✓		(323)	[100]	8160✓	(273)	[100]
cis-1,3-Dichloropropene	ND		(1.39)	[1]	NA	ND		(68.9)	[100]	ND	(58.2)	[100]
trans-1,2-Dichloroethene	ND		(2.02)	[1]	NA	ND		(212)	[100]	ND	(179)	[100]
trans-1,3-Dichloropropene	ND		(1.51)	[1]	NA	ND		(187)	[100]	ND	(158)	[100]
SW8270 - Semivolatile Organics (ug/g)												
1,2,4-Trichlorobenzene	ND	X	(0.0748)	[10]	NA	ND	X	(0.912)	[5]	0.302	(0.0234)	[1]
1,2-Dichlorobenzene	ND	X	(0.105)	[10]	NA	ND	X	(1.28)	[5]	2.64	(0.0329)	[1]
1,3-Dichlorobenzene	ND	X	(0.0982)	[10]	NA	ND	X	(1.2)	[5]	1.97	(0.0307)	[1]
1,4-Dichlorobenzene	ND	X	(0.167)	[10]	NA	ND	X	(2.03)	[5]	14.1	(0.0521)	[1]
2,4,5-Trichlorophenol	ND	X	(0.141)	[10]	NA	ND	X	(1.72)	[5]	ND	(0.044)	[1]
2,4,6-Trichlorophenol	ND	X	(0.129)	[10]	NA	ND	X	(1.58)	[5]	ND	(0.0405)	[1]
2,4-Dichlorophenol	ND	X	(0.108)	[10]	NA	ND	X	(1.31)	[5]	ND	(0.0337)	[1]
2,4-Dimethylphenol	ND	X	(0.433)	[10]	NA	ND	X	(5.27)	[5]	ND	(0.135)	[1]
2,4-Dinitrophenol	ND	X	(0.917)	[10]	NA	ND	X	(11.2)	[5]	ND	(0.287)	[1]
2,4-Dinitrotoluene	ND	X	(0.157)	[10]	NA	ND	X	(1.91)	[5]	ND	(0.0491)	[1]
2,6-Dinitrotoluene	ND	X	(0.133)	[10]	NA	ND	X	(1.62)	[5]	ND	(0.0416)	[1]
2-Chloronaphthalene	ND	X	(0.215)	[10]	NA	ND	X	(2.62)	[5]	ND	(0.0671)	[1]
2-Chlorophenol	ND	X	(0.155)	[10]	NA	ND	X	(1.89)	[5]	ND	(0.0485)	[1]
2-Methylnaphthalene	ND	X	(0.184)	[10]	NA	9.42	X	(2.25)	[5]	5.9	(0.0577)	[1]
2-Methylphenol	ND	X	(0.395)	[10]	NA	ND	X	(4.81)	[5]	ND	(0.124)	[1]
2-Nitroaniline	ND	X	(0.145)	[10]	NA	ND	X	(1.77)	[5]	ND	(0.0453)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)																
	9				9				9				9			
	AIA				AIA				AIA				AIA			
	KRF-AIA-U0002				KRF-AIA-U1618				KRF-AIA-U1820				KRF-AIA-U2627			
PARAMETER	0 - 2				16 - 18				18 - 20				26 - 27			
SW8270 - Semivolatile Organics, cont. (ug/g)																
2-Nitrophenol	ND	X	(0.172)	[10]	NA				ND	X	(2.1)	[5]	ND		(0.0539)	[1]
3,3'-Dichlorobenzidine	ND	X	(0.361)	[10]	NA				ND	X	(4.39)	[5]	ND		(0.113)	[1]
3-Nitroaniline	ND	X	(0.174)	[10]	NA				ND	X	(2.12)	[5]	ND		(0.0545)	[1]
4,6-Dinitro-2-methylphenol	ND	X	(0.26)	[10]	NA				ND	X	(3.17)	[5]	ND		(0.0814)	[1]
4-Bromophenyl phenyl ether	ND	X	(0.186)	[10]	NA				ND	X	(2.27)	[5]	ND		(0.0583)	[1]
4-Chloro-3-methylphenol	ND	X	(0.115)	[10]	NA				ND	X	(1.4)	[5]	ND		(0.036)	[1]
4-Chlorophenyl phenyl ether	ND	X	(0.259)	[10]	NA				ND	X	(3.16)	[5]	ND		(0.0811)	[1]
4-Methylphenol/3-Methylphenol	ND	X	(0.357)	[10]	NA				ND	X	(4.35)	[5]	ND		(0.112)	[1]
4-Nitroaniline	ND	X	(0.175)	[10]	NA				ND	X	(2.13)	[5]	ND		(0.0548)	[1]
4-Nitrophenol	ND	X	(0.156)	[10]	NA				ND	X	(1.9)	[5]	ND		(0.0489)	[1]
Acenaphthene	ND	X	(0.141)	[10]	NA				ND	X	(1.72)	[5]	ND		(0.0441)	[1]
Acenaphthylene	ND	X	(0.261)	[10]	NA				ND	X	(3.18)	[5]	ND		(0.0817)	[1]
Anthracene	ND	X	(0.175)	[10]	NA				ND	X	(2.13)	[5]	ND		(0.0548)	[1]
Benzo(a)anthracene	ND	X	(0.138)	[10]	NA				ND	X	(1.68)	[5]	ND		(0.0431)	[1]
Benzo(a)pyrene	0.222	X	(0.215)	[10]	NA				ND	X	(2.62)	[5]	ND		(0.0671)	[1]
Benzo(b)fluoranthene	0.608	XF	(0.338)	[10]	NA				ND	X	(4.11)	[5]	ND		(0.106)	[1]
Benzo(g,h,i)perylene	0.357	X	(0.149)	[10]	NA				ND	X	(1.82)	[5]	ND		(0.0467)	[1]
Benzo(k)fluoranthene	0.608	XF	(0.227)	[10]	NA				ND	X	(2.76)	[5]	ND		(0.0709)	[1]
Benzoic acid	ND	X	(2.07)	[10]	NA				ND	X	(25.2)	[5]	ND		(0.648)	[1]
Benzyl alcohol	ND	X	(0.158)	[10]	NA				ND	X	(1.93)	[5]	ND		(0.0495)	[1]
Butylbenzylphthalate	ND	X	(0.181)	[10]	NA				ND	X	(2.21)	[5]	ND		(0.0567)	[1]
Chrysene	0.265	X	(0.0941)	[10]	NA				ND	X	(1.15)	[5]	ND		(0.0294)	[1]
Di-n-octylphthalate	ND	X	(0.152)	[10]	NA				ND	X	(1.85)	[5]	ND		(0.0475)	[1]
Dibenz(a,h)anthracene	ND	X	(0.167)	[10]	NA				ND	X	(2.03)	[5]	ND		(0.0522)	[1]
Dibenzofuran	ND	X	(0.124)	[10]	NA				ND	X	(1.51)	[5]	ND		(0.0387)	[1]
Dibutylphthalate	ND	X	(0.15)	[10]	NA				ND	X	(1.83)	[5]	0.226		(0.047)	[1]
Diethylphthalate	ND	X	(0.108)	[10]	NA				ND	X	(1.32)	[5]	ND		(0.0338)	[1]
Dimethylphthalate	ND	X	(0.111)	[10]	NA				ND	X	(1.35)	[5]	ND		(0.0347)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 A1A KRF-A1A-U0002 0 - 2				9 A1A KRF-A1A-U1618 16 - 18				9 A1A KRF-A1A-U1820 18 - 20				9 A1A KRF-A1A-U2627 26 - 27			
SW8270 - Semivolatile Organics, cont. (ug/g)																
Diphenylamine	ND	X	(0.255)	[10]	NA				ND	X	(3.11)	[5]	ND		(0.0799)	[1]
Fluoranthene	ND	X	(0.058)	[10]	NA				3.93	X	(0.707)	[5]	0.852		(0.0182)	[1]
Fluorene	ND	X	(0.0975)	[10]	NA				ND	X	(1.19)	[5]	0.205		(0.0305)	[1]
Hexachlorobenzene	ND	X	(0.163)	[10]	NA				ND	X	(1.98)	[5]	ND		(0.0509)	[1]
Hexachlorobutadiene	ND	X	(0.0831)	[10]	NA				ND	X	(1.01)	[5]	ND		(0.026)	[1]
Hexachlorocyclopentadiene	ND	X	(0.563)	[10]	NA				ND	X	(6.86)	[5]	ND		(0.176)	[1]
Hexachloroethane	ND	X	(0.0845)	[10]	NA				ND	X	(1.03)	[5]	ND		(0.0264)	[1]
Indeno(1,2,3-cd)pyrene	0.282	X	(0.178)	[10]	NA				ND	X	(2.17)	[5]	ND		(0.0557)	[1]
Isophorone	ND	X	(0.127)	[10]	NA				ND	X	(1.54)	[5]	ND		(0.0396)	[1]
N-Nitroso-di-n-propylamine	ND	X	(0.195)	[10]	NA				ND	X	(2.38)	[5]	ND		(0.0611)	[1]
Naphthalene	ND	X	(0.215)	[10]	NA				ND	X	(2.62)	[5]	3.2		(0.0673)	[1]
Nitrobenzene	ND	X	(0.112)	[10]	NA				ND	X	(1.36)	[5]	ND		(0.0349)	[1]
Pentachlorophenol	ND	X	(0.0621)	[10]	NA				ND	X	(0.757)	[5]	ND		(0.0194)	[1]
Phenanthrene	ND	X	(0.128)	[10]	NA				ND	X	(1.57)	[5]	0.308		(0.0402)	[1]
Phenol	ND	X	(0.184)	[10]	NA				ND	X	(2.24)	[5]	ND		(0.0575)	[1]
Pyrene	ND	X	(0.0838)	[10]	NA				ND	X	(1.02)	[5]	0.148		(0.0262)	[1]
bis(2-Chloroethoxy)methane	ND	X	(0.0948)	[10]	NA				ND	X	(1.16)	[5]	ND		(0.0296)	[1]
bis(2-Chloroethyl)ether	ND	X	(0.136)	[10]	NA				ND	X	(1.66)	[5]	ND		(0.0426)	[1]
bis(2-Chloroisopropyl)ether	ND	X	(0.149)	[10]	NA				ND	X	(1.82)	[5]	ND		(0.0466)	[1]
bis(2-Ethylhexyl)phthalate	ND	X	(0.608)	[10]	NA				31.6	X	(7.41)	[5]	4.61		(0.19)	[1]
p-Chloroaniline	ND	X	(0.204)	[10]	NA				ND	X	(2.49)	[5]	ND		(0.0639)	[1]
SW846 - Percent Moisture (percent)																
Percent moisture	2.98 ✓		(0)	[1]	21 ✓		(0)	[1]	21.4 ✓		(0)	[1]	6.99 ✓		(0)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 A2A KRF-A2A-U0002 0 - 2			9 A2A KRF-A2A-U0204 2 - 4			9 A2A KRF-A2A-U0406 4 - 6			9 A2A KRF-A2A-U1012 10 - 12		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	8850 ✓	(65.7)	[10]	2570 ✓	(13.9)	[2]	154 ✓	(6.64)	[1]	< DL ✓	(6.66)	[1]
	X= 7/20, 09:17 00 7/21, 11:22:00			X= 7/20, 9:41:00 7/21, 19:46:00								
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(1.57)	[1]	ND	(1.65)	[1]	ND	(1.58)	[1]	NA		
1,1,2,2-Tetrachloroethane	~~ND~~ X	(~~4.27~~ 20.3)	[1]	~~ND~~ X	(~~4.48~~ 21.9)	[1]	ND	(4.29)	[1]	NA		
1,1,2-Trichloroethane	~~ND~~ X	(~~1.28~~ 6.10)	[1]	~~ND~~ X	(~~1.35~~ 10.57)	[1]	ND	(1.29)	[1]	NA		
1,1-Dichloroethane	ND	(1.44)	[1]	ND	(1.51)	[1]	ND	(1.45)	[1]	NA		
1,1-Dichloroethene	ND	(2.16)	[1]	ND	(2.27)	[1]	ND	(2.17)	[1]	NA		
1,2-Dichloroethane	ND	(1.46)	[1]	ND	(1.54)	[1]	ND	(1.47)	[1]	NA		
1,2-Dichloropropane	ND	(2.21)	[1]	ND	(2.32)	[1]	ND	(2.22)	[1]	NA		
2-Chloroethyl vinyl ether	ND	(2.41)	[1]	ND	(2.53)	[1]	ND	(2.42)	[1]	NA		
2-Hexanone	~~ND~~ X	(~~0.808~~ 3.83)	[1]	~~ND~~ X	(~~0.847~~ 4.15)	[1]	25.8 ✓	(0.811)	[1]	NA		
4-Methyl-2-Pentanone(MIBK)	ND	(0.771)	[1]	8.5	(0.808)	[1]	17 ✓	(0.774)	[1]	NA		
Acetone	60.3 B ~~33.0~~ B	(~~1.26~~ 6.01)	[1]	93.3 B ~~42.7~~ B	(~~1.33~~ 6.49)	[1]	831 ✓	(586)	[100]	NA		
Benzene	2 03	(1.45)	[1]	~~2.26~~ <DL	(1.52) 7.46	[1]	138 ✓	(1.46)	[1]	NA		
Bromodichloromethane	ND	(1.37)	[1]	ND	(1.44)	[1]	ND	(1.38)	[1]	NA		
Bromomethane	ND	(1.69)	[1]	ND	(1.78)	[1]	ND	(1.7)	[1]	NA		
Carbon disulfide	ND	(2.18)	[1]	ND	(2.29)	[1]	ND	(2.19)	[1]	NA		
Carbon tetrachloride	ND	(1.68)	[1]	ND	(1.77)	[1]	ND	(1.69)	[1]	NA		
Chlorobenzene	<DL ~~17.5~~ X	(~~3.91~~ 18.6)	[1]	307 ✓	(20.1)	[1]	46.4 ✓	(3.93)	[1]	NA		
Chloroethane	ND	(1.72)	[1]	ND	(1.81)	[1]	ND	(1.73)	[1]	NA		
Chloroform	ND	(1.76)	[1]	ND	(1.85)	[1]	ND	(1.77)	[1]	NA		
Chloromethane	ND	(2.05)	[1]	ND	(2.15)	[1]	ND	(2.06)	[1]	NA		
Dibromochloromethane	~~ND~~ X	(~~1.54~~ 7.22)	[1]	~~ND~~ X	(~~1.62~~ 7.92)	[1]	ND	(1.55)	[1]	NA		
Ethyl benzene	~~ND~~ X	(~~1.39~~ 6.67)	[1]	100 ~~45.9~~ X	(~~1.46~~ 7.16)	[1]	5.49 ✓	(1.4)	[1]	NA		
Methyl ethyl ketone	ND	(1.28) ✓	[1]	5.71	(1.35)	[1]	150 ✓	(1.29)	[1]	NA		
Methylene Chloride	~~3.23~~	(~~2.2~~ 10.5)	[1]	< DL	(2.31)	[1]	ND	(2.21)	[1]	NA		
Styrene	~~ND~~ X	(~~1.36~~ 6.18)	[1]	~~ND~~ X	(~~1.43~~ 7.88)	[1]	ND	(1.37)	[1]	NA		

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)	9 A2A KRF-A2A-U0002 0 - 2			9 A2A KRF-A2A-U0204 2 - 4			9 A2A KRF-A2A-U0406 4 - 6			9 A2A KRF-A2A-U1012 10 - 12
PARAMETER										
SW8240 - Volatile Organics, cont. (ug/kg)										
Tetrachloroethene	~~ND X~~	19.0 ~~(4)~~	[1]	23.6 ~~25.9 X~~	20.5 ~~(4.2)~~	[1]	ND	(4.02)	[1]	NA
Toluene	9.69 ~~12.3~~	(6.31 ~~1.43~~)	[1]	155 ~~192~~	(7.36 ~~1.5~~)	[1]	34.3✓	(1.44)	[1]	NA
Tribromomethane(Bromoform)	~~ND X~~	(6.02 ~~1.27~~)	[1]	~~ND X~~	6.54 ~~(1.34)~~	[1]	ND	(1.28)	[1]	NA
Trichloroethene	,104 ~~4.76~~	19.4 ~~(4.09)~~	[1]	29.8✓	(4.29)	[1]	ND	(4.11)	[1]	NA
Vinyl Chloride	ND	(1.74)	[1]	ND	(1.83)	[1]	ND	(1.75)	[1]	NA
Vinyl acetate	ND	(9.23)	[1]	ND	(9.68)	[1]	ND	(9.27)	[1]	NA
Xylene (total)	,10 ~~6.78~~ X	11.6 ~~(3.07)~~	[1]	✓213 ~~333~~ X	15.7 ~~(3.22)~~	[1]	31✓	(3.08)	[1]	NA
cis-1,3-Dichloropropene	ND	(1.35)	[1]	ND	(1.42)	[1]	ND	(1.36)	[1]	NA
trans-1,2-Dichloroethene	ND	(1.96)	[1]	ND	(2.06)	[1]	ND	(1.97)	[1]	NA
trans-1,3-Dichloropropene	ND	(1.46)	[1]	ND	(1.54)	[1]	ND	(1.47)	[1]	NA
SW8270 - Semivolatile Organics (ug/g)										
1,2,4-Trichlorobenzene	ND X	(3.67)	[50]	ND X	(0.456)	[20]	0.0416	(0.00725)	[1]	NA
1,2-Dichlorobenzene	ND X	(5.15)	[50]	40.5 X	(0.64)	[20]	3.15	(0.0107)	[1]	NA
1,3-Dichlorobenzene	ND X	(4.81)	[50]	0.999 X	(0.598)	[20]	0.135	(0.00952)	[1]	NA
1,4-Dichlorobenzene	ND X	(8.16)	[50]	3.35 X	(1.01)	[20]	0.383	(0.0161)	[1]	NA
2,4,5-Trichlorophenol	ND X	(6.9)	[50]	ND X	(0.857)	[20]	ND	(0.0136)	[1]	NA
2,4,6-Trichlorophenol	ND X	(6.34)	[50]	ND X	(0.788)	[20]	ND	(0.0125)	[1]	NA
2,4-Dichlorophenol	ND X	(5.28)	[50]	ND X	(0.657)	[20]	ND	(0.0104)	[1]	NA
2,4-Dimethylphenol	ND X	(21.2)	[50]	ND X	(2.63)	[20]	ND	(0.0419)	[1]	NA
2,4-Dinitrophenol	ND X	(44.9)	[50]	ND X	(5.58)	[20]	ND	(0.0889)	[1]	NA
2,4-Dinitrotoluene	ND X	(7.69)	[50]	ND X	(0.956)	[20]	ND	(0.0152)	[1]	NA
2,6-Dinitrotoluene	ND X	(6.51)	[50]	ND X	(0.809)	[20]	ND	(0.0129)	[1]	NA
2-Chloronaphthalene	ND X	(10.5)	[50]	ND X	(1.31)	[20]	ND	(0.0208)	[1]	NA
2-Chlorophenol	ND X	(7.6)	[50]	ND X	(0.945)	[20]	ND	(0.015)	[1]	NA
2-Methylnaphthalene	ND X	(9.03)	[50]	1.32 X	(1.12)	[20]	0 0589	(0.0179)	[1]	NA
2-Methylphenol	ND X	(19.3)	[50]	ND X	(2.4)	[20]	ND	(0.0383)	[1]	NA
2-Nitroaniline	ND X	(7.1)	[50]	ND X	(0.882)	[20]	ND	(0 014)	[1]	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)	9 A2A KRF-A2A-U0002 0 - 2				9 A2A KRF-A2A-U0204 2 - 4				9 A2A KRF-A2A-U0406 4 - 6				9 A2A KRF-A2A-U1012 10 - 12
PARAMETER													
SW8270 - Semivolatile Organics, cont. (ug/g)													
2-Nitrophenol	ND	X	(8.44)	[50]	ND	X	(1.05)	[20]	ND		(0.0167)	[1]	NA
3,3'-Dichlorobenzidine	ND	X	(17.7)	[50]	ND	X	(2.2)	[20]	ND		(0.0349)	[1]	NA
3-Nitroaniline	ND	X	(8.53)	[50]	ND	X	(1 06)	[20]	ND		(0.0169)	[1]	NA
4,6-Dinitro-2-methylphenol	ND	X	(12.8)	[50]	ND	X	(1.58)	[20]	ND		(0.0252)	[1]	NA
4-Bromophenyl phenyl ether	ND	X	(9.13)	[50]	ND	X	(1.14)	[20]	ND		(0.0181)	[1]	NA
4-Chloro-3-methylphenol	ND	X	(5.63)	[50]	ND	X	(0.7)	[20]	ND		(0.0111)	[1]	NA
4-Chlorophenyl phenyl ether	ND	X	(12.7)	[50]	ND	X	(1.58)	[20]	ND		(0.0251)	[1]	NA
4-Methylphenol/3-Methylphenol	ND	X	(17.5)	[50]	ND	X	(2.17)	[20]	ND		(0.0346)	[1]	NA
4-Nitroaniline	ND	X	(8.58)	[50]	ND	X	(1.07)	[20]	ND		(0.017)	[1]	NA
4-Nitrophenol	ND	X	(7.65)	[50]	ND	X	(0.951)	[20]	ND		(0.0151)	[1]	NA
Acenaphthene	ND	X	(6.91)	[50]	ND	X	(0.859)	[20]	ND		(0.0137)	[1]	NA
Acenaphthylene	ND	X	(12.8)	[50]	ND	X	(1.59)	[20]	ND		(0.0253)	[1]	NA
Anthracene	ND	X	(8.58)	[50]	ND	X	(1.07)	[20]	ND		(0.017)	[1]	NA
Benzo(a)anthracene	ND	X	(6.75)	[50]	ND	X	(0.838)	[20]	0.144		(0.0133)	[1]	NA
Benzo(a)pyrene	ND	X	(10.5)	[50]	ND	X	(1.31)	[20]	0.0955		(0.0208)	[1]	NA
Benzo(b)fluoranthene	ND	X	(16.5)	[50]	ND	X	(2.06)	[20]	0.241	F	(0.0327)	[1]	NA
Benzo(g,h,i)perylene	ND	X	(7.32)	[50]	ND	X	(0.91)	[20]	0.0875		(0.0145)	[1]	NA
Benzo(k)fluoranthene	ND	X	(11.1)	[50]	ND	X	(1.38)	[20]	0.241	F	(0.022)	[1]	NA
Benzoic acid	ND	X	(101)	[50]	ND	X	(12.6)	[20]	ND		(0.201)	[1]	NA
Benzyl alcohol	ND	X	(7.75)	[50]	ND	X	(0.964)	[20]	ND		(0.0153)	[1]	NA
Butylbenzylphthalate	ND	X	(8.88)	[50]	ND	X	(1.1)	[20]	ND		(0.0176)	[1]	NA
Chrysene	ND	X	(4.61)	[50]	ND	X	(0.573)	[20]	0.172		(0.00912)	[1]	NA
Di-n-octylphthalate	ND	X	(7.43)	[50]	ND	X	(0.924)	[20]	ND		(0.0147)	[1]	NA
Dibenz(a,h)anthracene	ND	X	(8.17)	[50]	ND	X	(1.02)	[20]	0.0212		(0.0162)	[1]	NA
Dibenzofuran	ND	X	(6.06)	[50]	ND	X	(0.753)	[20]	ND		(0.012)	[1]	NA
Dibutylphthalate	ND	X	(7.37)	[50]	ND	X	(0.916)	[20]	ND		(0.0146)	[1]	NA
Diethylphthalate	ND	X	(5.3)	[50]	ND	X	(0.659)	[20]	ND		(0.0105)	[1]	NA
Dimethylphthalate	ND	X	(5.43)	[50]	ND	X	(0.675)	[20]	ND		(0.0107)	[1]	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 A2A KRF-A2A-U0002 0 - 2				9 A2A KRF-A2A-U0204 2 - 4				9 A2A KRF-A2A-U0406 4 - 6			9 A2A KRF-A2A-U1012 10 - 12		
SW8270 - Semivolatile Organics, cont. (ug/g)														
Diphenylamine	ND	X	(12.5)	[50]	ND	X	(1.56)	[20]	ND	(0.0246)	[1]	NA		
Fluoranthene	ND	X	(2.84)	[50]	ND	X	(0.353)	[20]	0.341	(0.00562)	[1]	NA		
Fluorene	ND	X	(4.78)	[50]	ND	X	(0.594)	[20]	ND	(0.00945)	[1]	NA		
Hexachlorobenzene	ND	X	(7.97)	[50]	ND	X	(0.991)	[20]	ND	(0.0158)	[1]	NA		
Hexachlorobutadiene	ND	X	(4.07)	[50]	ND	X	(0.506)	[20]	ND	(0.00805)	[1]	NA		
Hexachlorocyclopentadiene	ND	X	(27.6)	[50]	ND	X	(3.43)	[20]	ND	(0.0546)	[1]	NA		
Hexachloroethane	ND	X	(4.14)	[50]	ND	X	(0.514)	[20]	ND	(0.00819)	[1]	NA		
Indeno(1,2,3-cd)pyrene	ND	X	(8.73)	[50]	ND	X	(1.09)	[20]	0.0755	(0.0173)	[1]	NA		
Isophorone	ND	X	(6.21)	[50]	ND	X	(0.772)	[20]	ND	(0.0123)	[1]	NA		
N-Nitroso-di-n-propylamine	ND	X	(9.57)	[50]	ND	X	(1.19)	[20]	ND	(0.0189)	[1]	NA		
Naphthalene	ND	X	(10.5)	[50]	ND	X	(1.31)	[20]	0.0592	(0.0209)	[1]	NA		
Nitrobenzene	ND	X	(5.47)	[50]	ND	X	(0.68)	[20]	ND	(0.0108)	[1]	NA		
Pentachlorophenol	ND	X	(3.04)	[50]	ND	X	(0.378)	[20]	ND	(0.00602)	[1]	NA		
Phenanthrene	ND	X	(6.29)	[50]	ND	X	(0.782)	[20]	0.133	(0.0124)	[1]	NA		
Phenol	ND	X	(9)	[50]	ND	X	(1.12)	[20]	ND	(0.0178)	[1]	NA		
Pyrene	ND	X	(4.1)	[50]	ND	X	(0.51)	[20]	0.13	(0.00812)	[1]	NA		
bis(2-Chloroethoxy)methane	ND	X	(4.64)	[50]	ND	X	(0.577)	[20]	ND	(0.00918)	[1]	NA		
bis(2-Chloroethyl)ether	ND	X	(6.68)	[50]	ND	X	(0.83)	[20]	ND	(0.0132)	[1]	NA		
bis(2-Chloroisopropyl)ether	ND	X	(7.3)	[50]	ND	X	(0.907)	[20]	ND	(0.0144)	[1]	NA		
bis(2-Ethylhexyl)phthalate	ND	X	(29.8)	[50]	ND	X	(3.7)	[20]	ND	(0.0589)	[1]	NA		
p-Chloroaniline	ND	X	(10)	[50]	ND	X	(1.24)	[20]	ND	(0.0198)	[1]	NA		
SW846 - Percent Moisture (percent)														
Percent moisture	1.18 ✓		(0)	[1]	5.95 ✓		(0)	[1]	0.4 ✓	(0)	[1]	0.2 ✓	(0)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.) PARAMETER	9 A2A KRF-A2A-U1214 12 - 14			9 A2A KRF-A2A-U1618 16 - 18			9 A2A KRF-A2A-U2022 20 - 22			9 A2A KRF-A2A-U2627 26 - 27		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	106	(6.68)	[1]	6500	(44.4)	[5]	58900	(451)	[50]	4800	(38.1)	[5]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	NA			ND	(134)	[100]	ND	(1350)	[1000]	NA		
1,1,2,2-Tetrachloroethane	NA			ND	(175)	[100]	ND	(1760)	[1000]	NA		
1,1,2-Trichloroethane	NA			ND	(133)	[100]	ND	(1330)	[1000]	NA		
1,1-Dichloroethane	NA			ND	(105)	[100]	ND	(1060)	[1000]	NA		
1,1-Dichloroethene	NA			ND	(260)	[100]	ND	(2620)	[1000]	NA		
1,2-Dichloroethane	NA			ND	(192)	[100]	ND	(1940)	[1000]	NA		
1,2-Dichloropropane	NA			ND	(363)	[100]	ND	(3650)	[1000]	NA		
2-Chloroethyl vinyl ether	NA			ND	(192)	[100]	ND	(1940)	[1000]	NA		
2-Hexanone	NA			ND	(213)	[100]	ND	(2140)	[1000]	NA		
4-Methyl-2-Pentanone(MIBK)	NA			ND	(144)	[100]	ND	(1440)	[1000]	NA		
Acetone	NA			< DL	(795)	[100]	10600	(8000)	[1000]	NA		
Benzene	NA			< DL	(89)	[100]	1390	(895)	[1000]	NA		
Bromodichloromethane	NA			ND	(486)	[100]	ND	(4890)	[1000]	NA		
Bromomethane	NA			ND	(251)	[100]	ND	(2520)	[1000]	NA		
Carbon disulfide	NA			ND	(199)	[100]	ND	(2000)	[1000]	NA		
Carbon tetrachloride	NA			ND	(196)	[100]	ND	(1980)	[1000]	NA		
Chlorobenzene	NA			1640	(137)	[100]	11800	(1380)	[1000]	NA		
Chloroethane	NA			ND	(183)	[100]	ND	(1840)	[1000]	NA		
Chloroform	NA			ND	(81.6)	[100]	ND	(820)	[1000]	NA		
Chloromethane	NA			ND	(132)	[100]	ND	(1330)	[1000]	NA		
Dibromochloromethane	NA			ND	(96.1)	[100]	ND	(966)	[1000]	NA		
Ethyl benzene	NA			ND	(149)	[100]	8740	(1500)	[1000]	NA		
Methyl ethyl ketone	NA			ND	(374)	[100]	ND	(3760)	[1000]	NA		
Methylene Chloride	NA			< DL	(251)	[100]	< DL	(2520)	[1000]	NA		
Styrene	NA			ND	(146)	[100]	ND	(1470)	[1000]	NA		

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 A2A KRF-A2A-U1214 12 - 14	9 A2A KRF-A2A-U1618 16 - 18				9 A2A KRF-A2A-U2022 20 - 22				9 A2A KRF-A2A-U2627 26 - 27
SW8240 - Volatile Organics, cont. (ug/kg)										
Tetrachloroethene	NA	ND		(198)	[100]	8250 ✓		(1990)	[1000]	NA
Toluene	NA	< DL		(109)	[100]	59600 ✓		(1100)	[1000]	NA
Tribromomethane(Bromoform)	NA	ND		(65.6)	[100]	ND		(660)	[1000]	NA
Trichloroethene	NA	ND		(211)	[100]	ND		(2130)	[1000]	NA
Vinyl Chloride	NA	ND		(167)	[100]	ND		(1680)	[1000]	NA
Vinyl acetate	NA	ND		(111)	[100]	ND		(1120)	[1000]	NA
Xylene (total)	NA	ND		(344)	[100]	64400 ✓		(3460)	[1000]	NA
cis-1,3-Dichloropropene	NA	ND		(73.4)	[100]	ND		(739)	[1000]	NA
trans-1,2-Dichloroethene	NA	ND		(226)	[100]	ND		(2280)	[1000]	NA
trans-1,3-Dichloropropene	NA	ND		(199)	[100]	ND		(2000)	[1000]	NA
SW8270 - Semivolatile Organics (ug/g)										
1,2,4-Trichlorobenzene	NA	ND	X	(0.294)	[10]	16.6	X	(2.61)	[10]	NA
1,2-Dichlorobenzene	NA	ND	X	(0.413)	[10]	684	X	(3.66)	[10]	NA
1,3-Dichlorobenzene	NA	ND	X	(0.386)	[10]	30.3	X	(3.42)	[10]	NA
1,4-Dichlorobenzene	NA	ND	X	(0.654)	[10]	270	X	(5.8)	[10]	NA
2,4,5-Trichlorophenol	NA	ND	X	(0.553)	[10]	ND	X	(4.91)	[10]	NA
2,4,6-Trichlorophenol	NA	ND	X	(0.508)	[10]	ND	X	(4.51)	[10]	NA
2,4-Dichlorophenol	NA	ND	X	(0.423)	[10]	ND	X	(3.76)	[10]	NA
2,4-Dimethylphenol	NA	ND	X	(1.7)	[10]	80.7	X	(15.1)	[10]	NA
2,4-Dinitrophenol	NA	ND	X	(3.6)	[10]	ND	X	(32)	[10]	NA
2,4-Dinitrotoluene	NA	ND	X	(0.616)	[10]	ND	X	(5.47)	[10]	NA
2,6-Dinitrotoluene	NA	ND	X	(0.522)	[10]	ND	X	(4.63)	[10]	NA
2-Chloronaphthalene	NA	ND	X	(0.843)	[10]	ND	X	(7.48)	[10]	NA
2-Chlorophenol	NA	ND	X	(0.609)	[10]	ND	X	(5.41)	[10]	NA
2-Methylnaphthalene	NA	ND	X	(0.724)	[10]	147	X	(6.43)	[10]	NA
2-Methylphenol	NA	ND	X	(1.55)	[10]	< DL	X	(13.8)	[10]	NA
2-Nitroaniline	NA	ND	X	(0.569)	[10]	ND	X	(5.05)	[10]	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)				
	9	9	9	9
	A2A	A2A	A2A	A2A
	KRF-A2A-U1214	KRF-A2A-U1618	KRF-A2A-U2022	KRF-A2A-U2627
PARAMETER	12 - 14	16 - 18	20 - 22	26 - 27
SW8270 - Semivolatile Organics, cont. (ug/g)				
2-Nitrophenol	NA	ND X (0.677) [10]	ND X (6.01) [10]	NA
3,3'-Dichlorobenzidine	NA	ND X (1.42) [10]	ND X (12.6) [10]	NA
3-Nitroaniline	NA	ND X (0.683) [10]	ND X (6.07) [10]	NA
4,6-Dinitro-2-methylphenol	NA	ND X (1.02) [10]	ND X (9.07) [10]	NA
4-Bromophenyl phenyl ether	NA	ND X (0.732) [10]	ND X (6.5) [10]	NA
4-Chloro-3-methylphenol	NA	ND X (0.452) [10]	ND X (4.01) [10]	NA
4-Chlorophenyl phenyl ether	NA	ND X (1.02) [10]	ND X (9.04) [10]	NA
4-Methylphenol/3-Methylphenol	NA	< DL XF (1.4) [10]	43.7 XF (12.4) [10]	NA
4-Nitroaniline	NA	ND X (0.688) [10]	ND X (6.1) [10]	NA
4-Nitrophenol	NA	ND X (0.613) [10]	ND X (5.45) [10]	NA
Acenaphthene	NA	ND X (0.554) [10]	ND X (4.92) [10]	NA
Acenaphthylene	NA	ND X (1.03) [10]	ND X (9.11) [10]	NA
Anthracene	NA	ND X (0.688) [10]	ND X (6.1) [10]	NA
Benzo(a)anthracene	NA	ND X (0.541) [10]	ND X (4.8) [10]	NA
Benzo(a)pyrene	NA	ND X (0.843) [10]	ND X (7.48) [10]	NA
Benzo(b)fluoranthene	NA	ND X (1.33) [10]	ND X (11.8) [10]	NA
Benzo(g,h,i)perylene	NA	ND X (0.586) [10]	ND X (5.21) [10]	NA
Benzo(k)fluoranthene	NA	ND X (0.89) [10]	ND X (7.9) [10]	NA
Benzoic acid	NA	ND X (8.13) [10]	ND X (72.2) [10]	NA
Benzyl alcohol	NA	ND X (0.621) [10]	ND X (5.52) [10]	NA
Butylbenzylphthalate	NA	ND X (0.712) [10]	ND X (6.32) [10]	NA
Chrysene	NA	ND X (0.369) [10]	ND X (3.28) [10]	NA
Di-n-octylphthalate	NA	ND X (0.596) [10]	ND X (5.29) [10]	NA
Dibenz(a,h)anthracene	NA	ND X (0.655) [10]	ND X (5.82) [10]	NA
Dibenzofuran	NA	ND X (0.485) [10]	ND X (4.31) [10]	NA
Dibutylphthalate	NA	ND X (0.59) [10]	ND X (5.24) [10]	NA
Diethylphthalate	NA	ND X (0.425) [10]	ND X (3.77) [10]	NA
Dimethylphthalate	NA	ND X (0.435) [10]	ND X (3.87) [10]	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating. Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9				9				9				9			
	A2A				A2A				A2A				A2A			
	KRF-A2A-U1214				KRF-A2A-U1618				KRF-A2A-U2022				KRF-A2A-U2627			
	12 - 14				16 - 18				20 - 22				26 - 27			
SW8270 - Semivolatile Organics, cont. (ug/g)																
Diphenylamine	NA				ND	X	(1)	[10]	ND	X	(8.9)	[10]	NA			
Fluoranthene	NA				ND	X	(0.228)	[10]	ND	X	(2.02)	[10]	NA			
Fluorene	NA				ND	X	(0.383)	[10]	ND	X	(3.4)	[10]	NA			
Hexachlorobenzene	NA				ND	X	(0.639)	[10]	ND	X	(5.67)	[10]	NA			
Hexachlorobutadiene	NA				ND	X	(0.326)	[10]	ND	X	(2.9)	[10]	NA			
Hexachlorocyclopentadiene	NA				ND	X	(2.21)	[10]	ND	X	(19.6)	[10]	NA			
Hexachloroethane	NA				ND	X	(0.332)	[10]	ND	X	(2.94)	[10]	NA			
Indeno(1,2,3-cd)pyrene	NA				ND	X	(0.7)	[10]	ND	X	(6.21)	[10]	NA			
Isophorone	NA				ND	X	(0.497)	[10]	ND	X	(4.42)	[10]	NA			
N-Nitroso-di-n-propylamine	NA				ND	X	(0.767)	[10]	ND	X	(6.81)	[10]	NA			
Naphthalene	NA				ND	X	(0.845)	[10]	69.5	X	(7.5)	[10]	NA			
Nitrobenzene	NA				ND	X	(0.438)	[10]	ND	X	(3.89)	[10]	NA			
Pentachlorophenol	NA				ND	X	(0.244)	[10]	ND	X	(2.17)	[10]	NA			
Phenanthrene	NA				ND	X	(0.504)	[10]	ND	X	(4.48)	[10]	NA			
Phenol	NA				ND	X	(0.721)	[10]	ND	X	(6.4)	[10]	NA			
Pyrene	NA				ND	X	(0.329)	[10]	ND	X	(2.92)	[10]	NA			
bis(2-Chloroethoxy)methane	NA				ND	X	(0.372)	[10]	ND	X	(3.3)	[10]	NA			
bis(2-Chloroethyl)ether	NA				ND	X	(0.535)	[10]	ND	X	(4.75)	[10]	NA			
bis(2-Chloroisopropyl)ether	NA				ND	X	(0.585)	[10]	ND	X	(5.19)	[10]	NA			
bis(2-Ethylhexyl)phthalate	NA				8.14	X	(2.39)	[10]	ND	X	(21.2)	[10]	NA			
p-Chloroaniline	NA				ND	X	(0.802)	[10]	ND	X	(7.12)	[10]	NA			
SW846 - Percent Moisture (percent)																
Percent moisture	0.79 ✓		(0)	[1]	26.7 ✓		(0)	[1]	26.7 ✓		(0)	[1]	14.3 ✓		(0)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

	9			9			9			9		
	E1A			E1A			E1A			E1A		
	KRF-E1A-U0002			KRF-E1A-U1012			KRF-E1A-U1618			KRF-E1A-U2425		
PARAMETER	0 - 2			10 - 12			16 - 18			24 - 25		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	4830 ✓	(42.9)	[5]	1160 ✓	(43.5)	[5]	19200 ✓	(160)	[20]	6830 ✓	(36.4)	[5]
							chlrbenz: 7/23 10:21:00 1:100 = 7/23 09:27:00					
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	NA			NA			ND	(1.93)	[1]	ND	(109)	[100]
1,1,2,2-Tetrachloroethane	NA			NA			ND *	(~~5.25~~ 133)	[100] [1]	ND	(142)	[100]
1,1,2-Trichloroethane	NA			NA			ND *	(~~1.58~~ 117)	[100] [1]	ND	(108)	[100]
1,1-Dichloroethane	NA			NA			ND	(1.77)	[1]	ND	(85.6)	[100]
1,1-Dichloroethene	NA			NA			ND	(2.66)	[1]	ND	(211)	[100]
1,2-Dichloroethane	NA			NA			ND	(1.8)	[1]	ND	(156)	[100]
1,2-Dichloropropane	NA			NA			ND	(2.72)	[1]	ND	(295)	[100]
2-Chloroethyl vinyl ether	NA			NA			ND	(2.96)	[1]	ND	(156)	[100]
2-Hexanone	NA			NA			ND *	(~~0.593~~ 171)	[100] ~~[1]~~	ND	(173)	[100]
4-Methyl-2-Pentanone(MIBK)	NA			NA			ND	(0.947)	[1]	ND	(117)	[100]
Acetone	NA			NA			< DL ✓	(715)	[100]	< DL	(647)	[100]
Benzene	NA			NA			521 ✓	(80)	[100]	332 ✓	(72.4)	[100]
Bromodichloromethane	NA			NA			ND	(1.69)	[1]	ND	(395)	[100]
Bromomethane	NA			NA			ND	(2.08)	[1]	ND	(204)	[100]
Carbon disulfide	NA			NA			ND	(2.68)	[1]	ND	(162)	[100]
Carbon tetrachloride	NA			NA			ND	(2.07)	[1]	ND	(160)	[100]
Chlorobenzene	NA			NA			33,000 ~~9420 *~~	~~(4.81)~~ 615	[500] ~~[1]~~	187000 ✓	(5560)	[5000]
Chloroethane	NA			NA			ND	(2.12)	[1]	ND	(149)	[100]
Chloroform	NA			NA			ND	(2.17)	[1]	ND	(66.3)	[100]
Chloromethane	NA			NA			ND	(2.52)	[1]	ND	(108)	[100]
Dibromochloromethane	NA			NA			ND *	(~~1.9~~ 86.3)	[100] ~~[1]~~	ND	(78.1)	[100]
Ethyl benzene	NA			NA			330 ~~195 *~~	(~~1.71~~ 134)	[100] ~~[1]~~	1190 ✓	(121)	[100]
Methyl ethyl ketone	NA			NA			39.8 B	(1.59)	[1]	ND	(304)	[100]
Methylene Chloride	NA			NA			2.85 B	(2.71)	[1]	ND	(204)	[100]
Styrene	NA			NA			ND *	(~~1.68~~ 132)	[1]	ND	(119)	[100]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)								
	9	9	9			9		
	E1A	E1A	E1A			E1A		
	KRF-E1A-U0002	KRF-E1A-U1012	KRF-E1A-U1618			KRF-E1A-U2425		
PARAMETER	0 - 2	10 - 12	16 - 18			24 - 25		
SW8240 - Volatile Organics, cont. (ug/kg)								
Tetrachloroethene	NA	NA	ND ✗	178 ~~(4.92)~~	[100] ~~[1]~~	ND	(161)	[100]
Toluene	NA	NA	5.17✓	(1.76)	[1]	1190✓	(88.7)	[100]
Tribromomethane(Bromoform)	NA	NA	ND *	58.1 ~~(1.57)~~	[100] ~~[1]~~	ND	(53.3)	[100]
Trichloroethene	NA	NA	ND	(5.03)	[1]	ND	(172)	[100]
Vinyl Chloride	NA	NA	ND	(2.14)	[1]	ND	(135)	[100]
Vinyl acetate	NA	NA	ND	(11.3)	[1]	ND	(90.3)	[100]
Xylene (total)	NA	NA	ND ~~35.1~~ *	303 ~~(3.77)~~	[100] ~~[1]~~	7810✓	(280)	[100]
cis-1,3-Dichloropropene	NA	NA	ND	(1.66)	[1]	ND	(59.7)	[100]
trans-1,2-Dichloroethene	NA	NA	ND	(2.41)	[1]	ND	(134)	[100]
trans-1,3-Dichloropropene	NA	NA	ND	(1.8)	[1]	ND	(162)	[100]
SW8270 - Semivolatile Organics (ug/g)								
1,2,4-Trichlorobenzene	NA	NA	ND	(0.217)	[1]	3.94	(0.195)	[1]
1,2-Dichlorobenzene	NA	NA	ND	(0.305)	[1]	28.1	(0.274)	[1]
1,3-Dichlorobenzene	NA	NA	ND	(0.285)	[1]	1.76	(0.256)	[1]
1,4-Dichlorobenzene	NA	NA	ND	(0.483)	[1]	5.74	(0.435)	[1]
2,4,5-Trichlorophenol	NA	NA	ND	(0.408)	[1]	ND	(0.368)	[1]
2,4,6-Trichlorophenol	NA	NA	ND	(0.375)	[1]	ND	(0.338)	[1]
2,4-Dichlorophenol	NA	NA	ND	(0.312)	[1]	ND	(0.281)	[1]
2,4-Dimethylphenol	NA	NA	ND	(1.25)	[1]	ND	(1.13)	[1]
2,4-Dinitrophenol	NA	NA	ND	(2.66)	[1]	ND	(2.39)	[1]
2,4-Dinitrotoluene	NA	NA	ND	(0.455)	[1]	ND	(0.41)	[1]
2,6-Dinitrotoluene	NA	NA	ND	(0.385)	[1]	ND	(0.347)	[1]
2-Chloronaphthalene	NA	NA	ND	(0.622)	[1]	ND	(0.56)	[1]
2-Chlorophenol	NA	NA	ND	(0.45)	[1]	ND	(0.405)	[1]
2-Methylnaphthalene	NA	NA	3.14	(0.534)	[1]	11.8	(0.481)	[1]
2-Methylphenol	NA	NA	ND	(1.14)	[1]	ND	(1.03)	[1]
2-Nitroaniline	NA	NA	ND	(0.42)	[1]	ND	(0.378)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E1A KRF-E1A-U0002 0 - 2	9 E1A KRF-E1A-U1012 10 - 12	9 E1A KRF-E1A-U1618 16 - 18			9 E1A KRF-E1A-U2425 24 - 25		
SW8270 - Semivolatile Organics, cont.	(ug/g)							
2-Nitrophenol	NA	NA	ND	(0.5)	[1]	ND	(0.45)	[1]
3,3'-Dichlorobenzidine	NA	NA	ND	(1.04)	[1]	ND	(0.941)	[1]
3-Nitroaniline	NA	NA	ND	(0.505)	[1]	ND	(0.455)	[1]
4,6-Dinitro-2-methylphenol	NA	NA	ND	(0.754)	[1]	ND	(0.68)	[1]
4-Bromophenyl phenyl ether	NA	NA	ND	(0.54)	[1]	ND	(0.487)	[1]
4-Chloro-3-methylphenol	NA	NA	ND	(0.333)	[1]	ND	(0.3)	[1]
4-Chlorophenyl phenyl ether	NA	NA	ND	(0.751)	[1]	ND	(0.677)	[1]
4-Methylphenol/3-Methylphenol	NA	NA	ND	(1.03)	[1]	ND	(0.932)	[1]
4-Nitroaniline	NA	NA	ND	(0.508)	[1]	ND	(0.457)	[1]
4-Nitrophenol	NA	NA	ND	(0.453)	[1]	ND	(0.408)	[1]
Acenaphthene	NA	NA	ND	(0.409)	[1]	ND	(0.368)	[1]
Acenaphthylene	NA	NA	ND	(0.757)	[1]	ND	(0.682)	[1]
Anthracene	NA	NA	ND	(0.508)	[1]	ND	(0.457)	[1]
Benzo(a)anthracene	NA	NA	ND	(0.399)	[1]	ND	(0.359)	[1]
Benzo(a)pyrene	NA	NA	ND	(0.622)	[1]	ND	(0.56)	[1]
Benzo(b)fluoranthene	NA	NA	ND	(0.978)	[1]	ND	(0.881)	[1]
Benzo(g,h,i)perylene	NA	NA	ND	(0.433)	[1]	ND	(0.39)	[1]
Benzo(k)fluoranthene	NA	NA	ND	(0.657)	[1]	ND	(0.592)	[1]
Benzoic acid	NA	NA	ND	(6)	[1]	ND	(5.41)	[1]
Benzyl alcohol	NA	NA	ND	(0.459)	[1]	ND	(0.413)	[1]
Butylbenzylphthalate	NA	NA	ND	(0.525)	[1]	ND	(0.473)	[1]
Chrysene	NA	NA	ND	(0.273)	[1]	ND	(0.246)	[1]
Di-n-octylphthalate	NA	NA	ND	(0.44)	[1]	ND	(0.396)	[1]
Dibenz(a,h)anthracene	NA	NA	ND	(0.484)	[1]	ND	(0.436)	[1]
Dibenzofuran	NA	NA	ND	(0.358)	[1]	ND	(0.323)	[1]
Dibutylphthalate	NA	NA	ND	(0.436)	[1]	ND	(0.393)	[1]
Diethylphthalate	NA	NA	ND	(0.313)	[1]	ND	(0.282)	[1]
Dimethylphthalate	NA	NA	ND	(0.321)	[1]	ND	(0.29)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)												
	9			9			9			9		
	E1A			E1A			E1A			E1A		
	KRF-E1A-U0002			KRF-E1A-U1012			KRF-E1A-U1618			KRF-E1A-U2425		
PARAMETER	0 - 2			10 - 12			16 - 18			24 · 25		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Diphenylamine	NA			NA			ND	(0.74)	[1]	ND	(0.667)	[1]
Fluoranthene	NA			NA			ND	(0.168)	[1]	1.03	(0.152)	[1]
Fluorene	NA			NA			ND	(0.283)	[1]	ND	(0.255)	[1]
Hexachlorobenzene	NA			NA			ND	(0.472)	[1]	ND	(0.425)	[1]
Hexachlorobutadiene	NA			NA			ND	(0.241)	[1]	ND	(0.217)	[1]
Hexachlorocyclopentadiene	NA			NA			ND	(1.63)	[1]	ND	(1.47)	[1]
Hexachloroethane	NA			NA			ND	(0.245)	[1]	ND	(0.221)	[1]
Indeno(1,2,3-cd)pyrene	NA			NA			ND	(0.516)	[1]	ND	(0.465)	[1]
Isophorone	NA			NA			ND	(0.367)	[1]	ND	(0.331)	[1]
N-Nitroso-di-n-propylamine	NA			NA			ND	(0.566)	[1]	ND	(0.51)	[1]
Naphthalene	NA			NA			1.21	(0.624)	[1]	4.14	(0.562)	[1]
Nitrobenzene	NA			NA			ND	(0.323)	[1]	ND	(0.291)	[1]
Pentachlorophenol	NA			NA			ND	(0.18)	[1]	ND	(0.162)	[1]
Phenanthrene	NA			NA			ND	(0.372)	[1]	0.557	(0.335)	[1]
Phenol	NA			NA			ND	(0.532)	[1]	ND	(0.48)	[1]
Pyrene	NA			NA			ND	(0.243)	[1]	ND	(0.219)	[1]
bis(2-Chloroethoxy)methane	NA			NA			ND	(0.275)	[1]	ND	(0.247)	[1]
bis(2-Chloroethyl)ether	NA			NA			ND	(0.395)	[1]	ND	(0.356)	[1]
bis(2-Chloroisopropyl)ether	NA			NA			ND	(0.432)	[1]	ND	(0.389)	[1]
bis(2-Ethylhexyl)phthalate	NA			NA			17.8	(1.76)	[1]	11.7	(1.59)	[1]
p-Chloroaniline	NA			NA			ND	(0.592)	[1]	ND	(0.533)	[1]
SW846 - Percent Moisture (percent)												
Percent moisture	22.6 ✓	(0)	[1]	23.3 ✓	(0)	[1]	18.3 ✓	(0)	[1]	9.31 ✓	(0)	[1]

Compiled: 1 September 1994   () = Detection Limit   [] = Dilution Factor   ND = Not Detected   NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)												
PARAMETER	9 E2A KRF-E2A-U0002 0 - 2			9 E2A KRF-E2A-U1012 10 - 12			9 E2A KRF-E2A-U2628 26 - 28			9 E3A KRF-E3A-U1416 14 - 16		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	3620 ✓	(36.5)	[5]	582 ✓	(7.96)	[1]	23,100 SD ~~23500~~	(146)	[20]	1770 ✓	(8.85)	[1]
SW846 - Percent Moisture (percent)												
Percent moisture	10 ✓	(0)	[1]	17.9 ✓	(0)	[1]	10.2 ✓	(0)	[1]	26.7 ✓	(0)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9			9			9			9		
	E3A			E3A			E3A			E3A		
	KRF-E3A-U1416D Dup of KRF-E3A-U1618			KRF-E3A-U1618			KRF-E3A-U1618D Dup of KRF-E3A-U1618			KRF-E3A-U2022		
	14 - 15			16 - 18			16 - 18			20 - 22		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	2470 ✓	(8.79)	[1]	2820 ✓	(17.1)	[2]	18300 ✓	(86.4)	[10]	58800 ✓	(454)	[50]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	NA			ND	(9.97)	[1]	ND	(57.4)	[100]	ND	(602)	[1000]
1,1,2,2-Tetrachloroethane	NA			ND	(27.1)	[1]	ND	(129)	[100]	ND	(1350)	[1000]
1,1,2-Trichloroethane	NA			ND	(8.14)	[1]	ND	(75.6)	[100]	ND	(793)	[1000]
1,1-Dichloroethane	NA			ND	(9.15)	[1]	ND	(38.2)	[100]	ND	(400)	[1000]
1,1-Dichloroethene	NA			ND	(13.7)	[1]	ND	(21.5)	[100]	ND	(225)	[1000]
1,2-Dichloroethane	NA			ND	(9.27)	[1]	ND	(177)	[100]	ND	(1850)	[1000]
1,2-Dichloropropane	NA			ND	(14)	[1]	ND	(44.4)	[100]	ND	(465)	[1000]
2-Chloroethyl vinyl ether	NA			ND	(15.3)	[1]	ND	(165)	[100]	ND	(1730)	[1000]
2-Hexanone	NA			ND	(5.12)	[1]	ND	(162)	[100]	ND	(1700)	[1000]
4-Methyl-2-Pentanone(MIBK)	NA			ND	(4.88)	[1]	ND	(183)	[100]	ND	(1920)	[1000]
Acetone	NA			218 ✓ B	(8.01)	[1]	614 ✓ B	(446)	[100]	8370 ✓ B	(4670)	[1000]
Benzene	NA			ND	(9.21)	[1]	ND	(37)	[100]	761 ✓	(387)	[1000]
Bromodichloromethane	NA			ND	(8.71)	[1]	ND	(36.6)	[100]	ND	(383)	[1000]
Bromomethane	NA			ND	(10.7)	[1]	ND	(82.9)	[100]	ND	(869)	[1000]
Carbon disulfide	NA			ND	(13.8)	[1]	ND	(85.8)	[100]	ND	(899)	[1000]
Carbon tetrachloride	NA			ND	(10.7)	[1]	ND	(33.5)	[100]	ND	(351)	[1000]
Chlorobenzene	NA			547 ✓	(24.8)	[1]	3900 ✓	(652)	[100]	< DL	(6830)	[1000]
Chloroethane	NA			ND	(10.9)	[1]	ND	(83.7)	[100]	ND	(977)	[1000]
Chloroform	NA			ND	(11.2)	[1]	ND	(43.8)	[100]	ND	(459)	[1000]
Chloromethane	NA			ND	(13)	[1]	ND	(70.4)	[100]	ND	(737)	[1000]
Dibromochloromethane	NA			ND	(9.78)	[1]	ND	(47.3)	[100]	ND	(495)	[1000]
Ethyl benzene	NA			16 ✓	(8.83)	[1]	325 ✓	(36.2)	[100]	9400 ✓	(379)	[1000]
Methyl ethyl ketone	NA			47.4 ✓ B	(8.14)	[1]	690 ✓	(161)	[100]	6130 ✓	(1690)	[1000]
Methylene Chloride	NA			< DL B	(13.9)	[1]	ND	(41.7)	[100]	ND	(437)	[1000]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E3A KRF-E3A-U1416D Dup of KRF-E3A-U1618 14 - 16	9 E3A KRF-E3A-U1618 16 - 18			9 E3A KRF-E3A-U1618D Dup of KRF-E3A-U1618 16 - 18			9 E3A KRF-E3A-U2022 20 - 22		
SW8240 - Volatile Organics, cont. (ug/kg)										
Styrene	NA	ND	(8.64)	[1]	ND	(29.8)	[100]	ND	(313)	[1000]
Tetrachloroethene	NA	ND	(25.4)	[1]	ND	(69.6)	[100]	3690 ✓	(729)	[1000]
Toluene	NA	ND	(9.09)	[1]	ND	(32.3)	[100]	45100 ✓	(339)	[1000]
Tribromomethane(Bromoform)	NA	ND	(8.08)	[1]	ND	(71)	[100]	ND	(744)	[1000]
Trichloroethene	NA	ND	(25.9)	[1]	ND	(46.5)	[100]	ND	(487)	[1000]
Vinyl Chloride	NA	ND	(11)	[1]	ND	(93.9)	[100]	ND	(983)	[1000]
Vinyl acetate	NA	ND	(58.5)	[1]	ND	(104)	[100]	ND	(1090)	[1000]
Xylene (total)	NA	ND	(19.4)	[1]	222 ✓	(83.2)	[100]	66200 ✓	(871)	[1000]
cis-1,3-Dichloropropene	NA	ND	(8.58)	[1]	ND	(34.6)	[100]	ND	(362)	[1000]
trans-1,2-Dichloroethene	NA	ND	(12.4)	[1]	ND	(42.5)	[100]	ND	(445)	[1000]
trans-1,3-Dichloropropene	NA	ND	(9.27)	[1]	ND	(37.1)	[100]	ND	(389)	[1000]
SW8270 - Semivolatile Organics (ug/g)										
1,2,4-Trichlorobenzene	NA	ND X	(0.167)	[20]	ND	(0.225)	[1]	4.63	(0.262)	[1]
1,2-Dichlorobenzene	NA	ND X	(0.557)	[20]	ND	(0.75)	[1]	74.4	(0.875)	[1]
1,3-Dichlorobenzene	NA	ND X	(0.618)	[20]	ND	(0.833)	[1]	4.75	(0.972)	[1]
1,4-Dichlorobenzene	NA	ND X	(0.614)	[20]	2.62	(0.828)	[1]	42.3	(0.965)	[1]
2,4,5-Trichlorophenol	NA	ND X	(0.509)	[20]	ND	(0.686)	[1]	ND	(0.8)	[1]
2,4,6-Trichlorophenol	NA	ND X	(0.421)	[20]	ND	(0.568)	[1]	ND	(0.662)	[1]
2,4-Dichlorophenol	NA	ND X	(0.505)	[20]	ND	(0.68)	[1]	ND	(0.793)	[1]
2,4-Dimethylphenol	NA	ND X	(1.1)	[20]	ND	(1.49)	[1]	37.9	(1.73)	[1]
2,4-Dinitrophenol	NA	ND X	(2.25)	[20]	ND	(3.03)	[1]	ND	(3.54)	[1]
2,4-Dinitrotoluene	NA	ND X	(0.668)	[20]	ND	(0.9)	[1]	ND	(1.05)	[1]
2,6-Dinitrotoluene	NA	ND X	(0.912)	[20]	ND	(1.23)	[1]	ND	(1.43)	[1]
2-Chloronaphthalene	NA	ND X	(0.781)	[20]	ND	(1.05)	[1]	ND	(1.23)	[1]
2-Chlorophenol	NA	ND X	(0.285)	[20]	ND	(0.384)	[1]	ND	(0.448)	[1]
2-Methylnaphthalene	NA	ND X	(0.525)	[20]	3.32	(0.708)	[1]	67.1	(0.826)	[1]

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TABLE A RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E3A KRF-E3A-U1416D Dup of KRF-E3A-U1618 14 - 16	9 E3A KRF-E3A-U1618 16 - 18			9 E3A KRF-E3A-U1618D Dup of KRF-E3A-U1618 16 - 18			9 E3A KRF-E3A-U2022 20 - 22		
SW8270 - Semivolatile Organics, cont.	(ug/g)									
2-Methylphenol	NA	ND X	(0.686)	[20]	ND	(0.925)	[1]	9.78	(1.08)	[1]
2-Nitroaniline	NA	ND X	(0.694)	[20]	ND	(0.935)	[1]	ND	(1.09)	[1]
2-Nitrophenol	NA	ND X	(0.369)	[20]	ND	(0.497)	[1]	ND	(0.58)	[1]
3,3'-Dichlorobenzidine	NA	ND X	(0.947)	[20]	ND	(1.28)	[1]	ND	(1.49)	[1]
3-Nitroaniline	NA	ND X	(0.28)	[20]	ND	(0.377)	[1]	ND	(0.44)	[1]
4,6-Dinitro-2-methylphenol	NA	ND X	(0.635)	[20]	ND	(0.856)	[1]	ND	(0.998)	[1]
4-Bromophenyl phenyl ether	NA	ND X	(0.53)	[20]	ND	(0.714)	[1]	ND	(0.833)	[1]
4-Chloro-3-methylphenol	NA	ND X	(0.398)	[20]	ND	(0.536)	[1]	ND	(0.625)	[1]
4-Chlorophenyl phenyl ether	NA	ND X	(0.636)	[20]	ND	(0.857)	[1]	ND	(1)	[1]
4-Methylphenol/3-Methylphenol	NA	ND X	(1.08)	[20]	ND	(1.45)	[1]	33.5 F	(1.69)	[1]
4-Nitroaniline	NA	ND X	(0.52)	[20]	ND	(0.701)	[1]	ND	(0.818)	[1]
4-Nitrophenol	NA	ND X	(0.548)	[20]	ND	(0.739)	[1]	ND	(0.862)	[1]
Acenaphthene	NA	ND X	(0.419)	[20]	ND	(0.564)	[1]	ND	(0.658)	[1]
Acenaphthylene	NA	ND X	(0.571)	[20]	ND	(0.77)	[1]	ND	(0.898)	[1]
Anthracene	NA	ND X	(0.468)	[20]	ND	(0.631)	[1]	ND	(0.736)	[1]
Benzo(a)anthracene	NA	ND X	(0.302)	[20]	ND	(0.407)	[1]	ND	(0.475)	[1]
Benzo(a)pyrene	NA	ND X	(0.469)	[20]	ND	(0.632)	[1]	ND	(0.737)	[1]
Benzo(b)fluoranthene	NA	ND X	(0.833)	[20]	ND	(1.12)	[1]	ND	(1.31)	[1]
Benzo(g,h,i)perylene	NA	ND X	(0.481)	[20]	ND	(0.648)	[1]	ND	(0.756)	[1]
Benzo(k)fluoranthene	NA	ND X	(0.712)	[20]	ND	(0.96)	[1]	ND	(1.12)	[1]
Benzoic acid	NA	ND X	(2.6)	[20]	ND	(3.5)	[1]	ND	(4.08)	[1]
Benzyl alcohol	NA	ND X	(1.25)	[20]	ND	(1.69)	[1]	ND	(1.97)	[1]
Butylbenzylphthalate	NA	ND X	(0.652)	[20]	ND	(0.879)	[1]	ND	(1.03)	[1]
Chrysene	NA	ND X	(0.508)	[20]	ND	(0.685)	[1]	< DL	(0.799)	[1]
Di-n-octylphthalate	NA	ND X	(0.505)	[20]	ND	(0.681)	[1]	ND	(0.795)	[1]
Dibenz(a,h)anthracene	NA	ND X	(0.593)	[20]	ND	(0.8)	[1]	ND	(0.933)	[1]
Dibenzofuran	NA	ND X	(0.34)	[20]	ND	(0.458)	[1]	ND	(0.534)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E3A KRF-E3A-U1416D Dup of KRF-E3A-U1618 14 - 16			9 E3A KRF-E3A-U1618 16 - 18				9 E3A KRF-E3A-U1618D Dup of KRF-E3A-U1618 16 - 18			9 E3A KRF-E3A-U2022 20 - 22		
SW8270 - Semivolatile Organics, cont. (ug/g)													
Dibutylphthalate	NA			ND	X	(0.269)	[20]	ND	(0.363)	[1]	2.62	(0.423)	[1]
Diethylphthalate	NA			ND	X	(0.321)	[20]	ND	(0.433)	[1]	ND	(0.505)	[1]
Dimethylphthalate	NA			ND	X	(0.409)	[20]	ND	(0.551)	[1]	ND	(0.643)	[1]
Diphenylamine	NA			ND	X	(0.664)	[20]	ND	(0.894)	[1]	ND	(1.04)	[1]
Fluoranthene	NA			ND	X	(0.369)	[20]	0.879	(0.497)	[1]	15.1	(0.58)	[1]
Fluorene	NA			ND	X	(0.3)	[20]	0.522	(0.404)	[1]	3.28	(0.471)	[1]
Hexachlorobenzene	NA			ND	X	(0.459)	[20]	ND	(0.618)	[1]	ND	(0.721)	[1]
Hexachlorobutadiene	NA			ND	X	(0.571)	[20]	ND	(0.769)	[1]	ND	(0.897)	[1]
Hexachlorocyclopentadiene	NA			ND	X	(1.42)	[20]	ND	(1.92)	[1]	ND	(2.24)	[1]
Hexachloroethane	NA			ND	X	(0.869)	[20]	ND	(1.17)	[1]	ND	(1.37)	[1]
Indeno(1,2,3-cd)pyrene	NA			ND	X	(0.418)	[20]	ND	(0.563)	[1]	ND	(0.657)	[1]
Isophorone	NA			ND	X	(0.262)	[20]	ND	(0.354)	[1]	ND	(0.412)	[1]
N-Nitroso-di-n-propylamine	NA			ND	X	(0.682)	[20]	ND	(0.919)	[1]	ND	(1.07)	[1]
Naphthalene	NA			ND	X	(0.58)	[20]	0.924	(0.782)	[1]	29.8	(0.912)	[1]
Nitrobenzene	NA			ND	X	(0.338)	[20]	ND	(0.455)	[1]	ND	(0.531)	[1]
Pentachlorophenol	NA			ND	X	(0.167)	[20]	ND	(0.225)	[1]	ND	(0.262)	[1]
Phenanthrene	NA			ND	X	(0.481)	[20]	1.38	(0.648)	[1]	3.63	(0.756)	[1]
Phenol	NA			ND	X	(0.877)	[20]	ND	(1.18)	[1]	2.06	(1.38)	[1]
Pyrene	NA			ND	X	(0.401)	[20]	< DL	(0.541)	[1]	1.33	(0.631)	[1]
bis(2-Chloroethoxy)methane	NA			ND	X	(0.29)	[20]	ND	(0.391)	[1]	ND	(0.456)	[1]
bis(2-Chloroethyl)ether	NA			ND	X	(0.405)	[20]	ND	(0.545)	[1]	ND	(0.636)	[1]
bis(2-Chloroisopropyl)ether	NA			ND	X	(0.496)	[20]	ND	(0.608)	[1]	ND	(0.78)	[1]
bis(2-Ethylhexyl)phthalate	NA			5.02	X	(1.42)	[20]	54.3	(1.92)	[1]	55	(2.24)	[1]
p-Chloroaniline	NA			ND	X	(0.851)	[20]	ND	(1.15)	[1]	ND	(1.34)	[1]
SW846 - Percent Moisture (percent)													
Percent moisture	24.7 ✓	(0)	[1]	23.8 ✓		(0)	[1]	24.4 ✓	(0)	[1]	28.2 ✓	(0)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

	SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)			
PARAMETER	9 E3A KRF-E3A-U1416D Dup of KRF-E3A-U1618 14 - 16	9 E3A KRF-E3A-U1618 16 - 18	9 E3A KRF-E3A-U1618D Dup of KRF-E3A-U1618 16 - 18	9 E3A KRF-E3A-U2022 20 - 22

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

PARAMETER	SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)											
	9 E3A KRF-E3A-U2830 28 - 30			9 E4A KRF-E4A-U0608 6 - 8			9 E4A KRF-E4A-U0911 9 - 11			9 E4A KRF-E4A-U2426 24 - 26		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	3810 ✓	(40.2)	[5]	1090 ✓	(7.32)	[1]	593 ✓	(6.96)	[1]	3170 ✓	(15.3)	[2]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	NA			NA			ND	(1.68)	[1]	ND	(573)	[500]
1,1,2,2-Tetrachloroethane	NA			NA			ND	(4.56)	[1]	ND	(746)	[500]
1,1,2-Trichloroethane	NA			NA			ND	(1.37)	[1]	ND	(566)	[500]
1,1-Dichloroethane	NA			NA			ND	(1.54)	[1]	ND	(450)	[500]
1,1-Dichloroethene	NA			NA			ND	(2.31)	[1]	ND	(1110)	[500]
1,2-Dichloroethane	NA			NA			ND	(1.56)	[1]	ND	(822)	[500]
1,2-Dichloropropane	NA			NA			ND	(2.36)	[1]	ND	(1550)	[500]
2-Chloroethyl vinyl ether	NA			NA			ND	(2.57)	[1]	ND	(822)	[500]
2-Hexanone	NA			NA			ND	(0.862)	[1]	ND	(908)	[500]
4-Methyl-2-Pentanone(MIBK)	NA			NA			ND	(0.823)	[1]	ND	(613)	[500]
Acetone	NA			NA			28.5 ✓ B	(1.35)	[1]	5200 ✓	(3400)	[500]
Benzene	NA			NA			ND	(1.55)	[1]	< DL	(380)	[500]
Bromodichloromethane	NA			NA			ND	(1.47)	[1]	ND	(2080)	[500]
Bromomethane	NA			NA			ND	(1.81)	[1]	ND	(1070)	[500]
Carbon disulfide	NA			NA			ND	(2.33)	[1]	ND	(851)	[500]
Carbon tetrachloride	NA			NA			ND	(1.8)	[1]	ND	(839)	[500]
Chlorobenzene	NA			NA			4.91 ✓	(4.18)	[1]	109000 ✓	(584)	[500]
Chloroethane	NA			NA			ND	(1.84)	[1]	ND	(781)	[500]
Chloroform	NA			NA			ND	(1.88)	[1]	ND	(348)	[500]
Chloromethane	NA			NA			ND	(2.19)	[1]	ND	(565)	[500]
Dibromochloromethane	NA			NA			ND	(1.65)	[1]	ND	(410)	[500]
Ethyl benzene	NA			NA			ND	(1.49)	[1]	856 ✓	(636)	[500]
Methyl ethyl ketone	NA			NA			3.16 ✓	(1.37)	[1]	ND	(1600)	[500]
Methylene Chloride	NA			NA			ND	(2.35)	[1]	< DL	(1070)	[500]
Styrene	NA			NA			ND	(1.46)	[1]	ND	(625)	[500]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

	SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)								
	9	9	9				9		
	E3A	E4A	E4A				E4A		
	KRF-E3A-U2830	KRF-E4A-U0608	KRF-E4A-U0911				KRF-E4A-U2426		
PARAMETER	28 - 30	6 - 8	9 - 11				24 - 26		
SW8240 - Volatile Organics, cont. (ug/kg)									
Tetrachloroethene	NA	NA	ND		(4.27)	[1]	ND	(845)	[500]
Toluene	NA	NA	ND		(1.53)	[1]	< DL	(466)	[500]
Tribromomethane(Bromoform)	NA	NA	ND		(1.36)	[1]	ND	(280)	[500]
Trichloroethene	NA	NA	ND		(4.37)	[1]	ND	(903)	[500]
Vinyl Chloride	NA	NA	ND		(1.86)	[1]	ND	(712)	[500]
Vinyl acetate	NA	NA	ND		(9.85)	[1]	ND	(474)	[500]
Xylene (total)	NA	NA	ND		(3.27)	[1]	5720✓	(1470)	[500]
cis-1,3-Dichloropropene	NA	NA	ND		(1.45)	[1]	ND	(314)	[500]
trans-1,2-Dichloroethene	NA	NA	ND		(2.09)	[1]	ND	(966)	[500]
trans-1,3-Dichloropropene	NA	NA	ND		(1.56)	[1]	ND	(851)	[500]
SW8270 - Semivolatile Organics (ug/g)									
1,2,4-Trichlorobenzene	NA	NA	ND	X	(0.0774)	[10]	0.105	(0.0247)	[1]
1,2-Dichlorobenzene	NA	NA	ND	X	(0.109)	[10]	0.381	(0.0347)	[1]
1,3-Dichlorobenzene	NA	NA	ND	X	(0.101)	[10]	0.348	(0.0324)	[1]
1,4-Dichlorobenzene	NA	NA	ND	X	(0.172)	[10]	2.97	(0.055)	[1]
2,4,5-Trichlorophenol	NA	NA	ND	X	(0.145)	[10]	ND	(0.0465)	[1]
2,4,6-Trichlorophenol	NA	NA	ND	X	(0.134)	[10]	ND	(0.0428)	[1]
2,4-Dichlorophenol	NA	NA	ND	X	(0.111)	[10]	ND	(0.0356)	[1]
2,4-Dimethylphenol	NA	NA	ND	X	(0.447)	[10]	ND	(0.143)	[1]
2,4-Dinitrophenol	NA	NA	ND	X	(0.947)	[10]	ND	(0.303)	[1]
2,4-Dinitrotoluene	NA	NA	ND	X	(0.162)	[10]	ND	(0.0519)	[1]
2,6-Dinitrotoluene	NA	NA	ND	X	(0.137)	[10]	ND	(0.0439)	[1]
2-Chloronaphthalene	NA	NA	ND	X	(0.222)	[10]	ND	(0.0709)	[1]
2-Chlorophenol	NA	NA	ND	X	(0.16)	[10]	ND	(0.0513)	[1]
2-Methylnaphthalene	NA	NA	ND	X	(0.191)	[10]	3.84	(0.0609)	[1]
2-Methylphenol	NA	NA	ND	X	(0.408)	[10]	ND	(0.13)	[1]
2-Nitroaniline	NA	NA	ND	X	(0.15)	[10]	ND	(0.0479)	[1]

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TABLE A RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E3A KRF-E3A-U2830 28 - 30	9 E4A KRF-E4A-U0608 6 - 8	9 E4A KRF-E4A-U0911 9 - 11				9 E4A KRF-E4A-U2426 24 - 26		
SW8270 - Semivolatile Organics, cont.	(ug/g)								
2-Nitrophenol	NA	NA	ND	X	(0.178)	[10]	ND	(0.057)	[1]
3,3'-Dichlorobenzidine	NA	NA	ND	X	(0.373)	[10]	ND	(0.119)	[1]
3-Nitroaniline	NA	NA	ND	X	(0.18)	[10]	ND	(0.0575)	[1]
4,6-Dinitro-2-methylphenol	NA	NA	ND	X	(0.269)	[10]	ND	(0.086)	[1]
4-Bromophenyl phenyl ether	NA	NA	ND	X	(0.193)	[10]	ND	(0.0616)	[1]
4-Chloro-3-methylphenol	NA	NA	ND	X	(0.119)	[10]	ND	(0.038)	[1]
4-Chlorophenyl phenyl ether	NA	NA	ND	X	(0.268)	[10]	ND	(0.0857)	[1]
4-Methylphenol/3-Methylphenol	NA	NA	ND	X	(0.369)	[10]	ND	(0.118)	[1]
4-Nitroaniline	NA	NA	ND	X	(0.181)	[10]	ND	(0.0579)	[1]
4-Nitrophenol	NA	NA	ND	X	(0.161)	[10]	ND	(0.0516)	[1]
Acenaphthene	NA	NA	ND	X	(0.146)	[10]	ND	(0.0466)	[1]
Acenaphthylene	NA	NA	ND	X	(0.27)	[10]	ND	(0.0863)	[1]
Anthracene	NA	NA	ND	X	(0.181)	[10]	ND	(0.0579)	[1]
Benzo(a)anthracene	NA	NA	ND	X	(0.142)	[10]	ND	(0.0455)	[1]
Benzo(a)pyrene	NA	NA	ND	X	(0.222)	[10]	ND	(0.0709)	[1]
Benzo(b)fluoranthene	NA	NA	ND	X	(0.349)	[10]	ND	(0.112)	[1]
Benzo(g,h,i)perylene	NA	NA	ND	X	(0.154)	[10]	ND	(0.0494)	[1]
Benzo(k)fluoranthene	NA	NA	ND	X	(0.234)	[10]	ND	(0.0749)	[1]
Benzoic acid	NA	NA	ND	X	(2.14)	[10]	ND	(0.684)	[1]
Benzyl alcohol	NA	NA	ND	X	(0.164)	[10]	ND	(0.0523)	[1]
Butylbenzylphthalate	NA	NA	ND	X	(0.187)	[10]	ND	(0.0599)	[1]
Chrysene	NA	NA	ND	X	(0.0972)	[10]	ND	(0.0311)	[1]
Di-n-octylphthalate	NA	NA	ND	X	(0.157)	[10]	ND	(0.0502)	[1]
Dibenz(a,h)anthracene	NA	NA	ND	X	(0.172)	[10]	ND	(0.0551)	[1]
Dibenzofuran	NA	NA	ND	X	(0.128)	[10]	ND	(0.0408)	[1]
Dibutylphthalate	NA	NA	ND	X	(0.155)	[10]	0.168	(0.0497)	[1]
Diethylphthalate	NA	NA	ND	X	(0.112)	[10]	ND	(0.0357)	[1]
Dimethylphthalate	NA	NA	ND	X	(0.115)	[10]	ND	(0.0366)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

	9			9			9			9		
	E3A			E4A			E4A			E4A		
	KRF-E3A-U2830			KRF-E4A-U0608			KRF-E4A-U0911			KRF-E4A-U2426		
PARAMETER	28 - 30			6 - 8			9 - 11			24 - 26		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Diphenylamine	NA			NA			ND X	(0.264)	[10]	ND	(0.0844)	[1]
Fluoranthene	NA			NA			ND X	(0.06)	[10]	0.543	(0.0192)	[1]
Fluorene	NA			NA			ND X	(0.101)	[10]	0.0993	(0.0322)	[1]
Hexachlorobenzene	NA			NA			ND X	(0.168)	[10]	ND	(0.0538)	[1]
Hexachlorobutadiene	NA			NA			ND X	(0.0859)	[10]	ND	(0.0275)	[1]
Hexachlorocyclopentadiene	NA			NA			ND X	(0.582)	[10]	ND	(0.186)	[1]
Hexachloroethane	NA			NA			ND X	(0.0873)	[10]	ND	(0.0279)	[1]
Indeno(1,2,3-cd)pyrene	NA			NA			ND X	(0.184)	[10]	ND	(0.0589)	[1]
Isophorone	NA			NA			ND X	(0.131)	[10]	ND	(0.0419)	[1]
N-Nitroso-di-n-propylamine	NA			NA			ND X	(0.202)	[10]	ND	(0.0646)	[1]
Naphthalene	NA			NA			ND X	(0.222)	[10]	1.76	(0.0711)	[1]
Nitrobenzene	NA			NA			ND X	(0.115)	[10]	ND	(0 0369)	[1]
Pentachlorophenol	NA			NA			ND X	(0.0642)	[10]	ND	(0.0205)	[1]
Phenanthrene	NA			NA			ND X	(0.133)	[10]	0.195	(0.0424)	[1]
Phenol	NA			NA			ND X	(0.19)	[10]	ND	(0.0607)	[1]
Pyrene	NA			NA			ND X	(0.0866)	[10]	0.0661	(0.0277)	[1]
bis(2-Chloroethoxy)methane	NA			NA			ND X	(0.0979)	[10]	ND	(0.0313)	[1]
bis(2-Chloroethyl)ether	NA			NA			ND X	(0.141)	[10]	ND	(0.045)	[1]
bis(2-Chloroisopropyl)ether	NA			NA			ND X	(0.154)	[10]	ND	(0.0492)	[1]
bis(2-Ethylhexyl)phthalate	NA			NA			ND X	(0.628)	[10]	3.34	(0.201)	[1]
p-Chloroaniline	NA			NA			ND X	(0.211)	[10]	ND	(0 0675)	[1]
SW846 - Percent Moisture (percent)												
Percent moisture	18 ✓	(0)	[1]	10.1 ✓	(0)	[1]	6.31 ✓	(0)	[1]	14.1 ✓	(0)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E5A KRF-E5A-U0406 4 - 6			9 E5A KRF-E5A-U0608 6 - 8			9 E5A KRF-E5A-U1012 10 - 12			9 E5A KRF-E5A-U1214 12 - 14		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	673 ✓	(7.24)	[1]	587 ✓	(7.16)	[1]	330 ✓	(6.74)	[1]	1450 ✓	(8.37)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(1.73)	[1]	ND	(1.71)	[1]	NA			NA		
1,1,2,2-Tetrachloroethane	ND	(4.71)	[1]	ND	(4.64)	[1]	NA			NA		
1,1,2-Trichloroethane	ND	(1.42)	[1]	ND	(1.39)	[1]	NA			NA		
1,1-Dichloroethane	ND	(1.59)	[1]	ND	(1.57)	[1]	NA			NA		
1,1-Dichloroethene	ND	(2.38)	[1]	ND	(2.35)	[1]	NA			NA		
1,2-Dichloroethane	ND	(1.61)	[1]	ND	(1.59)	[1]	NA			NA		
1,2-Dichloropropane	ND	(2.44)	[1]	ND	(2.4)	[1]	NA			NA		
2-Chloroethyl vinyl ether	ND	(2.66)	[1]	ND	(2.62)	[1]	NA			NA		
2-Hexanone	ND	(0.89)	[1]	15.5 ✓	(0.877)	[1]	NA			NA		
4-Methyl-2-Pentanone(MIBK)	ND	(0.85)	[1]	3.04 ✓	(0.837)	[1]	NA			NA		
Acetone	67.8 ✓ B	(1.39)	[1]	121 ✓ B	(1.37)	[1]	NA			NA		
Benzene	ND	(1.6)	[1]	ND	(1.58)	[1]	NA			NA		
Bromodichloromethane	ND	(1.51)	[1]	ND	(1.49)	[1]	NA			NA		
Bromomethane	ND	(1.87)	[1]	ND	(1.84)	[1]	NA			NA		
Carbon disulfide	ND	(2.4)	[1]	ND	(2.37)	[1]	NA			NA		
Carbon tetrachloride	ND	(1.85)	[1]	ND	(1.83)	[1]	NA			NA		
Chlorobenzene	31.8 ✓	(4.31)	[1]	4.65 ✓	(4.25)	[1]	NA			NA		
Chloroethane	ND	(1.9)	[1]	ND	(1.87)	[1]	NA			NA		
Chloroform	ND	(1.94)	[1]	ND	(1.91)	[1]	NA			NA		
Chloromethane	ND	(2.26)	[1]	ND	(2.23)	[1]	NA			NA		
Dibromochloromethane	ND	(1.7)	[1]	ND	(1.68)	[1]	NA			NA		
Ethyl benzene	ND	(1.54)	[1]	ND	(1.51)	[1]	NA			NA		
Methyl ethyl ketone	8.9 ✓	(1.42)	[1]	26.3 ✓	(1.39)	[1]	NA			NA		
Methylene Chloride	ND	(2.43)	[1]	ND	(2.39)	[1]	NA			NA		
Styrene	ND	(1.5)	[1]	ND	(1.48)	[1]	NA			NA		

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E5A KRF-E5A-U0406 4 - 6			9 E5A KRF-E5A-U0608 6 - 8			9 E5A KRF-E5A-U1012 10 - 12	9 E5A KRF-E5A-U1214 12 - 14
SW8240 - Volatile Organics, cont. (ug/kg)								
Tetrachloroethene	ND	(4.41)	[1]	ND	(4.35)	[1]	NA	NA
Toluene	< DL	(1.58)	[1]	ND	(1.56)	[1]	NA	NA
Tribromomethane(Bromoform)	ND	(1.4)	[1]	ND	(1.38)	[1]	NA	NA
Trichloroethene	ND	(4.51)	[1]	ND	(4.44)	[1]	NA	NA
Vinyl Chloride	ND	(1.92)	[1]	ND	(1.89)	[1]	NA	NA
Vinyl acetate	ND	(10.2)	[1]	ND	(10)	[1]	NA	NA
Xylene (total)	6.59✓	(3.38)	[1]	ND	(3.33)	[1]	NA	NA
cis-1,3-Dichloropropene	ND	(1.49)	[1]	ND	(1.47)	[1]	NA	NA
trans-1,2-Dichloroethene	ND	(2.16)	[1]	ND	(2.13)	[1]	NA	NA
trans-1,3-Dichloropropene	ND	(1.61)	[1]	ND	(1.59)	[1]	NA	NA
SW8270 - Semivolatile Organics (ug/g)								
1,2,4-Trichlorobenzene	ND X	(0.159)	[20]	ND X	(0.0788)	[10]	NA	NA
1,2-Dichlorobenzene	ND X	(0.224)	[20]	ND X	(0.111)	[10]	NA	NA
1,3-Dichlorobenzene	ND X	(0.209)	[20]	ND X	(0.103)	[10]	NA	NA
1,4-Dichlorobenzene	ND X	(0.354)	[20]	ND X	(0.175)	[10]	NA	NA
2,4,5-Trichlorophenol	ND X	(0.299)	[20]	ND X	(0.148)	[10]	NA	NA
2,4,6-Trichlorophenol	ND X	(0.275)	[20]	ND X	(0.136)	[10]	NA	NA
2,4-Dichlorophenol	ND X	(0.229)	[20]	ND X	(0.113)	[10]	NA	NA
2,4-Dimethylphenol	ND X	(0.92)	[20]	ND X	(0.455)	[10]	NA	NA
2,4-Dinitrophenol	ND X	(1.95)	[20]	ND X	(0.965)	[10]	NA	NA
2,4-Dinitrotoluene	ND X	(0.334)	[20]	ND X	(0.165)	[10]	NA	NA
2,6-Dinitrotoluene	ND X	(0.283)	[20]	ND X	(0.14)	[10]	NA	NA
2-Chloronaphthalene	ND X	(0.457)	[20]	ND X	(0.226)	[10]	NA	NA
2-Chlorophenol	ND X	(0.33)	[20]	ND X	(0.163)	[10]	NA	NA
2-Methylnaphthalene	ND X	(0.392)	[20]	ND X	(0.194)	[10]	NA	NA
2-Methylphenol	ND X	(0.84)	[20]	ND X	(0.415)	[10]	NA	NA
2-Nitroaniline	ND X	(0.308)	[20]	ND X	(0.152)	[10]	NA	NA

Compiled: 1 September 1994   () = Detection Limit   [] = Dilution Factor   ND = Not Detected   NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.) PARAMETER	9 E5A KRF-E5A-U0406 4 - 6	9 E5A KRF-E5A-U0608 6 - 8	9 E5A KRF-E5A-U1012 10 - 12	9 E5A KRF-E5A-U1214 12 - 14
SW8270 - Semivolatile Organics, cont. (ug/g)				
2-Nitrophenol	ND X (0.367) [20]	ND X (0.181) [10]	NA	NA
3,3'-Dichlorobenzidine	ND X (0.767) [20]	ND X (0.379) [10]	NA	NA
3-Nitroaniline	ND X (0.37) [20]	ND X (0.183) [10]	NA	NA
4,6-Dinitro-2-methylphenol	ND X (0.554) [20]	ND X (0.274) [10]	NA	NA
4-Bromophenyl phenyl ether	ND X (0.397) [20]	ND X (0.196) [10]	NA	NA
4-Chloro-3-methylphenol	ND X (0.245) [20]	ND X (0.121) [10]	NA	NA
4-Chlorophenyl phenyl ether	ND X (0.552) [20]	ND X (0.273) [10]	NA	NA
4-Methylphenol/3-Methylphenol	ND X (0.76) [20]	ND X (0.376) [10]	NA	NA
4-Nitroaniline	ND X (0.373) [20]	ND X (0.184) [10]	NA	NA
4-Nitrophenol	ND X (0.332) [20]	ND X (0.164) [10]	NA	NA
Acenaphthene	ND X (0.3) [20]	ND X (0.148) [10]	NA	NA
Acenaphthylene	ND X (0.556) [20]	ND X (0.275) [10]	NA	NA
Anthracene	ND X (0.373) [20]	ND X (0.184) [10]	NA	NA
Benzo(a)anthracene	ND X (0.293) [20]	ND X (0.145) [10]	NA	NA
Benzo(a)pyrene	ND X (0.457) [20]	ND X (0.226) [10]	NA	NA
Benzo(b)fluoranthene	ND X (0.718) [20]	ND X (0.355) [10]	NA	NA
Benzo(g,h,i)perylene	ND X (0.318) [20]	ND X (0.157) [10]	NA	NA
Benzo(k)fluoranthene	ND X (0.482) [20]	ND X (0.238) [10]	NA	NA
Benzoic acid	ND X (4.4) [20]	ND X (2.18) [10]	NA	NA
Benzyl alcohol	ND X (0.337) [20]	ND X (0.167) [10]	NA	NA
Butylbenzylphthalate	ND X (0.386) [20]	ND X (0.191) [10]	NA	NA
Chrysene	ND X (0.2) [20]	ND X (0.099) [10]	NA	NA
Di-n-octylphthalate	ND X (0.323) [20]	ND X (0.16) [10]	NA	NA
Dibenz(a.h)anthracene	ND X (0.355) [20]	ND X (0.176) [10]	NA	NA
Dibenzofuran	ND X (0.263) [20]	ND X (0.13) [10]	NA	NA
Dibutylphthalate	ND X (0.32) [20]	ND X (0.158) [10]	NA	NA
Diethylphthalate	ND X (0.23) [20]	ND X (0.114) [10]	NA	NA
Dimethylphthalate	ND X (0.236) [20]	ND X (0.117) [10]	NA	NA

Compiled: 1 September 1994   () = Detection Limit   [] = Dilution Factor   ND = Not Detected   NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, PF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E5A KRF-E5A-U0406 4 - 6			9 E5A KRF-E5A-U0608 6 - 8			9 E5A KRF-E5A-U1012 10 - 12			9 E5A KRF-E5A-U1214 12 - 14		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Diphenylamine	ND X	(0.543)	[20]	ND X	(0.269)	[10]	NA			NA		
Fluoranthene	ND X	(0.123)	[20]	ND X	(0.0611)	[10]	NA			NA		
Fluorene	ND X	(0.207)	[20]	ND X	(0.103)	[10]	NA			NA		
Hexachlorobenzene	ND X	(0.346)	[20]	ND X	(0.171)	[10]	NA			NA		
Hexachlorobutadiene	ND X	(0.177)	[20]	ND X	(0.0874)	[10]	NA			NA		
Hexachlorocyclopentadiene	ND X	(1.2)	[20]	ND X	(0.593)	[10]	NA			NA		
Hexachloroethane	ND X	(0.18)	[20]	ND X	(0.0889)	[10]	NA			NA		
Indeno(1,2,3-cd)pyrene	ND X	(0.379)	[20]	ND X	(0.188)	[10]	NA			NA		
Isophorone	ND X	(0.27)	[20]	ND X	(0.133)	[10]	NA			NA		
N-Nitroso-di-n-propylamine	ND X	(0.416)	[20]	ND X	(0.206)	[10]	NA			NA		
Naphthalene	ND X	(0.458)	[20]	ND X	(0.227)	[10]	NA			NA		
Nitrobenzene	ND X	(0.237)	[20]	ND X	(0.117)	[10]	NA			NA		
Pentachlorophenol	ND X	(0.132)	[20]	ND X	(0.0654)	[10]	NA			NA		
Phenanthrene	ND X	(0.273)	[20]	ND X	(0.135)	[10]	NA			NA		
Phenol	ND X	(0.391)	[20]	ND X	(0.193)	[10]	NA			NA		
Pyrene	ND X	(0.178)	[20]	ND X	(0.0882)	[10]	NA			NA		
bis(2-Chloroethoxy)methane	ND X	(0 202)	[20]	ND X	(0.0997)	[10]	NA			NA		
bis(2-Chloroethyl)ether	ND X	(0.29)	[20]	ND X	(0.143)	[10]	NA			NA		
bis(2-Chloroisopropyl)ether	ND X	(0.317)	[20]	ND X	(0.157)	[10]	NA			NA		
bis(2-Ethylhexyl)phthalate	ND X	(1.29)	[20]	ND X	(0.639)	[10]	NA			NA		
p-Chloroaniline	ND X	(0.435)	[20]	ND X	(0.215)	[10]	NA			NA		
SW846 - Percent Moisture (percent)												
Percent moisture	9.07 ✓	(0)	[1]	7.86 ✓	(0)	[1]	2.39 ✓	(0)	[1]	20.8 ✓	(0)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)												
	9 E5A KRF-E5A-U1820 18 - 20			9 E5A KRF-E5A-U2022 20 - 22			9 E6A KRF-E6A-U0810 8 - 10			9 E6A KRF-E6A-U1618 16 - 18		
PARAMETER												
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	35800 ✓	(173)	[20]	31200 ✓	(167)	[20]	930 ✓	(7.91)	[1]	253 ✓	(8.59)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	NA			NA			ND	(1.88)	[1]	ND	(57.1)	[100]
1,1,2,2-Tetrachloroethane	NA			NA			ND	(5.12)	[1]	ND	(129)	[100]
1,1,2-Trichloroethane	NA			NA			ND	(1.54)	[1]	ND	(75.2)	[100]
1,1-Dichloroethane	NA			NA			ND	(1.73)	[1]	ND	(38)	[100]
1,1-Dichloroethene	NA			NA			ND	(2.59)	[1]	ND	(21.4)	[100]
1,2-Dichloroethane	NA			NA			ND	(1.75)	[1]	ND	(176)	[100]
1,2-Dichloropropane	NA			NA			ND	(2.65)	[1]	ND	(44.1)	[100]
2-Chloroethyl vinyl ether	NA			NA			ND	(2.89)	[1]	ND	(164)	[100]
2-Hexanone	NA			NA			ND	(0.967)	[1]	ND	(162)	[100]
4-Methyl-2-Pentanone(MIBK)	NA			NA			ND	(0.923)	[1]	ND	(183)	[100]
Acetone	NA			NA			23.1 ✓ B	(1.51)	[1]	1090 B ✓	(444)	[100]
Benzene	NA			NA			< DL	(1.74)	[1]	ND	(36.8)	[100]
Bromodichloromethane	NA			NA			ND	(1.65)	[1]	ND	(36.4)	[100]
Bromomethane	NA			NA			ND	(2.03)	[1]	ND	(82.5)	[100]
Carbon disulfide	NA			NA			ND	(2.61)	[1]	ND	(85.4)	[100]
Carbon tetrachloride	NA			NA			ND	(2.02)	[1]	ND	(33.4)	[100]
Chlorobenzene	NA			NA			7.05 ✓	(4.69)	[1]	2390 ✓	(649)	[100]
Chloroethane	NA			NA			ND	(2.06)	[1]	ND	(83.3)	[100]
Chloroform	NA			NA			ND	(2.11)	[1]	ND	(43.6)	[100]
Chloromethane	NA			NA			ND	(2.46)	[1]	ND	(70)	[100]
Dibromochloromethane	NA			NA			ND	(1.85)	[1]	ND	(47)	[100]
Ethyl benzene	NA			NA			ND	(1.67)	[1]	ND	(36)	[100]
Methyl ethyl ketone	NA			NA			3.08 ✓	(1.54)	[1]	798 ✓	(160)	[100]
Methylene Chloride	NA			NA			5.32 ✓	(2.64)	[1]	173 B ✓	(41.5)	[100]
Styrene	NA			NA			ND	(1.63)	[1]	ND	(29.7)	[100]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E5A KRF-E5A-U1820 18 - 20	9 E5A KRF-E5A-U2022 20 - 22	9 E6A KRF-E6A-U0810 8 - 10				9 E6A KRF-E6A-U1618 16 - 18			
SW8240 - Volatile Organics, cont. (ug/kg)										
Tetrachloroethene	NA	NA	ND		(4.79)	[1]	ND		(69.2)	[100]
Toluene	NA	NA	2.02 ✓		(1.72)	[1]	ND		(32.2)	[100]
Tribromomethane(Bromoform)	NA	NA	ND		(1.53)	[1]	ND		(70.6)	[100]
Trichloroethene	NA	NA	ND		(4.9)	[1]	ND		(46.2)	[100]
Vinyl Chloride	NA	NA	ND		(2.03)	[1]	ND		(93.4)	[100]
Vinyl acetate	NA	NA	ND		(11.1)	[1]	ND		(103)	[100]
Xylene (total)	NA	NA	ND		(3.67)	[1]	ND		(82.7)	[100]
cis-1,3-Dichloropropene	NA	NA	ND		(1.62)	[1]	ND		(34.4)	[100]
trans-1,2-Dichloroethene	NA	NA	ND		(2.35)	[1]	ND		(42.3)	[100]
trans-1,3-Dichloropropene	NA	NA	ND		(1.75)	[1]	ND		(36.9)	[100]
SW8270 - Semivolatile Organics (ug/g)										
1,2,4-Trichlorobenzene	NA	NA	ND	X	(0.464)	[20]	ND	X	(0.0838)	[10]
1,2-Dichlorobenzene	NA	NA	ND	X	(1.55)	[20]	ND	X	(0.28)	[10]
1,3-Dichlorobenzene	NA	NA	ND	X	(1.72)	[20]	ND	X	(0.311)	[10]
1,4-Dichlorobenzene	NA	NA	ND	X	(1.71)	[20]	0.725	X	(0.309)	[10]
2,4,5-Trichlorophenol	NA	NA	ND	X	(1.42)	[20]	ND	X	(0.256)	[10]
2,4,6-Trichlorophenol	NA	NA	ND	X	(1.17)	[20]	ND	X	(0.212)	[10]
2,4-Dichlorophenol	NA	NA	ND	X	(1.4)	[20]	ND	X	(0.254)	[10]
2,4-Dimethylphenol	NA	NA	ND	X	(3.07)	[20]	ND	X	(0.555)	[10]
2,4-Dinitrophenol	NA	NA	ND	X	(6.26)	[20]	ND	X	(1.13)	[10]
2,4-Dinitrotoluene	NA	NA	ND	X	(1.86)	[20]	ND	X	(0.336)	[10]
2,6-Dinitrotoluene	NA	NA	ND	X	(2.54)	[20]	ND	X	(0.459)	[10]
2-Chloronaphthalene	NA	NA	ND	X	(2.17)	[20]	ND	X	(0.393)	[10]
2-Chlorophenol	NA	NA	ND	X	(0.792)	[20]	ND	X	(0.143)	[10]
2-Methylnaphthalene	NA	NA	ND	X	(1.46)	[20]	ND	X	(0.264)	[10]
2-Methylphenol	NA	NA	ND	X	(1.91)	[20]	ND	X	(0.345)	[10]
2-Nitroaniline	NA	NA	ND	X	(1.93)	[20]	ND	X	(0.349)	[10]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E5A KRF-E5A-U1820 18 - 20	9 E5A KRF-E5A-U2022 20 - 22	9 E6A KRF-E6A-U0810 8 - 10	9 E6A KRF-E6A-U1618 16 - 18
SW8270 - Semivolatile Organics, cont.	(ug/g)			
2-Nitrophenol	NA	NA	ND X (1.03) [20]	ND X (0.186) [10]
3,3'-Dichlorobenzidine	NA	NA	ND X (2.63) [20]	ND X (0.476) [10]
3-Nitroaniline	NA	NA	ND X (0.778) [20]	ND X (0.141) [10]
4,6-Dinitro-2-methylphenol	NA	NA	ND X (1.77) [20]	ND X (0.319) [10]
4-Bromophenyl phenyl ether	NA	NA	ND X (1.47) [20]	ND X (0.266) [10]
4-Chloro-3-methylphenol	NA	NA	ND X (1.11) [20]	ND X (0.2) [10]
4-Chlorophenyl phenyl ether	NA	NA	ND X (1.77) [20]	ND X (0.32) [10]
4-Methylphenol/3-Methylphenol	NA	NA	ND X (3) [20]	ND X (0.542) [10]
4-Nitroaniline	NA	NA	ND X (1.45) [20]	ND X (0.262) [10]
4-Nitrophenol	NA	NA	ND X (1.52) [20]	ND X (0.276) [10]
Acenaphthene	NA	NA	ND X (1.16) [20]	ND X (0.21) [10]
Acenaphthylene	NA	NA	ND X (1.59) [20]	ND X (0.287) [10]
Anthracene	NA	NA	ND X (1.3) [20]	ND X (0.235) [10]
Benzo(a)anthracene	NA	NA	ND X (0.841) [20]	ND X (0.152) [10]
Benzo(a)pyrene	NA	NA	ND X (1.3) [20]	ND X (0.236) [10]
Benzo(b)fluoranthene	NA	NA	ND X (2.32) [20]	ND X (0.419) [10]
Benzo(g,h,i)perylene	NA	NA	ND X (1.34) [20]	ND X (0.242) [10]
Benzo(k)fluoranthene	NA	NA	ND X (1.98) [20]	ND X (0.358) [10]
Benzoic acid	NA	NA	ND X (7.22) [20]	ND X (1.31) [10]
Benzyl alcohol	NA	NA	ND X (3.48) [20]	ND X (0.629) [10]
Butylbenzylphthalate	NA	NA	ND X (1.81) [20]	ND X (0.328) [10]
Chrysene	NA	NA	ND X (1.41) [20]	ND X (0.255) [10]
Di-n-octylphthalate	NA	NA	ND X (1.41) [20]	ND X (0.254) [10]
Dibenz(a,h)anthracene	NA	NA	ND X (1.65) [20]	ND X (0.298) [10]
Dibenzofuran	NA	NA	ND X (0.945) [20]	ND X (0.171) [10]
Dibutylphthalate	NA	NA	ND X (0.749) [20]	ND X (0.135) [10]
Diethylphthalate	NA	NA	ND X (0.894) [20]	ND X (0.162) [10]
Dimethylphthalate	NA	NA	ND X (1.14) [20]	ND X (0.206) [10]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)																
	9				9				9				9			
	E5A				E5A				E6A				E6A			
	KRF-E5A-U1820				KRF-E5A-U2022				KRF-E6A-U0810				KRF-E6A-U1618			
PARAMETER	18 - 20				20 - 22				8 - 10				16 - 18			
SW8270 - Semivolatile Organics, cont. (ug/g)																
Diphenylamine	NA				NA				ND	X	(1.85)	[20]	ND	X	(0.334)	[10]
Fluoranthene	NA				NA				ND	X	(1.03)	[20]	ND	X	(0.186)	[10]
Fluorene	NA				NA				ND	X	(0.834)	[20]	ND	X	(0.151)	[10]
Hexachlorobenzene	NA				NA				ND	X	(1.28)	[20]	ND	X	(0.231)	[10]
Hexachlorobutadiene	NA				NA				ND	X	(1.59)	[20]	ND	X	(0.287)	[10]
Hexachlorocyclopentadiene	NA				NA				ND	X	(3.96)	[20]	ND	X	(0.716)	[10]
Hexachloroethane	NA				NA				ND	X	(2.42)	[20]	ND	X	(0.437)	[10]
Indeno(1,2,3-cd)pyrene	NA				NA				ND	X	(1.16)	[20]	ND	X	(0.21)	[10]
Isophorone	NA				NA				ND	X	(0.73)	[20]	ND	X	(0.132)	[10]
N-Nitroso-di-n-propylamine	NA				NA				ND	X	(1.9)	[20]	ND	X	(0.343)	[10]
Naphthalene	NA				NA				ND	X	(1.61)	[20]	ND	X	(0.292)	[10]
Nitrobenzene	NA				NA				ND	X	(0.94)	[20]	ND	X	(0.17)	[10]
Pentachlorophenol	NA				NA				ND	X	(0.464)	[20]	ND	X	(0.0838)	[10]
Phenanthrene	NA				NA				ND	X	(1.34)	[20]	ND	X	(0.242)	[10]
Phenol	NA				NA				ND	X	(2.44)	[20]	ND	X	(0.441)	[10]
Pyrene	NA				NA				ND	X	(1.12)	[20]	ND	X	(0.202)	[10]
bis(2-Chloroethoxy)methane	NA				NA				ND	X	(0.807)	[20]	ND	X	(0.146)	[10]
bis(2-Chloroethyl)ether	NA				NA				ND	X	(1.13)	[20]	ND	X	(0.204)	[10]
bis(2-Chloroisopropyl)ether	NA				NA				ND	X	(1.38)	[20]	ND	X	(0.249)	[10]
bis(2-Ethylhexyl)phthalate	NA				NA				ND	X	(3.96)	[20]	ND	X	(0.716)	[10]
p-Chloroaniline	NA				NA				ND	X	(2.37)	[20]	ND	X	(0.428)	[10]
SW846 - Percent Moisture (percent)																
Percent moisture	24.7	✓	(0)	[1]	21.4	✓	(0)	[1]	17.3	✓	(0)	[1]	24	✓	(0)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES. RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E6A KRF-E6A-U2023 20 - 23			9 E7A KRF-E7A-U0204 2 - 4			9 E7A KRF-E7A-U0204D Dup of KRF-E7A-U0204 2 - 4			9 E7A KRF-E7A-U1214 12 - 14		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	92600 ✓	(440)	[50]	161 ✓	(8.61)	[1]	708 ✓	(8.29)	[1]	825 ✓	(8.95)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(58.4)	[100]	ND	(2.06)	[1]	ND	(1.98)	[1]	NA		
1,1,2,2-Tetrachloroethane	ND	(131)	[100]	ND	(5.6)	[1]	ND	(5.38)	[1]	NA		
1,1,2-Trichloroethane	ND	(76.9)	[100]	ND	(1.68)	[1]	ND	(1.62)	[1]	NA		
1,1-Dichloroethane	ND	(38.8)	[100]	ND	(1.89)	[1]	ND	(1.82)	[1]	NA		
1,1-Dichloroethene	ND	(21.9)	[100]	ND	(2.83)	[1]	ND	(2.72)	[1]	NA		
1,2-Dichloroethane	ND	(180)	[100]	ND	(1.92)	[1]	ND	(1.84)	[1]	NA		
1,2-Dichloropropane	ND	(45.1)	[100]	ND	(2.9)	[1]	ND	(2.78)	[1]	NA		
2-Chloroethyl vinyl ether	ND	(168)	[100]	ND	(3.16)	[1]	ND	(3.03)	[1]	NA		
2-Hexanone	ND	(165)	[100]	ND	(1.06)	[1]	ND	(1.02)	[1]	NA		
4-Methyl-2-Pentanone(MIBK)	ND	(187)	[100]	ND	(1.01)	[1]	ND	(0.971)	[1]	NA		
Acetone	998 ✓ B	(454)	[100]	18 B ✓	(1.66)	[1]	25 ✓ B	(1.59)	[1]	NA		
Benzene	6540 ✓	(37.6)	[100]	ND	(1.9)	[1]	ND	(1.83)	[1]	NA		
Bromodichloromethane	ND	(37.2)	[100]	ND	(1.8)	[1]	ND	(1.73)	[1]	NA		
Bromomethane	ND	(84.3)	[100]	ND	(2.22)	[1]	ND	(2.13)	[1]	NA		
Carbon disulfide	ND	(87.3)	[100]	ND	(2.86)	[1]	ND	(2.75)	[1]	NA		
Carbon tetrachloride	ND	(34.1)	[100]	ND	(2.2)	[1]	ND	(2.12)	[1]	NA		
Chlorobenzene	172000 ✓	(6630)	[1000]	ND	(5.13)	[1]	ND	(4.93)	[1]	NA		
Chloroethane	ND	(85.1)	[100]	ND	(2.26)	[1]	ND	(2.17)	[1]	NA		
Chloroform	ND	(44.6)	[100]	ND	(2.31)	[1]	ND	(2.22)	[1]	NA		
Chloromethane	ND	(71.6)	[100]	ND	(2.69)	[1]	ND	(2.58)	[1]	NA		
Dibromochloromethane	ND	(48.1)	[100]	ND	(2.02)	[1]	ND	(1.94)	[1]	NA		
Ethyl benzene	1510 ✓	(36.8)	[100]	ND	(1.83)	[1]	ND	(1.76)	[1]	NA		
Methyl ethyl ketone	905 ✓	(164)	[100]	5.84 ✓ B	(1.68)	[1]	6.51 ✓ B	(1.62)	[1]	NA		
Methylene Chloride	234 ✓ B	(42.4)	[100]	6.39 ✓ B	(2.88)	[1]	3.22 ✓ B	(2.77)	[1]	NA		

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

	9				9				9				9
	E6A				E7A				E7A				E7A
	KRF-E6A-U2023				KRF-E7A-U0204				KRF-E7A-U0204D Dup of KRF-E7A-U0204				KRF-E7A-U1214
PARAMETER	20 - 23				2 - 4				2 - 4				12 - 14
SW8240 - Volatile Organics, cont. (ug/kg)													
Styrene	ND		(30.3)	[100]	ND		(1.79)	[1]	ND		(1.72)	[1]	NA
Tetrachloroethene	ND		(70.8)	[100]	ND		(5.24)	[1]	ND		(5.04)	[1]	NA
Toluene	1270✓		(32.9)	[100]	< DL		(1.88)	[1]	ND		(1.81)	[1]	NA
Tribromomethane(Bromoform)	ND		(72.2)	[100]	ND		(1.67)	[1]	ND		(1.61)	[1]	NA
Trichloroethene	ND		(47.3)	[100]	ND		(5.36)	[1]	ND		(5.15)	[1]	NA
Vinyl Chloride	ND		(95.5)	[100]	ND		(2.28)	[1]	ND		(2.19)	[1]	NA
Vinyl acetate	ND		(106)	[100]	ND		(12.1)	[1]	ND		(11.6)	[1]	NA
Xylene (total)	3220✓		(84.6)	[100]	ND		(4.02)	[1]	ND		(3.86)	[1]	NA
cis-1,3-Dichloropropene	ND		(35.2)	[100]	ND		(1.77)	[1]	ND		(1.71)	[1]	NA
trans-1,2-Dichloroethene	ND		(43.2)	[100]	ND		(2.57)	[1]	ND		(2.47)	[1]	NA
trans-1,3-Dichloropropene	ND		(37.7)	[100]	ND		(1.92)	[1]	ND		(1.84)	[1]	NA
SW8270 - Semivolatile Organics (ug/g)													
1,2,4-Trichlorobenzene	ND	X	(2.49)	[10]	ND	X	(0.0832)	[10]	ND	X	(0.162)	[20]	NA
1,2-Dichlorobenzene	ND	X	(8.32)	[10]	ND	X	(0.278)	[10]	ND	X	(0.54)	[20]	NA
1,3-Dichlorobenzene	ND	X	(9.24)	[10]	ND	X	(0.309)	[10]	ND	X	(0.6)	[20]	NA
1,4-Dichlorobenzene	20	X	(9.17)	[10]	ND	X	(0.306)	[10]	ND	X	(0.596)	[20]	NA
2,4,5-Trichlorophenol	ND	X	(7.6)	[10]	ND	X	(0.254)	[10]	ND	X	(0.494)	[20]	NA
2,4,6-Trichlorophenol	ND	X	(6.29)	[10]	ND	X	(0.21)	[10]	ND	X	(0.409)	[20]	NA
2,4-Dichlorophenol	ND	X	(7.54)	[10]	ND	X	(0.252)	[10]	ND	X	(0.49)	[20]	NA
2,4-Dimethylphenol	ND	X	(16.5)	[10]	ND	X	(0.55)	[10]	ND	X	(1.07)	[20]	NA
2,4-Dinitrophenol	ND	X	(33.6)	[10]	ND	X	(1.12)	[10]	ND	X	(2.18)	[20]	NA
2,4-Dinitrotoluene	ND	X	(9.98)	[10]	ND	X	(0.333)	[10]	ND	X	(0.648)	[20]	NA
2,6-Dinitrotoluene	ND	X	(13.6)	[10]	ND	X	(0.455)	[10]	ND	X	(0.885)	[20]	NA
2-Chloronaphthalene	ND	X	(11.7)	[10]	ND	X	(0.39)	[10]	ND	X	(0.758)	[20]	NA
2-Chlorophenol	ND	X	(4.26)	[10]	ND	X	(0.142)	[10]	ND	X	(0.277)	[20]	NA
2-Methylnaphthalene	63.8	X	(7.85)	[10]	ND	X	(0.262)	[10]	ND	X	(0.51)	[20]	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E6A KRF-E6A-U2023 20 - 23				9 E7A KRF-E7A-U0204 2 - 4				9 E7A KRF-E7A-U0204D Dup of KRF-E7A-U0204 2 - 4				9 E7A KRF-E7A-U1214 12 - 14
SW8270 - Semivolatile Organics, cont. (ug/g)													
2-Methylphenol	ND	X	(10.3)	[10]	ND	X	(0.342)	[10]	ND	X	(0.666)	[20]	NA
2-Nitroaniline	ND	X	(10.4)	[10]	ND	X	(0.346)	[10]	ND	X	(0.674)	[20]	NA
2-Nitrophenol	ND	X	(5.51)	[10]	ND	X	(0.184)	[10]	ND	X	(0.358)	[20]	NA
3,3'-Dichlorobenzidine	ND	X	(14.1)	[10]	ND	X	(0.472)	[10]	ND	X	(0.919)	[20]	NA
3-Nitroaniline	ND	X	(4.18)	[10]	ND	X	(0.14)	[10]	ND	X	(0.272)	[20]	NA
4,6-Dinitro-2-methylphenol	ND	X	(9.49)	[10]	ND	X	(0.317)	[10]	ND	X	(0.616)	[20]	NA
4-Bromophenyl phenyl ether	ND	X	(7.92)	[10]	ND	X	(0.264)	[10]	ND	X	(0.514)	[20]	NA
4-Chloro-3-methylphenol	ND	X	(5.94)	[10]	ND	X	(0.199)	[10]	ND	X	(0.386)	[20]	NA
4-Chlorophenyl phenyl ether	ND	X	(9.5)	[10]	ND	X	(0.317)	[10]	ND	X	(0.617)	[20]	NA
4-Methylphenol/3-Methylphenol	ND	X	(16.1)	[10]	ND	X	(0.537)	[10]	ND	X	(1.05)	[20]	NA
4-Nitroaniline	ND	X	(7.77)	[10]	ND	X	(0.26)	[10]	ND	X	(0.505)	[20]	NA
4-Nitrophenol	ND	X	(8.19)	[10]	ND	X	(0.273)	[10]	ND	X	(0.532)	[20]	NA
Acenaphthene	ND	X	(6.25)	[10]	ND	X	(0.209)	[10]	ND	X	(0.406)	[20]	NA
Acenaphthylene	ND	X	(8.54)	[10]	ND	X	(0.285)	[10]	ND	X	(0.555)	[20]	NA
Anthracene	ND	X	(6.99)	[10]	0.958	X	(0.234)	[10]	ND	X	(0.454)	[20]	NA
Benzo(a)anthracene	ND	X	(4.52)	[10]	1.82	X	(0.151)	[10]	0.504	X	(0.293)	[20]	NA
Benzo(a)pyrene	ND	X	(7.01)	[10]	1.15	X	(0.234)	[10]	0.511	X	(0.455)	[20]	NA
Benzo(b)fluoranthene	ND	X	(12.4)	[10]	0.923	X	(0.416)	[10]	0.987	XF	(0.809)	[20]	NA
Benzo(g,h,i)perylene	ND	X	(7.19)	[10]	0.576	X	(0.24)	[10]	ND	X	(0.467)	[20]	NA
Benzo(k)fluoranthene	ND	X	(10.6)	[10]	1.01	X	(0.355)	[10]	0.987	XF	(0.691)	[20]	NA
Benzoic acid	ND	X	(38.8)	[10]	ND	X	(1.3)	[10]	ND	X	(2.52)	[20]	NA
Benzyl alcohol	ND	X	(18.7)	[10]	ND	X	(0.624)	[10]	ND	X	(1.21)	[20]	NA
Butylbenzylphthalate	ND	X	(9.75)	[10]	ND	X	(0.325)	[10]	ND	X	(0.633)	[20]	NA
Chrysene	ND	X	(7.59)	[10]	1.63	X	(0.254)	[10]	< DL	X	(0.493)	[20]	NA
Di-n-octylphthalate	ND	X	(7.55)	[10]	ND	X	(0.252)	[10]	ND	X	(0.491)	[20]	NA
Dibenz(a,h)anthracene	ND	X	(8.86)	[10]	< DL	X	(0.296)	[10]	ND	X	(0.576)	[20]	NA
Dibenzofuran	ND	X	(5.07)	[10]	ND	X	(0.169)	[10]	ND	X	(0.33)	[20]	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)	9 E6A KRF-E6A-U2023 20 - 23				9 E7A KRF-E7A-U0204 2 - 4				9 E7A KRF-E7A-U0204D Dup of KRF-E7A-U0204 2 - 4				9 E7A KRF-E7A-U1214 12 - 14		
PARAMETER															
SW8270 - Semivolatile Organics, cont. (ug/g)															
Dibutylphthalate	ND	X	(4.02)	[10]	ND	X	(0.134)	[10]	ND	X	(0.261)	[20]	NA		
Diethylphthalate	ND	X	(4.8)	[10]	ND	X	(0.16)	[10]	ND	X	(0.312)	[20]	NA		
Dimethylphthalate	ND	X	(6.11)	[10]	ND	X	(0.204)	[10]	ND	X	(0.397)	[20]	NA		
Diphenylamine	ND	X	(9.91)	[10]	ND	X	(0.331)	[10]	ND	X	(0.644)	[20]	NA		
Fluoranthene	11.4	X	(5.51)	[10]	3.61	X	(0.184)	[10]	0.61	X	(0.358)	[20]	NA		
Fluorene	ND	X	(4.48)	[10]	ND	X	(0.15)	[10]	ND	X	(0.291)	[20]	NA		
Hexachlorobenzene	ND	X	(6.85)	[10]	ND	X	(0.229)	[10]	ND	X	(0.445)	[20]	NA		
Hexachlorobutadiene	ND	X	(8.53)	[10]	ND	X	(0.285)	[10]	ND	X	(0.554)	[20]	NA		
Hexachlorocyclopentadiene	ND	X	(21.3)	[10]	ND	X	(0.711)	[10]	ND	X	(1.38)	[20]	NA		
Hexachloroethane	ND	X	(13)	[10]	ND	X	(0.433)	[10]	ND	X	(0.843)	[20]	NA		
Indeno(1,2,3-cd)pyrene	ND	X	(6.24)	[10]	0.52	X	(0.208)	[10]	< DL	X	(0.406)	[20]	NA		
Isophorone	ND	X	(3.92)	[10]	ND	X	(0.131)	[10]	ND	X	(0.255)	[20]	NA		
N-Nitroso-di-n-propylamine	ND	X	(10.2)	[10]	ND	X	(0.34)	[10]	ND	X	(0.662)	[20]	NA		
Naphthalene	22.1	X	(8.67)	[10]	ND	X	(0.29)	[10]	ND	X	(0.563)	[20]	NA		
Nitrobenzene	ND	X	(5.05)	[10]	ND	X	(0.169)	[10]	ND	X	(0.328)	[20]	NA		
Pentachlorophenol	ND	X	(2.49)	[10]	ND	X	(0.0832)	[10]	ND	X	(0.162)	[20]	NA		
Phenanthrene	< DL	X	(7.19)	[10]	2.09	X	(0.24)	[10]	ND	X	(0.467)	[20]	NA		
Phenol	ND	X	(13.1)	[10]	ND	X	(0.438)	[10]	ND	X	(0.852)	[20]	NA		
Pyrene	ND	X	(6)	[10]	2.96	X	(0.2)	[10]	0.551	X	(0.39)	[20]	NA		
bis(2-Chloroethoxy)methane	ND	X	(4.33)	[10]	ND	X	(0.145)	[10]	ND	X	(0.282)	[20]	NA		
bis(2-Chloroethyl)ether	ND	X	(6.05)	[10]	ND	X	(0.202)	[10]	ND	X	(0.393)	[20]	NA		
bis(2-Chloroisopropyl)ether	ND	X	(7.41)	[10]	ND	X	(0.247)	[10]	ND	X	(0.481)	[20]	NA		
bis(2-Ethylhexyl)phthalate	143	X	(21.3)	[10]	ND	X	(0.711)	[10]	ND	X	(1.38)	[20]	NA		
p-Chloroaniline	ND	X	(12.7)	[10]	NC	X	(0.425)	[10]	ND	X	(0.826)	[20]	NA		
SW846 - Percent Moisture (percent)															
Percent moisture	25.9 ✓		(0)	[1]	23.5 ✓		(0)	[1]	21.2 ✓		(0)	[1]	27 ✓	(0)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

	9	9	9	9
	E6A	E7A	E7A	E7A
	KRF-E6A-U2023	KRF-E7A-U0204	KRF-E7A-U0204D Dup of KRF-E7A-U0204	KRF-E7A-U1214
PARAMETER	20 - 23	2 - 4	2 - 4	12 - 14

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)												
	9 E8A KRF-E8A-U0608 6 - 8			9 E8A KRF-E8A-U2425 24 - 25			9 E8A KRF-E8A-U2627 26 - 27			9 F1A KRF-F1A-U0406 4 - 6		
PARAMETER												
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	861 ✓	(7.01)	[1]	6060 ✓	(36.2)	[5]	3060 ✓	(15.3)	[2]	828 ✓	(13.9)	[2]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(1.69)	[1]	NA			NA			ND	(1.67)	[1]
1,1,2,2-Tetrachloroethane	ND	(4.58)	[1]	NA			NA			ND	(4.54)	[1]
1,1,2-Trichloroethane	ND	(1.38)	[1]	NA			NA			ND	(1.37)	[1]
1,1-Dichloroethane	ND	(1.55)	[1]	NA			NA			ND	(1.54)	[1]
1,1-Dichloroethene	ND	(2.32)	[1]	NA			NA			ND	(2.3)	[1]
1,2-Dichloroethane	ND	(1.57)	[1]	NA			NA			ND	(1.56)	[1]
1,2-Dichloropropane	ND	(2.37)	[1]	NA			NA			ND	(2.35)	[1]
2-Chloroethyl vinyl ether	ND	(2.59)	[1]	NA			NA			ND	(2.56)	[1]
2-Hexanone	ND	(0.866)	[1]	NA			NA			ND	(0.859)	[1]
4-Methyl-2-Pentanone(MIBK)	ND	(0.827)	[1]	NA			NA			ND	(0.82)	[1]
Acetone	13.4 ✓ B	(1.36)	[1]	NA			NA			36.8 ✓ B	(1.35)	[1]
Benzene	< DL	(1.56)	[1]	NA			NA			ND	(1.55)	[1]
Bromodichloromethane	ND	(1.47)	[1]	NA			NA			ND	(1.46)	[1]
Bromomethane	ND	(1.82)	[1]	NA			NA			ND	(1.8)	[1]
Carbon disulfide	ND	(2.34)	[1]	NA			NA			ND	(2.32)	[1]
Carbon tetrachloride	ND	(1.81)	[1]	NA			NA			ND	(1.79)	[1]
Chlorobenzene	5.34 ✓	(4.2)	[1]	NA			NA			4.84 ✓	(4.16)	[1]
Chloroethane	ND	(1.85)	[1]	NA			NA			ND	(1.83)	[1]
Chloroform	ND	(1.89)	[1]	NA			NA			ND	(1.88)	[1]
Chloromethane	ND	(2.2)	[1]	NA			NA			ND	(2.18)	[1]
Dibromochloromethane	ND	(1.66)	[1]	NA			NA			ND	(1.64)	[1]
Ethyl benzene	ND	(1.5)	[1]	NA			NA			ND	(1.48)	[1]
Methyl ethyl ketone	ND	(1.38)	[1]	NA			NA			4.26 ✓	(1.37)	[1]
Methylene Chloride	4.82 ✓	(2.36)	[1]	NA			NA			7.14 ✓	(2.34)	[1]
Styrene	ND	(1.46)	[1]	NA			NA			ND	(1.45)	[1]

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RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 E8A KRF-E8A-U0608 6 - 8			9 E8A KRF-E8A-U2425 24 - 25	9 E8A KRF-E8A-U2627 26 - 27	9 F1A KRF-F1A-U0406 4 - 6		
SW8240 - Volatile Organics, cont. (ug/kg)								
Tetrachloroethene	ND	(4.29)	[1]	NA	NA	ND	(4.26)	[1]
Toluene	1.94✓	(1.54)	[1]	NA	NA	< DL	(1.53)	[1]
Tribromomethane(Bromoform)	ND	(1.37)	[1]	NA	NA	ND	(1.36)	[1]
Trichloroethene	ND	(4.39)	[1]	NA	NA	ND	(4.35)	[1]
Vinyl Chloride	ND	(1.87)	[1]	NA	NA	ND	(1.85)	[1]
Vinyl acetate	ND	(9.9)	[1]	NA	NA	ND	(9.82)	[1]
Xylene (total)	ND	(3.29)	[1]	NA	NA	ND	(3.26)	[1]
cis-1,3-Dichloropropene	ND	(1.45)	[1]	NA	NA	ND	(1.44)	[1]
trans-1,2-Dichloroethene	ND	(2.1)	[1]	NA	NA	ND	(2.09)	[1]
trans-1,3-Dichloropropene	ND	(1.57)	[1]	NA	NA	ND	(1.56)	[1]
SW8270 - Semivolatile Organics (ug/g)								
1,2,4-Trichlorobenzene	ND X	(0.136)	[20]	NA	NA	ND X	(0.154)	[20]
1,2-Dichlorobenzene	ND X	(0.453)	[20]	NA	NA	ND X	(0.216)	[20]
1,3-Dichlorobenzene	ND X	(0.503)	[20]	NA	NA	ND X	(0.202)	[20]
1,4-Dichlorobenzene	ND X	(0.499)	[20]	NA	NA	ND X	(0.342)	[20]
2,4,5-Trichlorophenol	ND X	(0.414)	[20]	NA	NA	ND X	(0.289)	[20]
2,4,6-Trichlorophenol	ND X	(0.342)	[20]	NA	NA	ND X	(0.266)	[20]
2,4-Dichlorophenol	ND X	(0.41)	[20]	NA	NA	ND X	(0.221)	[20]
2,4-Dimethylphenol	ND X	(0.897)	[20]	NA	NA	ND X	(0.889)	[20]
2,4-Dinitrophenol	ND X	(1.83)	[20]	NA	NA	ND X	(1.88)	[20]
2,4-Dinitrotoluene	ND X	(0.543)	[20]	NA	NA	ND X	(0.322)	[20]
2,6-Dinitrotoluene	ND X	(0.741)	[20]	NA	NA	ND X	(0.273)	[20]
2-Chloronaphthalene	ND X	(0.635)	[20]	NA	NA	ND X	(0.441)	[20]
2-Chlorophenol	ND X	(0.232)	[20]	NA	NA	ND X	(0.319)	[20]
2-Methylnaphthalene	ND X	(0.427)	[20]	NA	NA	ND X	(0.379)	[20]
2-Methylphenol	ND X	(0.558)	[20]	NA	NA	ND X	(0.811)	[20]
2-Nitroaniline	ND X	(0.564)	[20]	NA	NA	ND X	(0.298)	[20]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG DEPTH - END DEPTH (FT.)												
	9 E8A KRF-E8A-U0608 6 - 8				9 E8A KRF-E8A-U2425 24 - 25	9 E8A KRF-E8A-U2627 26 - 27	9 F1A KRF-F1A-U0406 4 - 6					
PARAMETER												
SW8270 - Semivolatile Organics, cont. (ug/g)												
2-Nitrophenol	ND	X	(0.3)	[20]	NA	NA	ND	X	(0.354)	[20]		
3,3'-Dichlorobenzidine	ND	X	(0.77)	[20]	NA	NA	ND	X	(0.741)	[20]		
3-Nitroaniline	ND	X	(0.227)	[20]	NA	NA	ND	X	(0.358)	[20]		
4,6-Dinitro-2-methylphenol	ND	X	(0.516)	[20]	NA	NA	ND	X	(0.535)	[20]		
4-Bromophenyl phenyl ether	ND	X	(0.431)	[20]	NA	NA	ND	X	(0.383)	[20]		
4-Chloro-3-methylphenol	ND	X	(0.323)	[20]	NA	NA	ND	X	(0.236)	[20]		
4-Chlorophenyl phenyl ether	ND	X	(0.517)	[20]	NA	NA	ND	X	(0.532)	[20]		
4-Methylphenol/3-Methylphenol	ND	X	(0.876)	[20]	NA	NA	ND	X	(0.733)	[20]		
4-Nitroaniline	ND	X	(0.423)	[20]	NA	NA	ND	X	(0.36)	[20]		
4-Nitrophenol	ND	X	(0.446)	[20]	NA	NA	ND	X	(0.321)	[20]		
Acenaphthene	ND	X	(0.34)	[20]	NA	NA	ND	X	(0.29)	[20]		
Acenaphthylene	ND	X	(0.465)	[20]	NA	NA	ND	X	(0.537)	[20]		
Anthracene	ND	X	(0.381)	[20]	NA	NA	ND	X	(0.36)	[20]		
Benzo(a)anthracene	ND	X	(0.246)	[20]	NA	NA	ND	X	(0.283)	[20]		
Benzo(a)pyrene	ND	X	(0.381)	[20]	NA	NA	ND	X	(0.441)	[20]		
Benzo(b)fluoranthene	ND	X	(0.677)	[20]	NA	NA	ND	X	(0.693)	[20]		
Benzo(g,h,i)perylene	ND	X	(0.391)	[20]	NA	NA	ND	X	(0.307)	[20]		
Benzo(k)fluoranthene	ND	X	(0.579)	[20]	NA	NA	ND	X	(0.465)	[20]		
Benzoic acid	ND	X	(2.11)	[20]	NA	NA	ND	X	(4.25)	[20]		
Benzyl alcohol	ND	X	(1.02)	[20]	NA	NA	ND	X	(0.325)	[20]		
Butylbenzylphthalate	ND	X	(0.53)	[20]	NA	NA	ND	X	(0.372)	[20]		
Chrysene	ND	X	(0.413)	[20]	NA	NA	ND	X	(0.193)	[20]		
Di-n-octylphthalate	ND	X	(0.411)	[20]	NA	NA	ND	X	(0.312)	[20]		
Dibenz(a,h)anthracene	ND	X	(0.482)	[20]	NA	NA	ND	X	(0.343)	[20]		
Dibenzofuran	ND	X	(0.276)	[20]	NA	NA	ND	X	(0.254)	[20]		
Dibutylphthalate	ND	X	(0.219)	[20]	NA	NA	ND	X	(0.309)	[20]		
Diethylphthalate	ND	X	(0.261)	[20]	NA	NA	ND	X	(0.222)	[20]		
Dimethylphthalate	ND	X	(0.333)	[20]	NA	NA	ND	X	(0.228)	[20]		

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)																
	9 E8A KRF-E8A-U0608 6 - 8				9 E8A KRF-E8A-U2425 24 - 25				9 E8A KRF-E8A-U2627 26 - 27				9 F1A KRF-F1A-U0406 4 - 6			
PARAMETER																
SW8270 - Semivolatile Organics, cont. (ug/g)																
Diphenylamine	ND	X	(0.539)	[20]	NA				NA				ND	X	(0.525)	[20]
Fluoranthene	ND	X	(0.3)	[20]	NA				NA				ND	X	(0.119)	[20]
Fluorene	ND	X	(0.244)	[20]	NA				NA				ND	X	(0.2)	[20]
Hexachlorobenzene	ND	X	(0.373)	[20]	NA				NA				ND	X	(0.334)	[20]
Hexachlorobutadiene	ND	X	(0.464)	[20]	NA				NA				ND	X	(0.171)	[20]
Hexachlorocyclopentadiene	ND	X	(1.16)	[20]	NA				NA				ND	X	(1.16)	[20]
Hexachloroethane	ND	X	(0.706)	[20]	NA				NA				ND	X	(0.174)	[20]
Indeno(1,2,3-cd)pyrene	ND	X	(0.34)	[20]	NA				NA				ND	X	(0.366)	[20]
Isophorone	ND	X	(0.213)	[20]	NA				NA				ND	X	(0.26)	[20]
N-Nitroso-di-n-propylamine	ND	X	(0.554)	[20]	NA				NA				ND	X	(0.401)	[20]
Naphthalene	ND	X	(0.472)	[20]	NA				NA				ND	X	(0.442)	[20]
Nitrobenzene	ND	X	(0.275)	[20]	NA				NA				ND	X	(0.229)	[20]
Pentachlorophenol	ND	X	(0.136)	[20]	NA				NA				ND	X	(0.128)	[20]
Phenanthrene	ND	X	(0.391)	[20]	NA				NA				ND	X	(0.264)	[20]
Phenol	ND	X	(0.713)	[20]	NA				NA				ND	X	(0.377)	[20]
Pyrene	ND	X	(0.326)	[20]	NA				NA				ND	X	(0.172)	[20]
bis(2-Chloroethoxy)methane	ND	X	(0.236)	[20]	NA				NA				ND	X	(0.195)	[20]
bis(2-Chloroethyl)ether	ND	X	(0.329)	[20]	NA				NA				ND	X	(0.28)	[20]
bis(2-Chloroisopropyl)ether	ND	X	(0.403)	[20]	NA				NA				ND	X	(0.306)	[20]
bis(2-Ethylhexyl)phthalate	< DL	X	(1.16)	[20]	NA				NA				ND	X	(1.25)	[20]
p-Chloroaniline	ND	X	(0.692)	[20]	NA				NA				ND	X	(0.42)	[20]
SW846 - Percent Moisture (percent)																
Percent moisture	6.39 ✓		(0)	[1]	9.72 ✓		(0)	[1]	14.5 ✓		(0)	[1]	5.79 ✓		(0)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)	9 F1A KRF-F1A-U1012			9 F1A KRF-F1A-U1820			9 F1A KRF-F1A-U1820D Dup of KRF-F1A-U1820			9 F2A KRF-F2A-U1416		
PARAMETER	10 - 12			18 - 20			18 - 20			14 - 16		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	1580 ✓	(33.7)	[5]	23100 ✓	(181)	[20]	31700 ✓	(166)	[20]	555 ✓	(7.1)	[1]
SW8240 - Volatile Organics (ug/kg)										use results from 7/20 2:16:00 for all		
1,1,1-Trichloroethane	NA			NA			NA			ND X	(1.72)	[1]
1,1,2,2-Tetrachloroethane	NA			NA			NA			ND X	(4.67)	[1]
1,1,2-Trichloroethane	NA			NA			NA			ND X	(1.41)	[1]
1,1-Dichloroethane	NA			NA			NA			ND X	(1.58)	[1]
1,1-Dichloroethene	NA			NA			NA			ND X	(2.36)	[1]
1,2-Dichloroethane	NA			NA			NA			ND X	(1.6)	[1]
1,2-Dichloropropane	NA			NA			NA			ND	(2.42)	[1]
2-Chloroethyl vinyl ether	NA			NA			NA			ND	(2.64)	[1]
2-Hexanone	NA			NA			NA			ND ~~13.9 X~~	~~(0.883)~~ 4.26	[1]
4-Methyl-2-Pentanone(MIBK)	NA			NA			NA			ND ~~7.91~~	~~(0.843)~~ 4.06	[1]
Acetone	NA			NA			NA			317 ✓ B	(6.66)	[1]
Benzene	NA			NA			NA			ND ~~1.72~~	~~(1.59)~~ 7.86	[1]
Bromodichloromethane	NA			NA			NA			ND	(1.5)	[1]
Bromomethane	NA			NA			NA			ND X	(1.85)	[1]
Carbon disulfide	NA			NA			NA			ND X	(2.39)	[1]
Carbon tetrachloride	NA			NA			NA			ND	(1.84)	[1]
Chlorobenzene	NA			NA			NA			606 ✓	(20.6)	[1]
Chloroethane	NA			NA			NA			ND X	(1.88)	[1]
Chloroform	NA			NA			NA			ND X	(1.93)	[1]
Chloromethane	NA			NA			NA			ND X	(2.24)	[1]
Dibromochloromethane	NA			NA			NA			ND X	(1.69)	[1]
Ethyl benzene	NA			NA			NA			<DL ~~3.93 X~~	~~(1.52)~~ (7.35)	[1]
Methyl ethyl ketone	NA			NA			NA			76.9 ~~31.1~~ BX	~~(1.41)~~ (6.77)	[1]
Methylene Chloride	NA			NA			NA			ND X	(2.41)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)				
	9	9	9	9
	F1A	F1A	F1A	F2A
	KRF-F1A-U1012	KRF-F1A-U1820	KRF-F1A-U1820D Dup of KRF-F1A-U1820	KRF-F2A-U1416
PARAMETER	10 - 12	18 - 20	18 - 20	14 - 16
SW8240 - Volatile Organics, cont. (ug/kg)				
Styrene	NA	NA	NA	ND X (1.49) [1]
Tetrachloroethene	NA	NA	NA	ND X (4.38) [1]
Toluene	NA	NA	NA	12.6 ~~14.2~~ ~~(1.37)~~ 7.56 [1]
Tribromomethane(Bromoform)	NA	NA	NA	ND X (1.39) [1]
Trichloroethene	NA	NA	NA	ND (4.48) [1]
Vinyl Chloride	NA	NA	NA	ND X (1.91) [1]
Vinyl acetate	NA	NA	NA	ND X (10.1) [1]
Xylene (total)	NA	NA	NA	36.6 ~~26.7 X~~ 10.2 ~~(3.36)~~ [1]
cis-1,3-Dichloropropene	NA	NA	NA	ND (1.48) [1]
trans-1,2-Dichloroethene	NA	NA	NA	ND X (2.15) [1]
trans-1,3-Dichloropropene	NA	NA	NA	ND (1.6) [1]
SW8270 - Semivolatile Organics (ug/g)				
1,2,4-Trichlorobenzene	NA	NA	NA	ND X (0.0789) [10]
1,2-Dichlorobenzene	NA	NA	NA	1.45 X (0.111) [10]
1,3-Dichlorobenzene	NA	NA	NA	ND X (0.103) [10]
1,4-Dichlorobenzene	NA	NA	NA	0.345 X (0.175) [10]
2,4,5-Trichlorophenol	NA	NA	NA	ND X (0.148) [10]
2,4,6-Trichlorophenol	NA	NA	NA	ND X (0.136) [10]
2,4-Dichlorophenol	NA	NA	NA	ND X (0.114) [10]
2,4-Dimethylphenol	NA	NA	NA	ND X (0.456) [10]
2,4-Dinitrophenol	NA	NA	NA	ND X (0.966) [10]
2,4-Dinitrotoluene	NA	NA	NA	ND X (0.165) [10]
2,6-Dinitrotoluene	NA	NA	NA	ND X (0.14) [10]
2-Chloronaphthalene	NA	NA	NA	ND X (0.226) [10]
2-Chlorophenol	NA	NA	NA	ND X (0.164) [10]
2-Methylnaphthalene	NA	NA	NA	ND X (0.194) [10]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 F1A KRF-F1A-U1012 10 - 12	9 F1A KRF-F1A-U1820 18 - 20	9 F1A KRF-F1A-U1820D Dup of KRF-F1A-U1820 18 - 20	9 F2A KRF-F2A-U1416 14 - 16
SW8270 - Semivolatile Organics, cont. (ug/g)				
2-Methylphenol	NA	NA	NA	ND X (0.416) [10]
2-Nitroaniline	NA	NA	NA	ND X (0.153) [10]
2-Nitrophenol	NA	NA	NA	ND X (0.182) [10]
3,3'-Dichlorobenzidine	NA	NA	NA	ND X (0.38) [10]
3-Nitroaniline	NA	NA	NA	ND X (0.183) [10]
4,6-Dinitro-2-methylphenol	NA	NA	NA	ND X (0.274) [10]
4-Bromophenyl phenyl ether	NA	NA	NA	ND X (0.196) [10]
4-Chloro-3-methylphenol	NA	NA	NA	ND X (0.121) [10]
4-Chlorophenyl phenyl ether	NA	NA	NA	ND X (0.273) [10]
4-Methylphenol/3-Methylphenol	NA	NA	NA	ND X (0.376) [10]
4-Nitroaniline	NA	NA	NA	ND X (0.185) [10]
4-Nitrophenol	NA	NA	NA	ND X (0.165) [10]
Acenaphthene	NA	NA	NA	ND X (0.149) [10]
Acenaphthylene	NA	NA	NA	ND X (0.275) [10]
Anthracene	NA	NA	NA	ND X (0.185) [10]
Benzo(a)anthracene	NA	NA	NA	ND X (0.145) [10]
Benzo(a)pyrene	NA	NA	NA	ND X (0.226) [10]
Benzo(b)fluoranthene	NA	NA	NA	ND X (0.356) [10]
Benzo(g,h,i)perylene	NA	NA	NA	ND X (0.157) [10]
Benzo(k)fluoranthene	NA	NA	NA	ND X (0.239) [10]
Benzoic acid	NA	NA	NA	ND X (2.18) [10]
Benzyl alcohol	NA	NA	NA	ND X (0.167) [10]
Butylbenzylphthalate	NA	NA	NA	ND X (0.191) [10]
Chrysene	NA	NA	NA	ND X (0.0991) [10]
Di-n-octylphthalate	NA	NA	NA	ND X (0.16) [10]
Dibenz(a,h)anthracene	NA	NA	NA	ND X (0.176) [10]
Dibenzofuran	NA	NA	NA	ND X (0.13) [10]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 F1A KRF-F1A-U1012 10 - 12	9 F1A KRF-F1A-U1820 18 - 20	9 F1A KRF-F1A-U1820D Dup of KRF-F1A-U1820 18 - 20	9 F2A KRF-F2A-U1416 14 - 16
SW8270 - Semivolatile Organics, cont. (ug/g)				
Dibutylphthalate	NA	NA	NA	ND X (0.158) [10]
Diethylphthalate	NA	NA	NA	ND X (0.114) [10]
Dimethylphthalate	NA	NA	NA	ND X (0.117) [10]
Diphenylamine	NA	NA	NA	ND X (0.269) [10]
Fluoranthene	NA	NA	NA	ND X (0.0611) [10]
Fluorene	NA	NA	NA	ND X (0.103) [10]
Hexachlorobenzene	NA	NA	NA	ND X (0.171) [10]
Hexachlorobutadiene	NA	NA	NA	ND X (0.0875) [10]
Hexachlorocyclopentadiene	NA	NA	NA	ND X (0.593) [10]
Hexachloroethane	NA	NA	NA	ND X (0.089) [10]
Indeno(1,2,3-cd)pyrene	NA	NA	NA	ND X (0.188) [10]
Isophorone	NA	NA	NA	ND X (0.133) [10]
N-Nitroso-di-n-propylamine	NA	NA	NA	ND X (0.206) [10]
Naphthalene	NA	NA	NA	ND X (0.227) [10]
Nitrobenzene	NA	NA	NA	ND X (0.118) [10]
Pentachlorophenol	NA	NA	NA	ND X (0.0655) [10]
Phenanthrene	NA	NA	NA	ND X (0.135) [10]
Phenol	NA	NA	NA	ND X (0.194) [10]
Pyrene	NA	NA	NA	ND X (0.0883) [10]
bis(2-Chloroethoxy)methane	NA	NA	NA	ND X (0.0998) [10]
bis(2-Chloroethyl)ether	NA	NA	NA	ND X (0.144) [10]
bis(2-Chloroisopropyl)ether	NA	NA	NA	ND X (0.157) [10]
bis(2-Ethylhexyl)phthalate	NA	NA	NA	ND X (0.64) [10]
p-Chloroaniline	NA	NA	NA	ND X (0.215) [10]
SW846 - Percent Moisture (percent)				
Percent moisture	3 ✓ (0) [1]	27 ✓ (0) [1]	20.9 ✓ (0) [1]	8.38 ✓ (0) [1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID	9	9	9	9
LOCATION ID	F1A	F1A	F1A	F2A
SAMPLE ID	KRF-F1A-U1012	KRF-F1A-U1820	KRF-F1A-U1820D Dup of KRF-F1A-U1820	KRF-F2A-U1416
BEG. DEPTH - END DEPTH (FT.)	10 - 12	18 - 20	18 - 20	14 - 16
PARAMETER				

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 F2A KRF-F2A-U2627 26 - 27			9 F2A KRF-F2A-U2627D Dup of KRF-F2A-U2627 26 - 27			9 F3A KRF-F3A-U0406 4 - 6			9 F3A KRF-F3A-U1012 10 - 12		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	6270 ✓	(38)	[5]	6900 ✓	(41.4)	[5]	702 ✓	(7.86)	[1]	4510 ✓	(34.3)	[5]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(114)	[100]	ND	(126)	[100]	NA			NA		
1,1,2,2-Tetrachloroethane	ND	(149)	[100]	ND	(164)	[100]	NA			NA		
1,1,2-Trichloroethane	ND	(113)	[100]	ND	(124)	[100]	NA			NA		
1,1-Dichloroethane	ND	(89.5)	[100]	ND	(98.5)	[100]	NA			NA		
1,1-Dichloroethene	ND	(221)	[100]	ND	(243)	[100]	NA			NA		
1,2-Dichloroethane	ND	(164)	[100]	ND	(180)	[100]	NA			NA		
1,2-Dichloropropane	ND	(309)	[100]	ND	(340)	[100]	NA			NA		
2-Chloroethyl vinyl ether	ND	(164)	[100]	ND	(180)	[100]	NA			NA		
2-Hexanone	ND	(181)	[100]	ND	(199)	[100]	NA			NA		
4-Methyl-2-Pentanone(MIBK)	ND	(122)	[100]	ND	(134)	[100]	NA			NA		
Acetone	813 ✓	(676)	[100]	< DL	(744)	[100]	NA			NA		
Benzene	627 ✓	(75.7)	[100]	2610 ✓	(83.3)	[100]	NA			NA		
Bromodichloromethane	ND	(414)	[100]	ND	(455)	[100]	NA			NA		
Bromomethane	ND	(213)	[100]	ND	(234)	[100]	NA			NA		
Carbon disulfide	ND	(169)	[100]	ND	(186)	[100]	NA			NA		
Carbon tetrachloride	ND	(167)	[100]	ND	(184)	[100]	NA			NA		
Chlorobenzene	291000 ✓	(5820)	[5000]	432000 ✓	(12800)	[10000]	NA			NA		
Chloroethane	ND	(156)	[100]	ND	(171)	[100]	NA			NA		
Chloroform	ND	(69.4)	[100]	ND	(76.3)	[100]	NA			NA		
Chloromethane	ND	(112)	[100]	ND	(124)	[100]	NA			NA		
Dibromochloromethane	ND	(81.7)	[100]	ND	(89.9)	[100]	NA			NA		
Ethyl benzene	2520 ✓	(127)	[100]	3260 ✓	(139)	[100]	NA			NA		
Methyl ethyl ketone	ND	(318)	[100]	ND	(350)	[100]	NA			NA		
Methylene Chloride	ND	(213)	[100]	< DL	(234)	[100]	NA			NA		

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 F2A KRF-F2A-U2627 26 - 27			9 F2A KRF-F2A-U2627D Dup of KRF-F2A-U2627 26 - 27				9 F3A KRF-F3A-U0406 4 - 6	9 F3A KRF-F3A-U1012 10 - 12
SW8240 - Volatile Organics, cont. (ug/kg)									
Styrene	ND	(124)	[100]	ND		(137)	[100]	NA	NA
Tetrachloroethene	ND	(168)	[100]	ND		(185)	[100]	NA	NA
Toluene	8010✓	(92.7)	[100]	11200✓		(102)	[100]	NA	NA
Tribromomethane(Bromoform)	ND	(55.8)	[100]	ND		(61.3)	[100]	NA	NA
Trichloroethene	ND	(180)	[100]	ND		(198)	[100]	NA	NA
Vinyl Chloride	ND	(142)	[100]	ND		(156)	[100]	NA	NA
Vinyl acetate	ND	(94.5)	[100]	ND		(104)	[100]	NA	NA
Xylene (total)	17700✓	(293)	[100]	21500✓		(322)	[100]	NA	NA
cis-1,3-Dichloropropene	ND	(62.4)	[100]	ND		(68.7)	[100]	NA	NA
trans-1,2-Dichloroethene	ND	(192)	[100]	ND		(212)	[100]	NA	NA
trans-1,3-Dichloropropene	ND	(169)	[100]	ND		(186)	[100]	NA	NA
SW8270 - Semivolatile Organics (ug/g)									
1,2,4-Trichlorobenzene	2.2	(0.174)	[1]	5.77		(0.196)	[1]	NA	NA
1,2-Dichlorobenzene	32.4	(0.245)	[1]	162	EX	(0.275)	[1]	NA	NA
1,3-Dichlorobenzene	1.5	(0.229)	[1]	11.5		(0.257)	[1]	NA	NA
1,4-Dichlorobenzene	5.12	(0.388)	[1]	37.5		(0.435)	[1]	NA	NA
2,4,5-Trichlorophenol	ND	(0.328)	[1]	ND		(0.368)	[1]	NA	NA
2,4,6-Trichlorophenol	ND	(0.302)	[1]	ND		(0.338)	[1]	NA	NA
2,4-Dichlorophenol	ND	(0.251)	[1]	ND		(0.282)	[1]	NA	NA
2,4-Dimethylphenol	ND	(1.01)	[1]	ND		(1.13)	[1]	NA	NA
2,4-Dinitrophenol	ND	(2.14)	[1]	ND		(2.4)	[1]	NA	NA
2,4-Dinitrotoluene	ND	(0.366)	[1]	ND		(0.41)	[1]	NA	NA
2,6-Dinitrotoluene	ND	(0.31)	[1]	ND		(0.347)	[1]	NA	NA
2-Chloronaphthalene	ND	(0.5)	[1]	ND		(0.561)	[1]	NA	NA
2-Chlorophenol	ND	(0.362)	[1]	ND		(0.405)	[1]	NA	NA
2-Methylnaphthalene	8.9	(0.43)	[1]	18		(0.482)	[1]	NA	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)								
	9 F2A KRF-F2A-U2627			9 F2A KRF-F2A-U2627D Dup of KRF-F2A-U2627			9 F3A KRF-F3A-U0406	9 F3A KRF-F3A-U1012
PARAMETER	26 - 27			26 - 27			4 - 6	10 - 12
SW8270 - Semivolatile Organics, cont. (ug/g)								
2-Methylphenol	ND	(0.92)	[1]	< DL	(1.03)	[1]	NA	NA
2-Nitroaniline	ND	(0.338)	[1]	ND	(0.379)	[1]	NA	NA
2-Nitrophenol	ND	(0.402)	[1]	ND	(0.45)	[1]	NA	NA
3,3'-Dichlorobenzidine	ND	(0.84)	[1]	ND	(0.942)	[1]	NA	NA
3-Nitroaniline	ND	(0.406)	[1]	ND	(0.455)	[1]	NA	NA
4,6-Dinitro-2-methylphenol	ND	(0.606)	[1]	ND	(0.68)	[1]	NA	NA
4-Bromophenyl phenyl ether	ND	(0.434)	[1]	ND	(0.487)	[1]	NA	NA
4-Chloro-3-methylphenol	ND	(0.268)	[1]	ND	(0.301)	[1]	NA	NA
4-Chlorophenyl phenyl ether	ND	(0.604)	[1]	ND	(0.677)	[1]	NA	NA
4-Methylphenol/3-Methylphenol	ND	(0.832)	[1]	< DL F	(0.933)	[1]	NA	NA
4-Nitroaniline	ND	(0.408)	[1]	ND	(0.458)	[1]	NA	NA
4-Nitrophenol	ND	(0.364)	[1]	ND	(0.408)	[1]	NA	NA
Acenaphthene	ND	(0.329)	[1]	ND	(0.369)	[1]	NA	NA
Acenaphthylene	ND	(0.609)	[1]	ND	(0.683)	[1]	NA	NA
Anthracene	ND	(0.408)	[1]	ND	(0.458)	[1]	NA	NA
Benzo(a)anthracene	ND	(0.321)	[1]	ND	(0.36)	[1]	NA	NA
Benzo(a)pyrene	ND	(0.5)	[1]	ND	(0.561)	[1]	NA	NA
Benzo(b)fluoranthene	ND	(0.786)	[1]	ND	(0.882)	[1]	NA	NA
Benzo(g,h,i)perylene	ND	(0.348)	[1]	ND	(0.39)	[1]	NA	NA
Benzo(k)fluoranthene	ND	(0.528)	[1]	ND	(0.592)	[1]	NA	NA
Benzoic acid	ND	(4.82)	[1]	ND	(5.41)	[1]	NA	NA
Benzyl alcohol	ND	(0.369)	[1]	ND	(0.414)	[1]	NA	NA
Butylbenzylphthalate	ND	(0.422)	[1]	ND	(0.474)	[1]	NA	NA
Chrysene	ND	(0.219)	[1]	ND	(0.246)	[1]	NA	NA
Di-n-octylphthalate	ND	(0.354)	[1]	ND	(0.397)	[1]	NA	NA
Dibenz(a,h)anthracene	ND	(0.389)	[1]	ND	(0.436)	[1]	NA	NA
Dibenzofuran	ND	(0.288)	[1]	0.339	(0.323)	[1]	NA	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)												
	9			9			9			9		
	F2A			F2A			F3A			F3A		
	KRF-F2A-U2627			KRF-F2A-U2627D Dup of KRF-F2A-U2627			KRF-F3A-U0406			KRF-F3A-U1012		
PARAMETER	26 - 27			26 - 27			4 - 6			10 - 12		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Dibutylphthalate	ND	(0.35)	[1]	ND	(0.393)	[1]	NA			NA		
Diethylphthalate	ND	(0.252)	[1]	ND	(0.283)	[1]	NA			NA		
Dimethylphthalate	ND	(0.258)	[1]	ND	(0.29)	[1]	NA			NA		
Diphenylamine	ND	(0.595)	[1]	ND	(0.667)	[1]	NA			NA		
Fluoranthene	0.904	(0.135)	[1]	1.75	(0.152)	[1]	NA			NA		
Fluorene	ND	(0.227)	[1]	ND	(0.255)	[1]	NA			NA		
Hexachlorobenzene	ND	(0.379)	[1]	ND	(0.425)	[1]	NA			NA		
Hexachlorobutadiene	ND	(0.194)	[1]	ND	(0.217)	[1]	NA			NA		
Hexachlorocyclopentadiene	ND	(1.31)	[1]	ND	(1.47)	[1]	NA			NA		
Hexachloroethane	ND	(0.197)	[1]	ND	(0.221)	[1]	NA			NA		
Indeno(1,2,3-cd)pyrene	ND	(0.415)	[1]	ND	(0.466)	[1]	NA			NA		
Isophorone	ND	(0.295)	[1]	ND	(0.331)	[1]	NA			NA		
N-Nitroso-di-n-propylamine	ND	(0.455)	[1]	ND	(0.51)	[1]	NA			NA		
Naphthalene	3.81	(0.502)	[1]	9.65	(0.562)	[1]	NA			NA		
Nitrobenzene	ND	(0.26)	[1]	ND	(0.292)	[1]	NA			NA		
Pentachlorophenol	ND	(0.145)	[1]	ND	(0.162)	[1]	NA			NA		
Phenanthrene	ND	(0.299)	[1]	0.748	(0.336)	[1]	NA			NA		
Phenol	ND	(0.428)	[1]	ND	(0.48)	[1]	NA			NA		
Pyrene	ND	(0.195)	[1]	ND	(0.219)	[1]	NA			NA		
bis(2-Chloroethoxy)methane	ND	(0.221)	[1]	ND	(0.248)	[1]	NA			NA		
bis(2-Chloroethyl)ether	ND	(0.318)	[1]	ND	(0.356)	[1]	NA			NA		
bis(2-Chloroisopropyl)ether	ND	(0.347)	[1]	ND	(0.389)	[1]	NA			NA		
bis(2-Ethylhexyl)phthalate	6.55	(1.42)	[1]	12	(1.59)	[1]	NA			NA		
p-Chloroaniline	ND	(0.476)	[1]	ND	(0.534)	[1]	NA			NA		
SW846 - Percent Moisture (percent)												
Percent moisture	13.2 ✓	(0)	[1]	21.5 ✓	(0)	[1]	16 ✓	(0)	[1]	4.15 ✓	(0)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

	9	9	9	9
	F2A	F2A	F3A	F3A
	KRF-F2A-U2627	KRF-F2A-U2627D Dup of KRF-F2A-U2627	KRF-F3A-U0406	KRF-F3A-U1012
PARAMETER	26 - 27	26 - 27	4 - 6	10 - 12

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 F4A KRF-F4A-U0002 0 - 2			9 F4A KRF-F4A-U1214 12 - 14			9 F4A KRF-F4A-U1214D Dup of KRF-F4A-U1214 12 - 14			9 F4A KRF-F4A-U1618 16 - 18		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	448 ✓	(7.96)	[1]	643 ✓	(8.85)	[1]	535 ✓	(8.53)	[1]	12500 ✓	(45.6)	[5]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(1.88)	[1]	NA			NA			NA		
1,1,2,2-Tetrachloroethane	ND	(5.11)	[1]	NA			NA			NA		
1,1,2-Trichloroethane	ND	(1.54)	[1]	NA			NA			NA		
1,1-Dichloroethane	ND	(1.73)	[1]	NA			NA			NA		
1,1-Dichloroethene	ND	(2.58)	[1]	NA			NA			NA		
1,2-Dichloroethane	ND	(1.75)	[1]	NA			NA			NA		
1,2-Dichloropropane	ND	(2.64)	[1]	NA			NA			NA		
2-Chloroethyl vinyl ether	ND	(2.88)	[1]	NA			NA			NA		
2-Hexanone	ND	(0.965)	[1]	NA			NA			NA		
4-Methyl-2-Pentanone(MIBK)	ND	(0.921)	[1]	NA			NA			NA		
Acetone	50.5 ✓B	(1.51)	[1]	NA			NA			NA		
Benzene	ND	(1.74)	[1]	NA			NA			NA		
Bromodichloromethane	ND	(1.64)	[1]	NA			NA			NA		
Bromomethane	ND	(2.02)	[1]	NA			NA			NA		
Carbon disulfide	ND	(2.61)	[1]	NA			NA			NA		
Carbon tetrachloride	ND	(2.01)	[1]	NA			NA			NA		
Chlorobenzene	< DL	(4.68)	[1]	NA			NA			NA		
Chloroethane	ND	(2.06)	[1]	NA			NA			NA		
Chloroform	ND	(2.11)	[1]	NA			NA			NA		
Chloromethane	ND	(2.45)	[1]	NA			NA			NA		
Dibromochloromethane	ND	(1.84)	[1]	NA			NA			NA		
Ethyl benzene	ND	(1.67)	[1]	NA			NA			NA		
Methyl ethyl ketone	2.63 ✓	(1.54)	[1]	NA			NA			NA		
Methylene Chloride	3.37 ✓	(2.63)	[1]	NA			NA			NA		

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 F4A KRF-F4A-U0002 0 - 2	9 F4A KRF-F4A-U1214 12 - 14	9 F4A KRF-F4A-U1214D Dup of KRF-F4A-U1214 12 - 14	9 F4A KRF-F4A-U1618 16 - 18
SW8240 - Volatile Organics, cont. (ug/kg)				
Styrene	ND (1.63) [1]	NA	NA	NA
Tetrachloroethene	ND (4.78) [1]	NA	NA	NA
Toluene	ND (1.71) [1]	NA	NA	NA
Tribromomethane(Bromoform)	ND (1.52) [1]	NA	NA	NA
Trichloroethene	ND (4.89) [1]	NA	NA	NA
Vinyl Chloride	ND (2.08) [1]	NA	NA	NA
Vinyl acetate	ND (11) [1]	NA	NA	NA
Xylene (total)	ND (3.67) [1]	NA	NA	NA
cis-1,3-Dichloropropene	ND (1.62) [1]	NA	NA	NA
trans-1,2-Dichloroethene	ND (2.34) [1]	NA	NA	NA
trans-1,3-Dichloropropene	ND (1.75) [1]	NA	NA	NA
SW8270 - Semivolatile Organics (ug/g)				
1,2,4-Trichlorobenzene	ND X (0.173) [20]	NA	NA	NA
1,2-Dichlorobenzene	ND X (0.243) [20]	NA	NA	NA
1,3-Dichlorobenzene	ND X (0.227) [20]	NA	NA	NA
1,4-Dichlorobenzene	ND X (0.385) [20]	NA	NA	NA
2,4,5-Trichlorophenol	ND X (0.325) [20]	NA	NA	NA
2,4,6-Trichlorophenol	ND X (0.299) [20]	NA	NA	NA
2,4-Dichlorophenol	ND X (0.249) [20]	NA	NA	NA
2,4-Dimethylphenol	ND X (0.999) [20]	NA	NA	NA
2,4-Dinitrophenol	ND X (2.12) [20]	NA	NA	NA
2,4-Dinitrotoluene	ND X (0.362) [20]	NA	NA	NA
2,6-Dinitrotoluene	ND X (0.307) [20]	NA	NA	NA
2-Chloronaphthalene	ND X (0.496) [20]	NA	NA	NA
2-Chlorophenol	ND X (0.358) [20]	NA	NA	NA
2-Methylnaphthalene	ND X (0.426) [20]	NA	NA	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 F4A KRF-F4A-U0002 0 - 2	9 F4A KRF-F4A-U1214 12 - 14	9 F4A KRF-F4A-U1214D Dup of KRF-F4A-U1214 12 - 14	9 F4A KRF-F4A-U1618 16 - 18
SW8270 - Semivolatile Organics, cont. (ug/g)				
2-Methylphenol	ND X (0.912) [20]	NA	NA	NA
2-Nitroaniline	ND X (0.335) [20]	NA	NA	NA
2-Nitrophenol	ND X (0.398) [20]	NA	NA	NA
3,3'-Dichlorobenzidine	ND X (0.832) [20]	NA	NA	NA
3-Nitroaniline	ND X (0.402) [20]	NA	NA	NA
4,6-Dinitro-2-methylphenol	ND X (0.601) [20]	NA	NA	NA
4-Bromophenyl phenyl ether	ND X (0.431) [20]	NA	NA	NA
4-Chloro-3-methylphenol	ND X (0.266) [20]	NA	NA	NA
4-Chlorophenyl phenyl ether	ND X (0.599) [20]	NA	NA	NA
4-Methylphenol/3-Methylphenol	ND X (0.825) [20]	NA	NA	NA
4-Nitroaniline	ND X (0.404) [20]	NA	NA	NA
4-Nitrophenol	ND X (0.361) [20]	NA	NA	NA
Acenaphthene	ND X (0.326) [20]	NA	NA	NA
Acenaphthylene	ND X (0.603) [20]	NA	NA	NA
Anthracene	ND X (0.404) [20]	NA	NA	NA
Benzo(a)anthracene	ND X (0.318) [20]	NA	NA	NA
Benzo(a)pyrene	ND X (0.496) [20]	NA	NA	NA
Benzo(b)fluoranthene	ND X (0.779) [20]	NA	NA	NA
Benzo(g,h,i)perylene	ND X (0.345) [20]	NA	NA	NA
Benzo(k)fluoranthene	ND X (0.523) [20]	NA	NA	NA
Benzoic acid	ND X (4.78) [20]	NA	NA	NA
Benzyl alcohol	ND X (0.365) [20]	NA	NA	NA
Butylbenzylphthalate	ND X (0.419) [20]	NA	NA	NA
Chrysene	ND X (0.217) [20]	NA	NA	NA
Di-n-octylphthalate	ND X (0.35) [20]	NA	NA	NA
Dibenz(a,h)anthracene	ND X (0.385) [20]	NA	NA	NA
Dibenzofuran	ND X (0.285) [20]	NA	NA	NA

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9				9				9				9			
	F4A				F4A				F4A				F4A			
	KRF-F4A-U0002				KRF-F4A-U1214				KRF-F4A-U1214D Dup of KRF-F4A-U1214				KRF-F4A-U1618			
	0 - 2				12 - 14				12 - 14				16 - 18			
SW8270 - Semivolatile Organics, cont. (ug/g)																
Dibutylphthalate	ND	X	(0.347)	[20]	NA				NA				NA			
Diethylphthalate	ND	X	(0.25)	[20]	NA				NA				NA			
Dimethylphthalate	ND	X	(0.256)	[20]	NA				NA				NA			
Diphenylamine	ND	X	(0.59)	[20]	NA				NA				NA			
Fluoranthene	0.465	X	(0.134)	[20]	NA				NA				NA			
Fluorene	ND	X	(0.225)	[20]	NA				NA				NA			
Hexachlorobenzene	ND	X	(0.376)	[20]	NA				NA				NA			
Hexachlorobutadiene	ND	X	(0.192)	[20]	NA				NA				NA			
Hexachlorocyclopentadiene	ND	X	(1.3)	[20]	NA				NA				NA			
Hexachloroethane	ND	X	(0.195)	[20]	NA				NA				NA			
Indeno(1,2,3-cd)pyrene	< DL	X	(0.411)	[20]	NA				NA				NA			
Isophorone	ND	X	(0.293)	[20]	NA				NA				NA			
N-Nitroso-di-n-propylamine	ND	X	(0.451)	[20]	NA				NA				NA			
Naphthalene	ND	X	(0.497)	[20]	NA				NA				NA			
Nitrobenzene	ND	X	(0.258)	[20]	NA				NA				NA			
Pentachlorophenol	ND	X	(0.144)	[20]	NA				NA				NA			
Phenanthrene	ND	X	(0.297)	[20]	NA				NA				NA			
Phenol	ND	X	(0.424)	[20]	NA				NA				NA			
Pyrene	0.465	X	(0.193)	[20]	NA				NA				NA			
bis(2-Chloroethoxy)methane	ND	X	(0.219)	[20]	NA				NA				NA			
bis(2-Chloroethyl)ether	ND	X	(0.315)	[20]	NA				NA				NA			
bis(2-Chloroisopropyl)ether	ND	X	(0.344)	[20]	NA				NA				NA			
bis(2-Ethylhexyl)phthalate	ND	X	(1.4)	[20]	NA				NA				NA			
p-Chloroaniline	ND	X	(0.472)	[20]	NA				NA				NA			
SW846 - Percent Moisture (percent)																
Percent moisture	16.8 ✓		(0)	[1]	25.9 ✓		(0)	[1]	23.8 ✓		(0)	[1]	28.1 ✓		(0)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)				
	9	9	9	9
	F4A	F4A	F4A	F4A
	KRF-F4A-U0002	KRF-F4A-U1214	KRF-F4A-U1214D Dup of KRF-F4A-U1214	KRF-F4A-U1618
PARAMETER	0 - 2	12 - 14	12 - 14	16 - 18

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)												
	9			9			9			9		
	F4A			F5A			F5A			F5A		
	KRF-F4A-U2829			KRF-F5A-U1214			KRF-F5A-U1618			KRF-F5A-U1820		
PARAMETER	28 - 29			12 - 14			16 - 18			18 - 20		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)										50		
Hydrocarbons	1520 ✓	(7.3)	[1]	1530 ✓	(33.7)	[5]	20900 ✓	(165)	[20]	53,200 ~~53300~~	(419)	[50]
							1:100 7/23 22:18:00					
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(111)	[100]	NA			ND	(1.99)	[1]	ND	(124)	[100]
1,1,2,2-Tetrachloroethane	ND	(145)	[100]	NA			ND ~~*~~	162 (~~5.4~~)	[100] ~~[1]~~	ND	(162)	[100]
1,1,2-Trichloroethane	ND	(110)	[100]	NA			ND ~~*~~	123 (~~1.62~~)	[100] ~~[1]~~	ND	(123)	[100]
1,1-Dichloroethane	ND	(87)	[100]	NA			ND	(1.82)	[1]	ND	(97.5)	[100]
1,1-Dichloroethene	ND	(215)	[100]	NA			ND	(2.73)	[1]	ND	(241)	[100]
1,2-Dichloroethane	ND	(159)	[100]	NA			ND	(1.85)	[1]	ND	(178)	[100]
1,2-Dichloropropane	ND	(300)	[100]	NA			ND	(2.79)	[1]	ND	(336)	[100]
2-Chloroethyl vinyl ether	ND	(159)	[100]	NA			ND	(3.04)	[1]	ND	(178)	[100]
2-Hexanone	ND	(176)	[100]	NA			ND ~~*~~	177 (~~1.02~~)	[100] ~~[1]~~	ND	(197)	[100]
4-Methyl-2-Pentanone(MIBK)	ND	(119)	[100]	NA			4.2 ✓	(0.973)	[1]	ND	(133)	[100]
Acetone	< DL	(658)	[100]	NA			< DL	(737)	[100]	1360 ✓	(737)	[100]
Benzene	ND	(73.6)	[100]	NA			28.7 ✓	(1.84)	[1]	321 ✓	(82.5)	[100]
Bromodichloromethane	ND	(402)	[100]	NA			ND	(1.74)	[1]	ND	(451)	[100]
Bromomethane	ND	(207)	[100]	NA			ND	(2.14)	[1]	ND	(232)	[100]
Carbon disulfide	ND	(165)	[100]	NA			ND	(2.75)	[1]	ND	(184)	[100]
Carbon tetrachloride	ND	(162)	[100]	NA			ND	(2.13)	[1]	ND	(182)	[100]
Chlorobenzene	20200 ✓	(113)	[100]	NA			2370 ✓	(127)	[100]	5400 ✓	(127)	[100]
Chloroethane	ND	(151)	[100]	NA			ND	(2.18)	[1]	ND	(169)	[100]
Chloroform	ND	(67.4)	[100]	NA			ND	(2.23)	[1]	ND	(75.6)	[100]
Chloromethane	ND	(109)	[100]	NA			ND	(2.59)	[1]	ND	(122)	[100]
Dibromochloromethane	ND	(79.4)	[100]	NA			ND X	(1.95)	[1]	ND	(89)	[100]
Ethyl benzene	133 ✓	(123)	[100]	NA			ND ~~57.3 X~~	138 (~~1.76~~)	[100] ~~[1]~~	2580 ✓	(138)	[100]
Methyl ethyl ketone	ND	(309)	[100]	NA			45 ✓ B	(1.62)	[1]	ND	(346)	[100]
Methylene Chloride	ND	(207)	[100]	NA			< DL B	(2.78)	[1]	ND	(232)	[100]
Styrene	ND	(121)	[100]	NA			ND ~~X~~	136 (~~1.72~~)	[100] ~~[1]~~	ND	(136)	[100]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)	9 F4A KRF-F4A-U2829 28 - 29			9 F5A KRF-F5A-U1214 12 - 14	9 F5A KRF-F5A-U1618 16 - 18			9 F5A KRF-F5A-U1820 18 - 20		
PARAMETER										
SW8240 - Volatile Organics, cont. (ug/kg)										
Tetrachloroethene	ND	(164)	[100]	NA	ND ~~X~~	163 ~~(5.06)~~	[100] ~~[1]~~	414 ✓	(183)	[100]
Toluene	196 ✓	(90.2)	[100]	NA	35.8 ✓	(1.81)	[1]	15800 ✓	(101)	[100]
Tribromomethane(Bromoform)	ND	(54.2)	[100]	NA	ND ~~X~~	60.7 ~~(1.61)~~	[100] [1]	ND	(60.7)	[100]
Trichloroethene	ND	(175)	[100]	NA	ND	(5.17)	[1]	ND	(196)	[100]
Vinyl Chloride	ND	(138)	[100]	NA	ND	(2.2)	[1]	ND	(154)	[100]
Vinyl acetate	ND	(91.9)	[100]	NA	ND	(11.7)	[1]	ND	(103)	[100]
Xylene (total)	1170 ✓	(285)	[100]	NA	<DL ~~100 X~~	319 ~~(3.87)~~	[100] [1]	18200 ✓	(319)	[100]
cis-1,3-Dichloropropene	ND	(60.7)	[100]	NA	ND	(1.71)	[1]	ND	(68)	[100]
trans-1,2-Dichloroethene	ND	(187)	[100]	NA	ND	(2.48)	[1]	ND	(210)	[100]
trans-1,3-Dichloropropene	ND	(165)	[100]	NA	ND	(1.85)	[1]	ND	(184)	[100]
SW8270 - Semivolatile Organics (ug/g)										
1,2,4-Trichlorobenzene	ND	(0.217)	[1]	NA	ND X	(0.271)	[10]	ND	(0.215)	[1]
1,2-Dichlorobenzene	8.29	(0.304)	[1]	NA	ND X	(0.381)	[10]	13.6	(0.302)	[1]
1,3-Dichlorobenzene	1.83	(0.284)	[1]	NA	ND X	(0.356)	[10]	ND	(0.282)	[1]
1,4-Dichlorobenzene	9.92	(0.482)	[1]	NA	< DL X	(0.604)	[10]	7.15	(0.478)	[1]
2,4,5-Trichlorophenol	ND	(0.408)	[1]	NA	ND X	(0.511)	[10]	ND	(0.404)	[1]
2,4,6-Trichlorophenol	ND	(0.375)	[1]	NA	ND X	(0.469)	[10]	ND	(0.372)	[1]
2,4-Dichlorophenol	ND	(0.312)	[1]	NA	ND X	(0.391)	[10]	ND	(0.31)	[1]
2,4-Dimethylphenol	ND	(1.25)	[1]	NA	ND X	(1.57)	[10]	ND	(1.24)	[1]
2,4-Dinitrophenol	ND	(2.65)	[1]	NA	ND X	(3.32)	[10]	ND	(2.63)	[1]
2,4-Dinitrotoluene	ND	(0.454)	[1]	NA	ND X	(0.569)	[10]	ND	(0.451)	[1]
2,6-Dinitrotoluene	ND	(0.385)	[1]	NA	ND X	(0.482)	[10]	ND	(0.382)	[1]
2-Chloronaphthalene	ND	(0.621)	[1]	NA	ND X	(0.778)	[10]	ND	(0.617)	[1]
2-Chlorophenol	ND	(0.449)	[1]	NA	ND X	(0.563)	[10]	ND	(0.446)	[1]
2-Methylnaphthalene	2.8	(0.534)	[1]	NA	< DL X	(0.669)	[10]	23.3	(0.53)	[1]
2-Methylphenol	ND	(1.14)	[1]	NA	ND X	(1.43)	[10]	ND	(1.13)	[1]
2-Nitroaniline	ND	(0.42)	[1]	NA	ND X	(0.525)	[10]	ND	(0.416)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 F4A KRF-F4A-U2829 28 - 29				9 F5A KRF-F5A-U1214 12 - 14	9 F5A KRF-F5A-U1618 16 - 18				9 F5A KRF-F5A-U1820 18 - 20			
SW8270 - Semivolatile Organics, cont.	(ug/g)												
2-Nitrophenol	ND		(0.499)	[1]	NA	ND	X	(0.625)	[10]	ND		(0.495)	[1]
3,3'-Dichlorobenzidine	ND		(1.04)	[1]	NA	ND	X	(1.31)	[10]	ND		(1.04)	[1]
3-Nitroaniline	ND		(0.504)	[1]	NA	ND	X	(0.631)	[10]	ND		(0.5)	[1]
4,6-Dinitro-2-methylphenol	ND		(0.754)	[1]	NA	ND	X	(0.944)	[10]	ND		(0.748)	[1]
4-Bromophenyl phenyl ether	ND		(0.54)	[1]	NA	ND	X	(0.676)	[10]	ND		(0.536)	[1]
4-Chloro-3-methylphenol	ND		(0.333)	[1]	NA	ND	X	(0.417)	[10]	ND		(0.33)	[1]
4-Chlorophenyl phenyl ether	ND		(0.751)	[1]	NA	ND	X	(0.94)	[10]	ND		(0.745)	[1]
4-Methylphenol/3-Methylphenol	ND		(1.03)	[1]	NA	ND	X	(1.3)	[10]	3.23	F	(1.03)	[1]
4-Nitroaniline	ND		(0.507)	[1]	NA	ND	X	(0.635)	[10]	ND		(0.503)	[1]
4-Nitrophenol	ND		(0.452)	[1]	NA	ND	X	(0.567)	[10]	ND		(0.449)	[1]
Acenaphthene	ND		(0.409)	[1]	NA	ND	X	(0.512)	[10]	ND		(0.405)	[1]
Acenaphthylene	ND		(0.757)	[1]	NA	ND	X	(0.948)	[10]	ND		(0.751)	[1]
Anthracene	ND		(0.507)	[1]	NA	ND	X	(0.635)	[10]	ND		(0.503)	[1]
Benzo(a)anthracene	ND		(0.399)	[1]	NA	ND	X	(0.499)	[10]	ND		(0.396)	[1]
Benzo(a)pyrene	ND		(0.621)	[1]	NA	ND	X	(0.778)	[10]	ND		(0.617)	[1]
Benzo(b)fluoranthene	ND		(0.977)	[1]	NA	ND	X	(1.22)	[10]	< DL	F	(0.97)	[1]
Benzo(g,h,i)perylene	ND		(0.433)	[1]	NA	ND	X	(0.542)	[10]	ND		(0.429)	[1]
Benzo(k)fluoranthene	ND		(0.656)	[1]	NA	ND	X	(0.822)	[10]	0.769	F	(0.651)	[1]
Benzoic acid	ND		(6)	[1]	NA	ND	X	(7.51)	[10]	ND		(5.95)	[1]
Benzyl alcohol	ND		(0.458)	[1]	NA	ND	X	(0.574)	[10]	ND		(0.455)	[1]
Butylbenzylphthalate	ND		(0.525)	[1]	NA	ND	X	(0.657)	[10]	ND		(0.521)	[1]
Chrysene	ND		(0.272)	[1]	NA	ND	X	(0.341)	[10]	ND		(0.27)	[1]
Di-n-octylphthalate	ND		(0.439)	[1]	NA	ND	X	(0.55)	[10]	ND		(0.436)	[1]
Dibenz(a,h)anthracene	ND		(0.483)	[1]	NA	ND	X	(0.605)	[10]	ND		(0.479)	[1]
Dibenzofuran	ND		(0.358)	[1]	NA	ND	X	(0.448)	[10]	ND		(0.355)	[1]
Dibutylphthalate	ND		(0.436)	[1]	NA	ND	X	(0.545)	[10]	ND		(0.432)	[1]
Diethylphthalate	ND		(0.313)	[1]	NA	ND	X	(0.392)	[10]	ND		(0.311)	[1]
Dimethylphthalate	ND		(0.321)	[1]	NA	ND	X	(0.402)	[10]	ND		(0.319)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

PARAMETER	SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)												
	9			9			9				9		
	F4A			F5A			F5A				F5A		
	KRF-F4A-U2829			KRF-F5A-U1214			KRF-F5A-U1618				KRF-F5A-U1820		
	28 - 29			12 - 14			16 - 18				18 - 20		
SW8270 - Semivolatile Organics, cont. (ug/g)													
Diphenylamine	ND	(0.74)	[1]	NA			ND	X	(0.926)	[10]	ND	(0.734)	[1]
Fluoranthene	ND	(0.168)	[1]	NA			0.574	X	(0.21)	[10]	24	(0.167)	[1]
Fluorene	ND	(0.282)	[1]	NA			ND	X	(0.354)	[10]	1.91	(0.28)	[1]
Hexachlorobenzene	ND	(0.471)	[1]	NA			ND	X	(0.59)	[10]	ND	(0.468)	[1]
Hexachlorobutadiene	ND	(0.241)	[1]	NA			ND	X	(0.301)	[10]	ND	(0.239)	[1]
Hexachlorocyclopentadiene	ND	(1.63)	[1]	NA			ND	X	(2.04)	[10]	ND	(1.62)	[1]
Hexachloroethane	ND	(0.245)	[1]	NA			ND	X	(0.306)	[10]	ND	(0.243)	[1]
Indeno(1,2,3-cd)pyrene	ND	(0.516)	[1]	NA			ND	X	(0.646)	[10]	< DL	(0.512)	[1]
Isophorone	ND	(0.367)	[1]	NA			ND	X	(0.459)	[10]	ND	(0.364)	[1]
N-Nitroso-di-n-propylamine	ND	(0.565)	[1]	NA			ND	X	(0.709)	[10]	ND	(0.561)	[1]
Naphthalene	1.52	(0.623)	[1]	NA			ND	X	(0.781)	[10]	9.33	(0.618)	[1]
Nitrobenzene	ND	(0.323)	[1]	NA			ND	X	(0.405)	[10]	ND	(0.321)	[1]
Pentachlorophenol	ND	(0.18)	[1]	NA			ND	X	(0.225)	[10]	ND	(0.179)	[1]
Phenanthrene	ND	(0.372)	[1]	NA			0.833	X	(0.466)	[10]	5.05	(0.369)	[1]
Phenol	ND	(0.532)	[1]	NA			ND	X	(0.566)	[10]	ND	(0.528)	[1]
Pyrene	ND	(0.243)	[1]	NA			ND	X	(0.304)	[10]	1.86	(0.241)	[1]
bis(2-Chloroethoxy)methane	ND	(0.274)	[1]	NA			ND	X	(0.344)	[10]	ND	(0.272)	[1]
bis(2-Chloroethyl)ether	ND	(0.395)	[1]	NA			ND	X	(0.494)	[10]	ND	(0.392)	[1]
bis(2-Chloroisopropyl)ether	ND	(0.432)	[1]	NA			ND	X	(0.54)	[10]	ND	(0.428)	[1]
bis(2-Ethylhexyl)phthalate	1.89	(1.76)	[1]	NA			30	X	(2.2)	[10]	93.5	(1.75)	[1]
p-Chloroaniline	ND	(0.592)	[1]	NA			ND	X	(0.741)	[10]	ND	(0.587)	[1]
SW846 - Percent Moisture (percent)													
Percent moisture	11 ✓	(0)	[1]	2.59 ✓	(0)	[1]	20.8 ✓		(0)	[1]	20.8 ✓	(0)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 F5A KRF-F5A-U2224 22 - 24			9 TD3A KRF-TD3A-U0608 6 - 8			9 TD3A KRF-TD3A-U1416 14 - 16			9 TD3A KRF-TD3A-U2425 24 - 25		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	7590 ✓	(34.3)	[5]	4740 ✓	(39.3)	[5]	1940 ✓	(41.9)	[5]	5040 ✓	(40.7)	[5]
SW846 - Percent Moisture (percent)												
Percent moisture	4.9 ✓	(0)	[1]	16.2 ✓	(0)	[1]	20.8 ✓	(0)	[1]	19 ✓	(0)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSFS FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)	9 TD5A KRF-TD5A-U0406 4 - 6			9 TD5A KRF-TD5A-U1416 14 - 16			9 TD5A KRF-TD5A-U2425 24 - 25			9 TD6A KRF-TD6A-U0406 4 - 6		
PARAMETER												
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)												
Hydrocarbons	762 ✓	(8.53)	[1]	1540 ✓	(8.19)	[1]	14300 ✓	(144)	[20]	893 ✓	(8.62)	[1]
SW8240 - Volatile Organics (ug/kg)												
1,1,1-Trichloroethane	ND	(2.08)	[1]	NA			ND	(48.1)	[100]	ND	(2.07)	[1]
1,1,2,2-Tetrachloroethane	ND	(5.64)	[1]	NA			ND	(108)	[100]	ND	(5.61)	[1]
1,1,2-Trichloroethane	ND	(1.7)	[1]	NA			ND	(63.4)	[100]	ND	(1.69)	[1]
1,1-Dichloroethane	ND	(1.91)	[1]	NA			ND	(32)	[100]	ND	(1.9)	[1]
1,1-Dichloroethene	ND	(2.85)	[1]	NA			ND	(18)	[100]	ND	(2.84)	[1]
1,2-Dichloroethane	ND	(1.93)	[1]	NA			ND	(148)	[100]	ND	(1.92)	[1]
1,2-Dichloropropane	ND	(2.92)	[1]	NA			ND	(37.2)	[100]	ND	(2.9)	[1]
2-Chloroethyl vinyl ether	ND	(3.18)	[1]	NA			ND	(138)	[100]	ND	(3.17)	[1]
2-Hexanone	ND	(1.07)	[1]	NA			ND	(136)	[100]	ND	(1.06)	[1]
4-Methyl-2-Pentanone(MIBK)	ND	(1.02)	[1]	NA			ND	(154)	[100]	ND	(1.01)	[1]
Acetone	69.2 ✓ B	(1.67)	[1]	NA			458 ✓ B	(374)	[100]	34 ✓ B	(1.66)	[1]
Benzene	< DL	(1.92)	[1]	NA			2740 ✓	(31)	[100]	ND	(1.91)	[1]
Bromodichloromethane	ND	(1.81)	[1]	NA			ND	(30.6)	[100]	ND	(1.8)	[1]
Bromomethane	ND	(2.23)	[1]	NA			ND	(69.4)	[100]	ND	(2.22)	[1]
Carbon disulfide	ND	(2.88)	[1]	NA			ND	(71.9)	[100]	ND	(2.86)	[1]
Carbon tetrachloride	ND	(2.22)	[1]	NA			ND	(28.1)	[100]	ND	(2.21)	[1]
Chlorobenzene	13.9 ✓	(5.16)	[1]	NA			174000 ✓	(5460)	[1000]	ND	(5.14)	[1]
Chloroethane	ND	(2.27)	[1]	NA			ND	(70.1)	[100]	ND	(2.26)	[1]
Chloroform	ND	(2.33)	[1]	NA			ND	(36.7)	[100]	ND	(2.32)	[1]
Chloromethane	ND	(2.71)	[1]	NA			ND	(58.9)	[100]	ND	(2.69)	[1]
Dibromochloromethane	ND	(2.04)	[1]	NA			ND	(39.6)	[100]	ND	(2.03)	[1]
Ethyl benzene	ND	(1.84)	[1]	NA			1450 ✓	(30.3)	[100]	ND	(1.83)	[1]
Methyl ethyl ketone	ND	(1.7)	[1]	NA			615 ✓	(135)	[100]	6.44 ✓ B	(1.69)	[1]
Methylene Chloride	9.07 ✓	(2.9)	[1]	NA			ND	(34.5)	[100]	< DL B	(2.89)	[1]
Styrene	ND	(1.8)	[1]	NA			ND	(25)	[100]	ND	(1.79)	[1]

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TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 TD5A KRF-TD5A-U0406 4 - 6				9 TD5A KRF-TD5A-U1416 14 - 16	9 TD5A KRF-TD5A-U2425 24 - 25			9 TD6A KRF-TD6A-U0406 4 - 6			
SW8240 - Volatile Organics, cont. (ug/kg)												
Tetrachloroethene	ND		(5.28)	[1]	NA	ND	(58.3)	[100]	ND		(5.26)	[1]
Toluene	2.27✓		(1.89)	[1]	NA	337✓	(27.1)	[100]	ND		(1.88)	[1]
Tribromomethane(Bromoform)	ND		(1.68)	[1]	NA	ND	(59.5)	[100]	ND		(1.67)	[1]
Trichloroethene	ND		(5.4)	[1]	NA	ND	(38.9)	[100]	ND		(5.38)	[1]
Vinyl Chloride	ND		(2.3)	[1]	NA	ND	(78.6)	[100]	ND		(2.29)	[1]
Vinyl acetate	ND		(12.2)	[1]	NA	ND	(87)	[100]	ND		(12.1)	[1]
Xylene (total)	ND		(4.05)	[1]	NA	1670✓	(69.7)	[100]	ND		(4.03)	[1]
cis-1,3-Dichloropropene	ND		(1.79)	[1]	NA	ND	(29)	[100]	ND		(1.78)	[1]
trans-1,2-Dichloroethene	ND		(2 59)	[1]	NA	ND	(35.6)	[100]	ND		(2.58)	[1]
trans-1,3-Dichloropropene	ND		(1.93)	[1]	NA	ND	(31.1)	[100]	ND		(1.92)	[1]
SW8270 - Semivolatile Organics (ug/g)												
1,2,4-Trichlorobenzene	ND	X	(0.0837)	[10]	NA	ND	(0.207)	[1]	ND	X	(0.168)	[20]
1,2-Dichlorobenzene	ND	X	(0.279)	[10]	NA	ND	(0.691)	[1]	ND	X	(0.56)	[20]
1,3-Dichlorobenzene	ND	X	(0.31)	[10]	NA	ND	(0.767)	[1]	ND	X	(0.622)	[20]
1,4-Dichlorobenzene	ND	X	(0.308)	[10]	NA	1.83	(0.762)	[1]	ND	X	(0.618)	[20]
2,4,5-Trichlorophenol	ND	X	(0.255)	[10]	NA	ND	(0.632)	[1]	ND	X	(0.512)	[20]
2,4,6-Trichlorophenol	ND	X	(0.211)	[10]	NA	ND	(0.523)	[1]	ND	X	(0.424)	[20]
2,4-Dichlorophenol	ND	X	(0.253)	[10]	NA	ND	(0.626)	[1]	ND	X	(0.508)	[20]
2,4-Dimethylphenol	ND	X	(0.554)	[10]	NA	ND	(1.37)	[1]	ND	X	(1.11)	[20]
2,4-Dinitrophenol	ND	X	(1.13)	[10]	NA	ND	(2.79)	[1]	ND	X	(2.26)	[20]
2,4-Dinitrotoluene	ND	X	(0.335)	[10]	NA	ND	(0.829)	[1]	ND	X	(0.672)	[20]
2,6-Dinitrotoluene	ND	X	(0.458)	[10]	NA	ND	(1.13)	[1]	ND	X	(0.918)	[20]
2-Chloronaphthalene	ND	X	(0.392)	[10]	NA	ND	(0.969)	[1]	ND	X	(0.786)	[20]
2-Chlorophenol	ND	X	(0.143)	[10]	NA	ND	(0.354)	[1]	ND	X	(0.287)	[20]
2-Methylnaphthalene	ND	X	(0.264)	[10]	NA	14	(0.652)	[1]	ND	X	(0.529)	[20]
2-Methylphenol	ND	X	(0.344)	[10]	NA	ND	(0.851)	[1]	ND	X	(0.69)	[20]
2-Nitroaniline	ND	X	(0.348)	[10]	NA	ND	(0.861)	[1]	ND	X	(0.698)	[20]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

PARAMETER													
SITE ID	9				9	9				9			
LOCATION ID	TD5A				TD5A	TD5A				TD6A			
SAMPLE ID	KRF-TD5A-U0406				KRF-TD5A-U1416	KRF-TD5A-U2425				KRF-TD6A-U0406			
BEG. DEPTH - END DEPTH (FT.)	4 - 6				14 - 16	24 - 25				4 - 6			
SW8270 - Semivolatile Organics, cont. (ug/g)													
2-Nitrophenol	ND	X	(0.185)	[10]	NA	ND		(0.458)	[1]	ND	X	(0.371)	[20]
3,3'-Dichlorobenzidine	ND	X	(0.475)	[10]	NA	ND		(1.17)	[1]	ND	X	(0.953)	[20]
3-Nitroaniline	ND	X	(0.14)	[10]	NA	ND		(0.347)	[1]	ND	X	(0.281)	[20]
4,6-Dinitro-2-methylphenol	ND	X	(0.319)	[10]	NA	ND		(0.788)	[1]	ND	X	(0.639)	[20]
4-Bromophenyl phenyl ether	ND	X	(0.266)	[10]	NA	ND		(0.657)	[1]	ND	X	(0.533)	[20]
4-Chloro-3-methylphenol	ND	X	(0.2)	[10]	NA	ND		(0.494)	[1]	ND	X	(0.4)	[20]
4-Chlorophenyl phenyl ether	ND	X	(0.319)	[10]	NA	ND		(0.789)	[1]	ND	X	(0.64)	[20]
4-Methylphenol/3-Methylphenol	ND	X	(0.54)	[10]	NA	ND		(1.34)	[1]	ND	X	(1.08)	[20]
4-Nitroaniline	ND	X	(0.261)	[10]	NA	ND		(0.646)	[1]	ND	X	(0.524)	[20]
4-Nitrophenol	ND	X	(0.275)	[10]	NA	ND		(0.68)	[1]	ND	X	(0.551)	[20]
Acenaphthene	ND	X	(0.21)	[10]	NA	ND		(0.519)	[1]	ND	X	(0.421)	[20]
Acenaphthylene	ND	X	(0.287)	[10]	NA	ND		(0.709)	[1]	ND	X	(0.575)	[20]
Anthracene	ND	X	(0.235)	[10]	NA	ND		(0.581)	[1]	ND	X	(0.471)	[20]
Benzo(a)anthracene	0.241	X	(0 152)	[10]	NA	ND		(0.375)	[1]	ND	X	(0.304)	[20]
Benzo(a)pyrene	< DL	X	(0.235)	[10]	NA	ND		(0.582)	[1]	ND	X	(0.472)	[20]
Benzo(b)fluoranthene	0.636	XF	(0.418)	[10]	NA	ND		(1.03)	[1]	ND	X	(0.838)	[20]
Benzo(g,h,i)perylene	ND	X	(0.241)	[10]	NA	ND		(0.597)	[1]	ND	X	(0.484)	[20]
Benzo(k)fluoranthene	0.636	XF	(0.357)	[10]	NA	ND		(0.884)	[1]	ND	X	(0.717)	[20]
Benzoic acid	ND	X	(1.3)	[10]	NA	ND		(3.22)	[1]	ND	X	(2.61)	[20]
Benzyl alcohol	ND	X	(0.628)	[10]	NA	ND		(1.55)	[1]	ND	X	(1.26)	[20]
Butylbenzylphthalate	ND	X	(0.327)	[10]	NA	ND		(0.809)	[1]	ND	X	(0.656)	[20]
Chrysene	0.397	X	(0.255)	[10]	NA	ND		(0.631)	[1]	ND	X	(0.511)	[20]
Di-n-octylphthalate	ND	X	(0.254)	[10]	NA	ND		(0.627)	[1]	ND	X	(0.509)	[20]
Dibenz(a,h)anthracene	ND	X	(0.298)	[10]	NA	ND		(0.736)	[1]	ND	X	(0.597)	[20]
Dibenzofuran	ND	X	(0.17)	[10]	NA	ND		(0.421)	[1]	ND	X	(0.342)	[20]
Dibutylphthalate	ND	X	(0.135)	[10]	NA	0.653		(0.334)	[1]	ND	X	(0.271)	[20]
Diethylphthalate	ND	X	(0.161)	[10]	NA	ND		(0.399)	[1]	ND	X	(0.323)	[20]
Dimethylphthalate	ND	X	(0.205)	[10]	NA	ND		(0.508)	[1]	ND	X	(0.412)	[20]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 TD5A KRF-TD5A-U0406 4 - 6			9 TD5A KRF-TD5A-U1416 14 - 16			9 TD5A KRF-TD5A-U2425 24 - 25			9 TD6A KRF-TD6A-U0406 4 - 6		
SW8270 - Semivolatile Organics, cont. (ug/g)												
Diphenylamine	ND X	(0.333)	[10]	NA			ND	(0.823)	[1]	ND X	(0.668)	[20]
Fluoranthene	0.312 X	(0.185)	[10]	NA			2.88	(0.458)	[1]	ND X	(0.371)	[20]
Fluorene	ND X	(0.15)	[10]	NA			0.556	(0.372)	[1]	ND X	(0.302)	[20]
Hexachlorobenzene	ND X	(0.23)	[10]	NA			ND	(0.569)	[1]	ND X	(0.461)	[20]
Hexachlorobutadiene	ND X	(0.286)	[10]	NA			ND	(0.708)	[1]	ND X	(0.574)	[20]
Hexachlorocyclopentadiene	ND X	(0.715)	[10]	NA			ND	(1.77)	[1]	ND X	(1.43)	[20]
Hexachloroethane	ND X	(0.436)	[10]	NA			ND	(1.08)	[1]	ND X	(0.874)	[20]
Indeno(1,2,3-cd)pyrene	< DL X	(0.21)	[10]	NA			ND	(0.518)	[1]	ND X	(0.42)	[20]
Isophorone	ND X	(0.132)	[10]	NA			ND	(0.325)	[1]	ND X	(0.264)	[20]
N-Nitroso-di-n-propylamine	ND X	(0.342)	[10]	NA			ND	(0.846)	[1]	ND X	(0.686)	[20]
Naphthalene	ND X	(0.291)	[10]	NA			4.7	(0.72)	[1]	ND X	(0.584)	[20]
Nitrobenzene	ND X	(0.17)	[10]	NA			ND	(0.419)	[1]	ND X	(0.34)	[20]
Pentachlorophenol	ND X	(0.0837)	[10]	NA			ND	(0.207)	[1]	ND X	(0.168)	[20]
Phenanthrene	ND X	(0.241)	[10]	NA			0.939	(0.597)	[1]	ND X	(0.484)	[20]
Phenol	ND X	(0.44)	[10]	NA			ND	(1.09)	[1]	ND X	(0.883)	[20]
Pyrene	0.325 X	(0.201)	[10]	NA			< DL	(0.498)	[1]	ND X	(0.404)	[20]
bis(2-Chloroethoxy)methane	ND X	(0.146)	[10]	NA			ND	(0.36)	[1]	ND X	(0.292)	[20]
bis(2-Chloroethyl)ether	ND X	(0.203)	[10]	NA			ND	(0.502)	[1]	ND X	(0.407)	[20]
bis(2-Chloroisopropyl)ether	ND X	(0.249)	[10]	NA			ND	(0.615)	[1]	ND X	(0.499)	[20]
bis(2-Ethylhexyl)phthalate	< DL X	(0.715)	[10]	NA			13.7	(1.77)	[1]	ND X	(1.43)	[20]
p-Chloroaniline	ND X	(0.427)	[10]	NA			ND	(1.06)	[1]	ND X	(0.857)	[20]
SW846 - Percent Moisture (percent)												
Percent moisture	23.9 ✓	(0)	[1]	20.8 ✓	(0)	[1]	9.92 ✓	(0)	[1]	24 ✓	(0)	[1]

() = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 TD6A KRF-TD6A-U1416 14 - 16			9 TD6A KRF-TD6A-U2627 25 - 26		
E418.1 - Total Recoverable Petroleum Hydrocarbons (mg/kg)						
Hydrocarbons	6120 ✓	(38.1)	[5]	2020 ✓	(7.83)	[1]
SW8240 - Volatile Organics (ug/kg)						
1,1,1-Trichloroethane	ND	(9.15)	[1]	NA		
1,1,2,2-Tetrachloroethane	ND	(24.9)	[1]	NA		
1,1,2-Trichloroethane	ND	(7.47)	[1]	NA		
1,1-Dichloroethane	ND	(8.4)	[1]	NA		
1,1-Dichloroethene	ND	(12.6)	[1]	NA		
1,2-Dichloroethane	ND	(8.52)	[1]	NA		
1,2-Dichloropropane	ND	(12.9)	[1]	NA		
2-Chloroethyl vinyl ether	ND	(14)	[1]	NA		
2-Hexanone	ND	(4.7)	[1]	NA		
4-Methyl-2-Pentanone(MIBK)	ND	(4.48)	[1]	NA		
Acetone	186✓ B	(7.36)	[1]	NA		
Benzene	ND	(8.46)	[1]	NA		
Bromodichloromethane	ND	(8)	[1]	NA		
Bromomethane	ND	(9.85)	[1]	NA		
Carbon disulfide	ND	(12.7)	[1]	NA		
Carbon tetrachloride	ND	(9.79)	[1]	NA		
Chlorobenzene	383✓	(22.8)	[1]	NA		
Chloroethane	ND	(10)	[1]	NA		
Chloroform	ND	(10.3)	[1]	NA		
Chloromethane	ND	(11.9)	[1]	NA		
Dibromochloromethane	ND	(8.98)	[1]	NA		
Ethyl benzene	< DL	(8.11)	[1]	NA		
Methyl ethyl ketone	38.7✓B	(7.47)	[1]	NA		
Methylene Chloride	< DL B	(12.8)	[1]	NA		
Styrene	ND	(7.94)	[1]	NA		

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID LOCATION ID SAMPLE ID BEG. DEPTH - END DEPTH (FT.)				
	9 TD6A KRF-TD6A-U1416 14 - 16			9 TD6A KRF-TD6A-U2627 25 - 26
PARAMETER				
SW8240 - Volatile Organics, cont. (ug/kg)				
Tetrachloroethene	ND	(23.3)	[1]	NA
Toluene	ND	(8.34)	[1]	NA
Tribromomethane(Bromoform)	ND	(7.42)	[1]	NA
Trichloroethene	ND	(23.8)	[1]	NA
Vinyl Chloride	ND	(10.1)	[1]	NA
Vinyl acetate	ND	(53.7)	[1]	NA
Xylene (total)	ND	(17.8)	[1]	NA
cis-1,3-Dichloropropene	ND	(7.88)	[1]	NA
trans-1,2-Dichloroethene	ND	(11.4)	[1]	NA
trans-1,3-Dichloropropene	ND	(8.52)	[1]	NA
SW8270 - Semivolatile Organics (ug/g)				
1,2,4-Trichlorobenzene	ND	(0.182)	[1]	NA
1,2-Dichlorobenzene	ND	(0.609)	[1]	NA
1,3-Dichlorobenzene	ND	(0.676)	[1]	NA
1,4-Dichlorobenzene	ND	(0.672)	[1]	NA
2,4,5-Trichlorophenol	ND	(0.557)	[1]	NA
2,4,6-Trichlorophenol	ND	(0.461)	[1]	NA
2,4-Dichlorophenol	ND	(0.552)	[1]	NA
2,4-Dimethylphenol	ND	(1.21)	[1]	NA
2,4-Dinitrophenol	ND	(2.46)	[1]	NA
2,4-Dinitrotoluene	ND	(0.73)	[1]	NA
2,6-Dinitrotoluene	ND	(0.997)	[1]	NA
2-Chloronaphthalene	ND	(0.854)	[1]	NA
2-Chlorophenol	ND	(0.312)	[1]	NA
2-Methylnaphthalene	ND	(0.575)	[1]	NA
2-Methylphenol	ND	(0.75)	[1]	NA
2-Nitroaniline	ND	(0.759)	[1]	NA

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 TD6A KRF-TD6A-U1416 14 - 16			9 TD6A KRF-TD6A-U2627 25 - 26
SW8270 - Semivolatile Organics, cont.	(ug/g)			
2-Nitrophenol	ND	(0.404)	[1]	NA
3,3'-Dichlorobenzidine	ND	(1.04)	[1]	NA
3-Nitroaniline	ND	(0.306)	[1]	NA
4,6-Dinitro-2-methylphenol	ND	(0.694)	[1]	NA
4-Bromophenyl phenyl ether	ND	(0.579)	[1]	NA
4-Chloro-3-methylphenol	ND	(0.435)	[1]	NA
4-Chlorophenyl phenyl ether	ND	(0.695)	[1]	NA
4-Methylphenol/3-Methylphenol	ND	(1.18)	[1]	NA
4-Nitroaniline	ND	(0.569)	[1]	NA
4-Nitrophenol	ND	(0.599)	[1]	NA
Acenaphthene	ND	(0.458)	[1]	NA
Acenaphthylene	ND	(0.625)	[1]	NA
Anthracene	ND	(0.512)	[1]	NA
Benzo(a)anthracene	ND	(0.331)	[1]	NA
Benzo(a)pyrene	ND	(0.513)	[1]	NA
Benzo(b)fluoranthene	ND	(0.911)	[1]	NA
Benzo(g,h,i)perylene	ND	(0.526)	[1]	NA
Benzo(k)fluoranthene	ND	(0.779)	[1]	NA
Benzoic acid	ND	(2.84)	[1]	NA
Benzyl alcohol	ND	(1.37)	[1]	NA
Butylbenzylphthalate	ND	(0.713)	[1]	NA
Chrysene	ND	(0.556)	[1]	NA
Di-n-octylphthalate	ND	(0.553)	[1]	NA
Dibenz(a,h)anthracene	ND	(0.649)	[1]	NA
Dibenzofuran	ND	(0.371)	[1]	NA
Dibutylphthalate	ND	(0.294)	[1]	NA
Diethylphthalate	ND	(0.351)	[1]	NA
Dimethylphthalate	ND	(0.447)	[1]	NA

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

TABLE A

RESULTS OF ORGANIC ANALYSES FOR SOIL SAMPLES, RF Heating, Kelly AFB.

SITE ID
LOCATION ID
SAMPLE ID
BEG. DEPTH - END DEPTH (FT.)

PARAMETER	9 TD6A KRF-TD6A-U1416 14 - 16			9 TD6A KRF-TD6A-U2627 25 - 26		
SW8270 - Semivolatile Organics, cont. (ug/g)						
Diphenylamine	ND	(0.726)	[1]	NA		
Fluoranthene	0.481	(0.404)	[1]	NA		
Fluorene	ND	(0.328)	[1]	NA		
Hexachlorobenzene	ND	(0.501)	[1]	NA		
Hexachlorobutadiene	ND	(0.624)	[1]	NA		
Hexachlorocyclopentadiene	ND	(1.56)	[1]	NA		
Hexachloroethane	ND	(0.95)	[1]	NA		
Indeno(1,2,3-cd)pyrene	ND	(0.457)	[1]	NA		
Isophorone	ND	(0.287)	[1]	NA		
N-Nitroso-di-n-propylamine	ND	(0.746)	[1]	NA		
Naphthalene	ND	(0.634)	[1]	NA		
Nitrobenzene	ND	(0.369)	[1]	NA		
Pentachlorophenol	ND	(0.182)	[1]	NA		
Phenanthrene	0.802	(0.526)	[1]	NA		
Phenol	ND	(0.959)	[1]	NA		
Pyrene	ND	(0.439)	[1]	NA		
bis(2-Chloroethoxy)methane	ND	(0.317)	[1]	NA		
bis(2-Chloroethyl)ether	ND	(0.443)	[1]	NA		
bis(2-Chloroisopropyl)ether	ND	(0.542)	[1]	NA		
bis(2-Ethylhexyl)phthalate	35.6	(1.56)	[1]	NA		
p-Chloroaniline	ND	(0.931)	[1]	NA		
SW846 - Percent Moisture (percent)						
Percent moisture	13.7 ✓	(0)	[1]	16.2 ✓	(0)	[1]

Compiled: 1 September 1994 () = Detection Limit [] = Dilution Factor ND = Not Detected NA = Not Applicable

APPENDIX B.6.

RCN 269-014-49-01
DCN 94-269-014-49-01

Superfund Innovative Technology Evaluation

KAI Technologies, Inc.
Radio Frequency Heating Demonstration

Final Report

Prepared for:

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September 7, 1994

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 SUMMARY INFORMATION

Radian Corporation (Radian) was contracted by Science Applications International Corporation (SAIC) to collect and analyze vapor samples as part of a Superfund Innovative Technology Evaluation (SITE) program of a radio frequency (RF) heating demonstration system. This section provides summary information about the sampling and analytical methodologies.

The technology, Radio Frequency Heating (RFH), was developed by KAI Technologies, Inc. of Woburn, Massachusetts and was being evaluated as a remediation technology coupled with traditional soil vapor extraction (SVE). The technique is designed to rapidly remove a wide range of volatile and semi-volatile organic compounds, including many polynuclear aromatic hydrocarbons (PAHs). In theory, the system will remove any organic compound with a vapor pressure of 1 mm Hg at the target temperature.

This demonstration test was conducted at a site contaminated with a variety of volatile and semi-volatile organics, including chlorinated organics and polynuclear aromatic hydrocarbon (PAH) compounds located at Kelly Air Force Base (KAFB) in San Antonio, Texas.

1.1 Project Objectives

The overall program objectives were to access the removal of these various hydrocarbon species from the soil through the use of pre- and post-testing soil sampling and analysis. The goal of the program was to demonstrate a 90% reduction in total recoverable petroleum hydrocarbons (TRPH) during the course of the treatment. The goals of the vapor sampling were to augment the soil data and help explain any anomalies that may be encountered through use of the soil data alone.

Radian's role in this evaluation was to characterize, both quantitatively and qualitatively, the compounds being removed during system operation. This was accomplished by collecting samples of the soil vapor at varying stages of the test program. Table 1-1 shows the sampling matrix for the monitoring program. In addition, prior to the start of soil heating, soil vapor samples were collected from six soil probes located in the test area. These probes were originally used to determine system vacuum, but were modified so that soil vapor samples could be collected. To collect the vapor samples, a stainless steel probe was inserted into the bottom section of each well. The well was then purged using a low flow pump and after sufficient purging, a grab sample of the vapor was extracted from each well.

Samples of soil vapor at the site were collected prior the start of RF heating. The objective of collecting these samples was to determine what compounds were present in the soils prior to heating. These data were used to help assess what volatile compounds were present in the soil gas prior to system start-up and whether new compounds were being formed due to the heating process. Soil vapor samples were only collected prior to the start of the system.

The second part of this study was to collect samples of the SVE system exhaust gases for determination of volatile organic compounds (VOCs) and semi-volatile organic compound (SVOC) speciation. The VOCs were collected in SUMMA® polished stainless steel canisters and analyzed using an adapted TO-14 method. The SVOCs were collected on XAD-2 resin and analyzed by EPA Method 8270. Details of the sampling and analytical methods used for collecting and analyzing these samples can be found in the Quality Assurance Project Plan (QAPP) titled "Superfund Innovative Technology Evaluation, KAI, Inc. Radio Frequency Heating Demonstration" dated March 30, 1994.

Table 1-1
Summary of Program Sampling Matrix

Sample Date	System Condition	Samples Collected
4/08/94	SVE system on, Heating yet to begin	Vent Exhaust (VOC-2), (SVOC-1 plus field blank), Soil Vapor Samples (6)
5/06/94	Heating system on	Vent Exhaust (VOC-2), (SVOC-1)
5/31/94	Soil temperature at approximately 100°C	Vent Exhaust (VOC-2), (SVOC-1 plus field blank)
6/07/94	Maximum soil temperature achieved, Heating system turned off	Vent Exhaust (VOC-2), (SVOC-1 plus field duplicate sample)
6/14/94	Soil cooling off	Vent Exhaust (VOC-1), (SVOC-1)
6/24/94	SVE system turned off, program complete	Vent Exhaust (VOC-2), (SVOC-1 plus field blank)

1.2 Project Organization

The individuals primarily responsible for collecting the vapor samples were the project coordinator, Mr. Eric Anderson, and Mr. Carl Galloway. Mr. Anderson has 14 years experience performing air sampling and analysis of various industrial processes including over 10 years experience working with SVE systems. Mr. Galloway, also has 14 years field experience, with a specialty in conducting a wide variety of source level measurements.

Mr. Anderson also was the prime technical reviewer for the program and performed final data review. He was assisted in the analytical tasks by Ms. Linda Bendele and Ms. Julie Peacock. They served as analytical task leaders for the VOC and SVOC analyses, respectively. They were responsible for sample tracking, review the analytical results for consistency, and adherence to analytical protocol specifications. They consulted with Mr. Anderson frequently during this project to ensure that the data were meeting the requirements of the program.

1.3 Sampling Procedures

Two types of samples from the (SVE) system off-gas were collected during this sampling program. VOCs were collected in SUMMA® polished stainless steel canisters while SVOCs were collected on XAD-2 resin. In addition VOC and SVOC sample collection, flow rate measurements were also made during each monitoring episode.

1.3.1 Volatile Organic Compound (VOC) Sampling

VOC samples were collected in SUMMA® polished stainless steel canisters using a grab sampling technique. This was an appropriate technique since the composition of SVE system off-gas remains constant over short periods and only changes slowly over time.

Vacuum for the SVE system was supplied via an air compressor and series of inductors which create a venturi effect, thus drawing vapor out of the extraction wells. The piping system used to create the venturi vacuum was referred to as the "christmas tree." Vapor samples were collected from the combined header exhaust port, at a location approximately half-way between the point where the individual well-heads were connected to the combined header line and where the header line connected to the "christmas tree." This location is assumed to have been well mixed and non-stratified.

Canister samples were collected from the combined header exhaust pipe using the canister vacuum to fill the canister. The canisters were connected directly to the exhaust header using a very short section of ⅛-inch stainless steel tubing. This acted to minimize the internal dead-volume between SVE piping and the canister.

1.3.2 Semi-Volatile Organic Compound (SVOC) Sampling

Semi-volatile organic compounds (SVOCs) were collected using a modified version of EPA Method 0010 (otherwise known as modified Method 5 or MM5). This method was developed to simultaneously collect both particulate matter and semi-volatile organic compounds. The full method consists of using a heated probe, heated filter holder, condenser system, and XAD-2 resin cartridge to collect the particulate matter and organic compounds. This method is normally used for collecting samples from industrial stacks. Since the "duct" was only two-inches in diameter and the particulate loading of the exhaust gas was negligible, Radian adapted this method for SVOC collection by eliminating the heated probe, heated filter holder, and filter. The sample line was connected directly from the header exhaust line to the sample condenser. Immediately following the condenser, the gas flowed through a XAD-2 resin cartridge which collected the SVOCs. The lines were kept short to minimize the potential for condensation to occur in the sample line prior to the condenser. The gas flow rate and total volume were controlled and measured by a sampling console, located downstream of the XAD-2 resin. The samples were collected at a flow rate near 0.5 cubic feet per minute (CFM) for a period of approximately four hours. The goal was to collect a minimum of 106 standard cubic feet (SCF) of sample.

1.3.3 Flow Rate Measurements

The flow rate through the exhaust header was monitored each sampling event using an ⅛-inch diameter standard pitot tube. The pitot tube was placed at the centroid of the 2-inch diameter pipe and the differential pressure recorded. That measurement, along with the duct static pressure, duct temperature, and cross-sectional area were used to calculate the volumetric flow rate.

1.4 Analytical Procedures

The analysis of the VOCs collected in SUMMA® polished stainless steel canisters were performed using a gas chromatograph (GC) with dual columns and multiple detectors (GC/MD). The detectors included a flame ionization detector (FID), a photoionization detector (PID), and an electrolytic conductivity detector (ELCD). Two columns were used for compound separation and quantitation. One column eluent was analyzed by the PID and FID detectors arranged in series and the eluent from the second column was analyzed by the ELCD. The PID/FID combination was used to quantitate aromatic and aliphatic hydrocarbons while the ELCD was used to quantitate most of the halogenated hydrocarbon species.

Identification of sample peaks was based on normalized retention times, detector responses, and individual responses from the daily calibration standard. The retention time of each peak on the FID was calculated relative to the retention time of toluene (RRT). The PID data were scanned for any peaks that matched the FID retention times. The corresponding PID/FID response ratio was then compared with the sample's PID/FID response for toluene to generate a toluene-normalized response (TNR) factor. Different compound classes and individual compounds produce characteristic TNRs. The

RRT and TNR data were compared to target compound database parameters for potential matches. The potential matches were then reviewed and validated by experienced personnel to ensure data quality. The quantitation of compounds was based on individual response factors where they were available and based on an average carbon-based response factor for remaining compounds.

The SVOCs were analyzed using EPA SW-846 Method 8270. This method is used to quantify neutral, acidic, and basic semivolatile organic compounds by GC/MS. SVOCs analytes were extracted from the XAD-2 resin using EPA SW-846 Method 3540 (soxhlet extraction). Extraction efficiency was determined by spiking each of the resin cartridges prior to extraction with the Method 8270 surrogates, phenol-d6, 2-fluorophenol, nitrobenzene-d5, 2-fluorobiphenyl, 2,4,6-tribromophenol, and terphenyl-d14. Extraction were performed within 14 days of sample collection.

Extracts were analyzed using Radian's Hewlett-Packard 5971 GC/MS system. Analytes were identified by comparison of both GC retention times and mass spectra to those of known standards in the calibration mixture. Quantitation was performed by ratioing the responses of the sample analytes to those of the internal standards which are added before GC/MS analysis. Response factors determined from the initial calibration were used to correct for the different detector responses obtained from different analytes.

2.0 SAMPLE IDENTIFICATION

All samples were given a unique sample identification number, which identified sample media type, date the sample was collected, and the sample type (i.e., regular, blank, collocated). This information helped facilitate data manipulation.

Each sample number had five distinct parts. The first two letters designate the monitoring program, the second part designates the sample type: 01 indicates a VOC sample while 02 indicates a SVOC sample. The next six numbers are the date the sample was collected (MMDDYY) while the next letter indicates the sample type: R for Regular, D for Collocated, or B for Blank. The last three digits were a sequential sample number for the program. The sample log for this program is shown in Table 2-1.

Table 2-1
KAI Sample Log

Date	Sample ID	Sample Type	Sample Description
4/08/94	SC-01-040894-R-001	VOC	Well TD-1 (Deep Well)
4/08/94	SC-01-040894-R-002	VOC	Well TD-2 (Shallow Well)
4/08/94	SC-01-040894-R-003	VOC	Well TD-7 (Deep Well)
4/08/94	SC-01-040894-R-004	VOC	Well TD-3 (Shallow Well)
4/08/94	SC-01-040894-R-005	VOC	Well TD-8 (Shallow Well)
4/08/94	SC-01-040894-R-006	VOC	Well TD-6 (Shallow Well)
4/08/94	SC-01-040894-R-007	VOC	Combined Exhaust
4/08/94	SC-01-040894-D-008	VOC Dup	Combined Exhaust
4/08/94	SC-02-040894-R-009	SVOC	Combined Exhaust
4/08/94	SC-02-040894-B-010	SVOC Blank	Blank
5/06/94	SC-02-050694-R-011	SVOC	Combined Exhaust
5/06/94	SC-01-050694-R-012	VOC	Combined Exhaust
5/06/94	SC-01-050694-D-013	VOC Dup	Combined Exhaust
5/31/94	SC-01-053194-R-014	VOC	Combined Exhaust
5/31/94	SC-01-053194-D-015	VOC Dup	Combined Exhaust
5/31/94	SC-02-053194-R-016	SVOC	Combined Exhaust
5/31/94	SC-02-053194-B-017	SVOC Blank	Blank
6/07/94	SC-01-060794-R-018	VOC	Combined Exhaust
6/07/94	SC-01-060794-D-019	VOC Dup	Combined Exhaust
6/07/94	SC-02-060794-R-020	SVOC	Combined Exhaust
6/07/94	SC-02-060794-D-021	SVOC Dup	Combined Exhaust
6/14/94	SC-01-061494-R-022	VOC	Combined Exhaust
6/14/94	SC-02-061494-R-023	SVOC	Combined Exhaust
6/14/94	SC-02-061494-B-024	SVOC Blank	Blank
6/24/94	SC-02-062494-R-025	SVOC	Combined Exhaust
6/24/94	SC-01-062494-R-026	VOC	Combined Exhaust
6/24/94	SC-01-062494-D-027	VOC Dup	Combined Exhaust

3.0 SAMPLE HOLDING TIMES

The project specified sample hold times were 30 days for the VOC samples and 14 days to extraction and 40 days from extraction to analysis for SVOC samples. Table 3-1 lists the collection and analysis dates for the VOC analysis and Table 3-2 lists the collection, extraction, and analysis dates for the SVOC samples. None of the samples collected during this program were analyzed outside of project specified sample hold times.

The VOC samples are subject to an internal laboratory-imposed 14-day hold time as well as the project specific hold time of 30 days. The 14-day hold time was established to facilitate flow of samples through the laboratory and ensure that sufficient resources (i.e., canisters) are available to meet project needs. This 14-day hold time is "hard-wired" into the laboratory protocols so that if any portion of the analysis goes beyond this 14-day period, the samples will be flagged with the footnote "d", which implies that the "sample was analyzed outside of the recommended laboratory internal hold-time of 14 days." Calculation of the recommended acceptable hold-time is based on the sampling date recorded on the canister's chain of custody. This flag is part of the laboratory documentation and does not affect the validity of the sample data. Based on studies, both by Radian and other researchers, most volatile compounds, particularly aliphatic, aromatic, and halogenated species, exhibit sample stability up to 30 days (few studies have gone beyond 30 days). The only potential exception to the 30 day stability period are some of the oxygenated compounds such as the aldehydes, ketones, and ethers. Their stabilities are not well documented.

Table 3-1
Summary of VOC Analysis Dates

Sample ID	Date Collected	FID Analysis Date	ELCD Analysis Date
SC-01-040894-R-001	4/08/94	4/15/94	4/26/94
SC-01-040894-R-002	4/08/94	4/15/94	4/25/94
SC-01-040894-R-003	4/08/94	4/15/94	4/26/94
SC-01-040894-R-004	4/08/94	4/15/94	4/26/94
SC-01-040894-R-005	4/08/94	4/15/94	4/26/94
SC-01-040894-R-006	4/08/94	4/15/94	4/26/94
SC-01-040894-R-007	4/08/94	4/18/94	4/25/94
SC-01-040894-D-008	4/08/94	4/18/94	4/27/94
SC-01-050694-R-012	5/06/94	5/18/94	5/19/94
SC-01-050694-D-013	5/06/94	5/18/94	5/19/94
SC-01-053194-R-014	5/31/94	6/09/94	6/22/94
SC-01-053194-D-015	5/31/94	6/09/94	6/22/94
SC-01-060794-R-018	6/07/94	6/10/94	6/21/94
SC-01-060794-D-019	6/07/94	6/10/94	6/22/94
SC-01-061494-R-022	6/14/94	6/17/94	6/22/94
SC-01-062494-R-026	6/24/94	7/06/94	7/06/94
SC-01-062494-D-027	6/24/94	7/01/94	7/06/94

FID Analysis Date is the date FID and PID analytical runs were completed.
ELCD Analysis Date is the date the ELCD analytical run was completed.

Table 3-2
Summary of SVOC Analysis Dates

Sample ID	Date Collected	Date Extracted	Date Analyzed
SC-02-040894-R-009	4/08/94	4/14/94	4/21/94
SC-02-040894-B-010	4/08/94	4/14/94	4/21/94
SC-02-050694-R-011	5/06/94	5/12/94	5/16/94
SC-02-053194-R-016	5/31/94	6/07/94	6/13/94
SC-02-053194-B-017	5/31/94	6/07/94	6/13/94
SC-02-060794-R-020	6/07/94	6/13/94	6/26/94
SC-02-060794-D-021	6/07/94	6/13/94	6/26/94
SC-02-061494-R-023	6/14/94	6/17/94	6/26/94
SC-02-061494-B-024	6/14/94	6/17/94	6/26/94
SC-02-062494-R-025	6/24/94	6/28/94	7/07/94

4.0 QUALITY ASSURANCE DISCUSSION

The quality control (QC) activities associated with this monitoring effort are presented in this section. Specific QC activities included the collection of duplicate field samples, the duplicate analysis of selected field samples, collection of field blanks (SVOC only), and use of sampling and analytical surrogate compounds (SVOC only). Additional QC activities were associated with the sample analysis, such as system blanks, continuing calibrations, laboratory control samples (LCS), and canister blanking. The exact QC procedures employed during this monitoring program, along with their performance frequency, were presented in the project specific QAPP. Unless otherwise specified, all of the laboratory QC checks meet project specific objectives outlined in the QAPP.

4.1 VOC Quality Control Procedures

The main QC procedures associated with VOC monitoring, were the collection and analysis of duplicate canister samples. Duplicate VOC samples were collected during five of the six sampling periods. The decision was made to not collect canister field blanks due to the high VOC concentrations in the samples and the fact that these were grab samples. With grab samples, there is minimal chance to potentially contaminate the sample media prior to collection and even if a small amount of ambient air were introduced into the canister, the effect on the analysis would have been negligible. Of the five duplicate samples collected, one pair was analyzed using a "nested" design, that is each sample was analyzed in duplicate, while the other four pairs only had a single sample analyzed in duplicate. The results of these duplicate analyses are shown in Tables 4-1 (analytical variability) and 4-2 (sampling variability). Table 4-3 presents a summary of the sampling and analytical variabilities by individual analyte.

Table 4-1
Summary of VOC Analytical Variability Estimates

	4/08/94			4/08/94			5/31/94			6/7/94			6/24/94			Pooled
Compound	1A	1B	CV (%)	2A	2B	CV (%)	2A	2B	CV (%)	2A	2B	CV (%)	2A	2B	CV (%)	CV (%)
Ethane	98,700	238,000	41.4	204,000	166,000	10.3	33,700	20,600	24.1	21,600	26,100	9.4	97,700	106,000	4.1	22.4
Propane	ND	ND	NA	ND	ND	NA	1,310	1,210	4.0	278	ND	NA	ND	ND	NA	4.0
Chloromethane	ND	ND	NA	ND	ND	NA	62.2	60.7	1.2	ND	ND	NA	ND	ND	NA	1.2
Dichlorodifluoromethane	ND	ND	NA	ND	ND	NA	ND	ND	NA	ND	ND	NA	ND	ND	NA	NA
Isobutane	ND	ND	NA	ND	ND	NA	ND	ND	NA	ND	ND	NA	303	287	2.7	2.7
Vinyl Chloride	34.5	30.1	6.8	29.7	36.4	10.1	10.9	9	9.5	1.4	ND	NA	ND	8	NA	8.9
Isobutene + 1-Butene	ND	ND	NA	ND	ND	NA	ND	ND	NA	ND	151	NA	127	116	4.5	4.5
n-Butane	353	298	8.4	305	314	1.5	174	270	21.6	216	ND	NA	918	886	1.8	11.7
Isopentane	5,660	5,840	1.6	4,680	5,050	3.8	1,810	1,760	1.4	2,140	2,140	0.0	20,500	20,200	0.7	2.0
Trichlorofluoromethane	ND	ND	NA	ND	ND	NA	1.5	2.7	28.6	1.3	3.3	43.5	ND	ND	NA	36.8
n-Pentane	2,240	2,310	1.5	1,840	1,960	3.2	643	628	1.2	740	728	0.8	7,380	7,290	0.6	1.7
1,1-Dichloroethylene	24.7	39	22.4	65.1	130	33.3	2.8	3.7	13.8	ND	ND	NA	27.8	38	15.5	20.2
Methylene Chloride	ND	ND	NA	ND	ND	NA	7.2	8.8	10.0	71.4	76.4	3.4	ND	ND	NA	7.5
2-Methyl-2-butene	ND	ND	NA	ND	ND	NA	ND	ND	NA	ND	ND	NA	ND	ND	NA	NA
Neohexane	1,170	1,210	1.7	984	1,070	4.2	381	368	1.7	450	448	0.2	4,220	4,140	1.0	2.2
Cyclopentane	516	544	2.6	440	467	3.0	122	118	1.7	145	142	1.0	1,380	1,380	0.0	2.0
2,3-Dimethylbutane	2,610	2,700	1.7	2,180	2,300	2.7	656	624	2.5	773	787	0.9	5,740	5,640	0.9	1.9
MTBE, Isohexane, c-4-M-2-Pentene	3,360	3,460	1.5	2,800	3,010	3.6	740	712	1.9	861	861	0.0	7,150	7,040	0.8	2.0
3-Methylpentane	4,670	4,800	1.4	3,850	4,160	3.9	1,160	1,120	1.8	1,370	1,370	0.0	12,600	12,400	0.8	2.0
c-1,2-Dichloroethylene	133	128	1.9	204	185	4.9	74.2	75.7	1.0	9.7	9.6	0.5	81.6	83.3	1.0	2.4
n-Hexane	1,750	1,800	1.4	1,450	1,540	3.0	393	377	2.1	415	415	0.0	1,510	1,480	1.0	1.8
Chloroform	ND	ND	NA	ND	ND	NA	1.5	2	14.3	ND	ND	NA	ND	ND	NA	14.3
Methylcyclopentane	2,600	2,690	1.7	2,150	2,310	3.6	545	569	2.2	700	714	1.0	4,120	4,290	2.0	2.3
2,4-Dimethylpentane	2,740	2,820	1.4	2,270	2,450	3.8	666	657	0.7	817	818	0.1	3,680	3,720	0.8	1.9
1,1,1-Trichloroethane	ND	ND	NA	ND	ND	NA	3.1	3.9	11.4	1.6	2.3	17.9	27.1	24.7	4.6	12.6
Benzene	3,900	3,980	1.0	3,170	3,330	2.5	1,450	1,410	1.4	1,730	1,730	0.0	6,320	6,200	1.0	1.4

Table 4-1, (Continued)

Compound	4/08/94			4/08/94			5/31/94			6/7/94			6/24/94			Pooled
	1A	1B	CV (%)	2A	2B	CV (%)	2A	2B	CV (%)	2A	2B	CV (%)	2A	2B	CV (%)	CV (%)
1-Butanol + Cyclohexane	4,040	4,140	1.2	3,310	3,610	4.3	980	967	0.7	1,200	1,210	0.4	6,990	6,890	0.7	2.1
Isoheptane + 2,3-Dimethylpentane	5,450	5,610	1.4	4,500	4,890	4.2	1,390	1,360	1.1	1,720	1,710	0.3	6,790	6,690	0.7	2.1
3-Methylhexane	2,520	2,580	1.2	2,050	2,240	4.4	615	601	1.2	747	742	0.3	2,790	2,770	0.4	2.1
Trichloroethylene + BromoDCmethane	15	13.5	5.3	13.7	14.8	3.9	24.3	23.2	2.3	3.9	4	1.3	26.7	26.8	0.2	3.1
1,4-Dioxane + 2,2,4-Trimethylpentane	16,800	17,400	1.8	13,800	15,000	4.2	5,290	5,230	0.6	6,550	6,540	0.1	18,000	17,900	0.3	2.0
n-Heptane	873	885	0.7	707	778	4.8	302	323	3.4	365	338	3.8	ND	508		3.5
Methlycyclohexane	7,080	7,290	1.5	5,820	6,300	4.0	1,980	1,930	1.3	2,530	2,520	0.2	11,000	10,800	0.9	2.0
Methylisobutylketone	847	868	1.2	693	773	5.5	250	256	1.2	320	323	0.5	1,320	1,320	0.0	2.6
2,5-Dimethylhexane	1,900	1,960	1.6	1,560	1,700	4.3	584	566	1.6	725	707	1.3	2,400	2,260	3.0	2.6
2,2,3-Trimethylpentane	2,470	2,560	1.8	2,040	2,190	3.5	808	796	0.7	1,010	1,010	0.0	3,050	3,080	0.5	1.8
2,3,4-Trimethylpentane	4,000	4,130	1.6	3,290	3,570	4.1	1,640	1,600	1.2	2,040	2,040	0.0	4,830	4,740	0.9	2.1
Toluene	5,730	5,910	1.5	4,700	4,910	2.2	2,690	2,630	1.1	3,160	3,150	0.2	7,250	7,120	0.9	1.4
3-Methylheptane	1,100	1,140	1.8	895	968	3.9	387	379	1.0	489	493	0.4	1,260	1,220	1.6	2.1
Hexanal	3,290	3,430	2.1	2,730	2,950	3.9	1,200	1,170	1.3	1,490	1,480	0.3	5,800	5,700	0.9	2.1
2,2,5-Trimethylhexane	ND	ND	NA	1,980	2,130	3.6	1,040	1,000	2.0	1,270	1,280	0.4	3,290	3,230	0.9	2.1
1-Octene	171	134	12.1	113	148	13.4	ND	ND	NA	68.9	59.7	7.2	173	163	3.0	9.8
n-Octane	1,110	1,130	0.9	900	975	4.0	577	559	1.6	654	653	0.1	1,820	1,780	1.1	2.0
Tetrachloroethylene	8	8.2	1.2	11.9	11.9	0.0	20.8	20.3	1.2	3.4	3.1	4.6	49.9	50.9	1.0	2.2
Chlorobenzene	20,500	21,200	1.7	16,800	18,400	4.5	12,800	12,500	1.2	17,400	17,300	0.3	34,400	33,700	1.0	2.3
Ethylbenzene	444	477	3.6	368	434	8.2	351	189	30.0	266	277	2.0	798	801	0.2	14.0
p-Xylene + m-Xylene	701	517	15.1	409	467	6.6	406	398	1.0	434	443	1.0	583	626	3.6	7.6
Styrene	613	413	19.5	326	364	5.5	ND	ND	NA	ND	ND	NA	742	756	0.9	11.7
Heptanal	ND	ND	NA	ND	ND	NA	259	234	5.1	54.2	55.4	1.1	186	204	4.6	4.0
o-Xylene	198	138	17.9	105	115	4.5	44.1	37.3	8.4	102	106	1.9	ND	ND	NA	10.2
n-Nonane	ND	ND	NA	ND	ND	NA	260	256	0.8	300	304	0.7	71.8	79.7	5.2	3.1
Isopropylbenzene	175	206	8.1	162	137	8.4	106	105	0.5	106	119	5.8	344	352	1.1	5.8

Table 4-1, (Continued)

Compound	4/08/94			4/08/94			5/31/94			6/7/94			6/24/94			Pooled
	1A	1B	CV (%)	2A	2B	CV (%)	2A	2B	CV (%)	2A	2B	CV (%)	2A	2B	CV (%)	CV (%)
a-Pinene + Benzaldehyde	771	880	6.6	702	746	3.0	425	398	3.3	465	385	9.4	1,430	1,390	1.4	5.6
n-Propylbenzene	302	501	24.8	226	432	31.3	ND	ND	NA	78.2	99.6	12.0	1,310	1,270	1.6	18.7
m-Ethyltoluene	ND	88	NA	ND	120	NA	150	141	3.1	129	169	13.4	214	218	0.9	8.0
p-Ethyltoluene	428	489	6.7	392	89.3	62.9	313	302	1.8	332	366	4.9	933	901	1.7	28.4
1,3,5-Trimethylbenzene	106	150	17.2	119	440	57.4	95.7	92.9	1.5	295	299	0.7	379	188	33.7	30.8
o-Ethyltoluene	ND	83.4	NA	ND	ND	NA	190	182	2.2	193	254	13.6	83.1	155	30.2	19.2
b-Pinene	ND	ND	NA	ND	ND	NA	ND	ND	NA	171	258	20.3	710	683	1.9	14.4
1,2,4-Trimethylbenzene	283	233	9.7	186	271	18.6	295	293	0.3	333	375	5.9	480	454	2.8	9.8
Benzyl Chloride + m-Dichlorobenzene	464	221	35.5	200	491	42.1	468	458	1.1	534	563	2.6	1,030	932	5.0	24.8
n-Decane + p-Dichlorobenzene	470	361	13.1	179	408	39.0	1,510	1,460	1.7	2,030	2,060	0.7	1,270	1,250	0.8	18.4
1,2,3-Trimethylbenzene	ND	ND	NA	ND	ND	NA	228	222	1.3	266	269	0.6	760	707	3.6	2.2
o-Dichlorobenzene	2,040	1,240	24.4	976	825	8.4	5,390	5,120	2.6	6,660	6,580	0.6	3,740	3,590	2.0	11.6
Limonene	ND	ND	NA	ND	ND	NA	ND	ND	NA	ND	ND	NA	278	244	6.5	6.5
Indene	ND	ND	NA	ND	ND	NA	322	309	2.1	ND	ND	NA	ND	ND	NA	2.1
m-Diethylbenzene	188	216	6.9	160	73	37.3	122	118	1.7	355	356	0.1	410	378	4.1	17.1
n-Butylbenzene	334	336	0.3	265	119	38.0	129	124	2.0	146	147	0.3	486	446	4.3	17.1
p-Diethylbenzene	225	247	4.7	200	254	11.9	50.6	50.3	0.3	159	159	0.0	487	436	5.5	6.2
n-Undecane	125	ND	NA	ND	75.7	NA	274	245	5.6	350	360	1.4	488	243	33.5	19.6

ND = Not detected.
NA = Not calculated or calculation meaning less.

Table 4-2
Summary of VOC Sampling Variability

Compound	4/08/94			5/06/94			5/31/94			6/7/94			6/24/94			Pooled CV (%)
	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	
Ethane	98,700	204,000	34.8	114,000	120,000	2.6	16,300	33,700	34.8	31,300	21,600	18.3	122,000	97,700	11.1	24.0
Propane	ND	ND	NA	ND	ND	NA	609	1,310	36.5	ND	278	NA	ND	ND	NA	25.8
Chloromethane	ND	ND	NA	88.7	95.8	3.8	60.3	62.2	1.6	ND	ND	NA	ND	ND	NA	2.9
Dichlorodifluoromethane	ND	ND	NA	ND	ND	NA	ND	ND	NA	ND	ND	NA	16.3	ND	NA	NA
Isobutane	ND	ND	NA	212	251	8.4	ND	ND	NA	ND	ND	NA	340	303	5.8	7.2
Vinyl Chloride	34.5	29.7	7.5	14	13.7	1.1	10.8	10.9	0.5	10.5	1.4	76.5	10.1	ND	NA	38.4
Isobutene + 1-Butene	ND	ND	NA	360	277	13.0	ND	ND	NA	ND	ND	NA	158	127	10.9	12.0
n-Butane	353	305	7.3	623	606	1.4	307	174	27.7	ND	216	NA	1,160	918	11.6	13.8
Isopentane	5,660	4,680	9.5	8,810	9,010	1.1	1,820	1,810	0.3	2,330	2,140	4.3	24,100	20,500	8.1	5.9
Acetone	ND	ND	NA	914	944	1.6	ND	ND	NA	ND	ND	NA	ND	ND	NA	1.6
Trichlorofluoromethane	ND	ND	NA	ND	ND	NA	3.5	1.5	40.0	230	1.3	98.9	94.8	ND	NA	75.4
n-Pentane	2,240	1,840	9.8	2,980	3,090	1.8	715	643	5.3	785	740	3.0	8,690	7,380	8.2	6.4
1,1-Dichloroethylene	24.7	65.1	45.0	48.7	58.8	9.4	2.2	2.8	12.0	ND	ND	NA	35.2	27.8	11.7	24.5
Methylene Chloride	ND	ND	NA	ND	ND	NA	3.5	7.2	34.6	14,000	71.4	99.0	81.1	ND	NA	74.1
Neohexane	1,170	984	8.6	1,930	1,990	1.5	388	381	0.9	466	450	1.7	4,930	4,220	7.8	5.3
Cyclopentane	516	440	7.9	552	575	2.0	124	122	0.8	155	145	3.3	1,640	1,380	8.6	5.5
2,3-Dimethylbutane	2,610	2,180	9.0	2,530	2,620	1.7	643	656	1.0	837	773	4.0	6,770	5,740	8.2	5.8
MTBE, Isohexane, c-4-M-2-Pentene	3,360	2,800	9.1	2,600	2,720	2.3	719	740	1.4	898	861	2.1	8,460	7,150	8.4	5.7
3-Methylpentane	4,670	3,850	9.6	4,890	5,120	2.3	1,150	1,160	0.4	1,460	1,370	3.2	14,800	12,600	8.0	5.9

Table 4-2, (Continued)

Compound	4/08/94			5/06/94			5/31/94			6/7/94			6/24/94			Pooled CV (%)
	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	
c-1,2-Dichloroethylene	133	204	21.1	33.1	35.9	4.1	78.7	74.2	2.9	100	9.7	82.3	103	81.6	11.6	38.4
n-Hexane	1,750	1,450	9.4	1,020	933	4.5	412	393	2.4	446	415	3.6	1,800	1,510	8.8	6.4
Chloroform	ND	ND	NA	ND	ND	NA	1.6	1.5	3.2	ND	ND	NA	ND	ND	NA	3.2
Methylcyclopentane	2,600	2,150	9.5	1,580	1,630	1.6	561	545	1.4	703	700	0.2	4,960	4,120	9.3	6.0
2,4-Dimethylpentane	2,740	2,270	9.4	1,780	1,860	2.2	668	666	0.1	862	817	2.7	4,350	3,680	8.3	5.8
1,1,1-Trichloroethane	ND	ND	NA	62.9	78.6	11.1	5.3	3.1	26.2	21.4	1.6	86.1	70.6	27.1	44.5	50.5
Benzene	3,900	3,170	10.3	1,480	1,540	2.0	1,420	1,450	1.0	1,840	1,730	3.1	6,980	6,320	5.0	5.4
1-Butanol + Cyclohexane	4,040	3,310	9.9	2,850	2,950	1.7	994	980	0.7	1,270	1,200	2.8	8,270	6,990	8.4	6.0
Isoheptane + 2,3-Dimethylpentane	5,450	4,500	9.5	3,250	3,380	2.0	1,400	1,390	0.4	1,820	1,720	2.8	8,060	6,790	8.6	5.9
3-Methylhexane	2,520	2,050	10.3	1,230	1,270	1.6	614	615	0.1	790	747	2.8	3,310	2,790	8.5	6.1
Trichloroethylene + BromoDCmethane	15.0	13.7	4.5	8.0	6.9	7.4	25.7	24.3	2.8	37.1	3.9	81.0	34.0	26.7	12.0	36.8
1,4-Dioxane + 2,2,4-Trimethylpentane	16,800	13,800	9.8	10,300	10,700	1.9	5,300	5,290	0.1	6,930	6,550	2.8	21,600	18,000	9.1	6.2
n-Heptane	873	707	10.5	215	225	2.3	326	302	3.8	388	365	3.1	635	ND	NA	5.9
Methlycyclohexane	7,080	5,820	9.8	3,660	3,820	2.1	1,980	1,980	0.0	2,690	2,530	3.1	13,000	11,000	8.3	6.0
Methylisobutylketone	847	693	10.0	759	800	2.6	246	250	0.8	335	320	2.3	1,620	1,320	10.2	6.6
2,5-Dimethylhexane	1,900	1,560	9.8	866	901	2.0	577	584	0.6	764	725	2.6	2,810	2,400	7.9	5.8
2,2,3-Trimethylpentane	2,470	2,040	9.5	1,410	1,470	2.1	803	808	0.3	1,050	1,010	1.9	3,670	3,050	9.2	6.1
2,3,4-Trimethylpentane	4,000	3,290	9.7	2,480	2,590	2.2	1,640	1,640	0.0	2,160	2,040	2.9	5,730	4,830	8.5	6.0

Table 4-2, (Continued)

Compound	4/08/94			5/06/94			5/31/94			6/7/94			6/24/94			Pooled CV (%)
	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	
Toluene	5,730	4,700	9.9	3,720	3,880	2.1	2,690	2,690	0.0	3,350	3,160	2.9	8,930	7,250	10.4	6.6
3-Methylheptane	1,100	895	10.3	458	480	2.3	387	387	0.0	520	489	3.1	1,460	1,260	7.4	5.9
Hexanal	3,290	2,730	9.3	2,030	2,120	2.2	1,190	1,200	0.4	1,580	1,490	2.9	6,870	5,800	8.4	5.9
2,2,5-Trimethylhexane	ND	1,980	NA	1,420	1,490	2.4	1,030	1,040	0.5	1,350	1,270	3.1	3,910	3,290	8.6	4.7
1-Octene	171	113	20.4	65.5	66.7	0.9	ND	ND	NA	73.6	68.9	3.3	190	173	4.7	10.6
n-Octane	1,110	900	10.4	702	732	2.1	576	577	0.1	219	654	49.8	2,120	1,820	7.6	23.0
Tetrachloroethylene	8.0	11.9	19.6	14.3	14.1	0.7	21.6	20.8	1.9	35.7	3.4	82.6	62.3	49.9	11.1	38.3
Chlorobenzene	20,500	16,800	9.9	7,110	7,410	2.1	12,700	12,800	0.4	18,600	17,400	3.3	40,400	34,400	8.0	6.0
Ethylbenzene	444	368	9.4	328	307	3.3	199	351	27.6	291	266	4.5	990	798	10.7	14.1
p-Xylene + m-Xylene	701	409	26.3	211	331	22.1	401	406	0.6	475	434	4.5	752	583	12.7	16.5
Styrene	613	326	30.6	183	234	12.2	ND	ND	NA	ND	ND	NA	974	742	13.5	20.5
Heptanal	ND	ND	NA	ND	ND	NA	259	259	0.0	60.9	54.2	5.8	254	186	15.5	9.5
o-Xylene	198	105	30.7	ND	101	NA	38.6	44.1	6.7	114	102	5.6	ND	ND	NA	18.4
n-Nonane	ND	ND	NA	93.9	53.8	27.1	260	260	0.0	326	300	4.2	103	71.8	17.8	16.4
Isopropylbenzene	175	162	3.9	98.3	94.2	2.1	107	106	0.5	128	106	9.4	438	344	12.0	7.1
a-Pinene + Benzaldehyde	771	702	4.7	256	247	1.8	423	425	0.2	550	465	8.4	1,710	1,430	8.9	5.9
n-Propylbenzene	302	226	14.4	102	ND	NA	ND	ND	NA	108	78.2	16.0	1,680	1,310	12.4	14.3
m-Ethyltoluene	ND	ND	NA	101	102	0.5	145	150	1.7	182	129	17.0	271	214	11.8	10.4
p-Ethyltoluene	428	392	4.4	191	201	2.6	308	313	0.8	393	332	8.4	1290	933	16.1	8.4
1,3,5-Trimethylbenzene	106	119	5.8	149	147	0.7	92.9	95.7	1.5	321	295	4.2	226	379	25.3	11.8

Table 4-2, (Continued)

Compound	4/08/94			5/06/94			5/31/94			6/7/94			6/24/94			Pooled CV (%)
	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	1A	2A	CV (%)	
o-Ethyltoluene	ND	ND	NA	98.2	100	0.9	187	190	0.8	272	193	17.0	102	83.1	10.2	9.9
b-Pinene	ND	ND	NA	173	173	0.0	ND	ND	NA	273	171	23.0	873	710	10.3	14.5
1,2,4-Trimethylbenzene	283	186	20.7	185	195	2.6	290	295	0.9	403	333	9.5	588	480	10.1	11.2
Benzyl Chloride + m-Dichlorobenzene	464	200	39.8	414	444	3.5	450	468	2.0	618	534	7.3	854	1,030	9.3	18.6
Isobutylbenzene	ND	ND	NA	66.1	66.6	0.4	ND	ND	NA	ND	ND	NA	ND	ND	NA	0.4
n-Decane + p-Dichlorobenzene	470	179	44.8	765	798	2.1	1,470	1,510	1.3	2,250	2,030	5.1	1,640	1,270	12.7	21.0
1,2,3-Trimethylbenzene	ND	ND	NA	ND	72	NA	225	228	0.7	293	266	4.8	929	760	10.0	5.6
o-Dichlorobenzene	2,040	976	35.3	2,730	3,030	5.2	5,160	5,390	2.2	7,280	6,660	4.4	5,010	3,740	14.5	17.4
Limonene	ND	ND	NA	ND	48.9	NA	ND	ND	NA	ND	ND	NA	339	278	9.9	9.9
Indene	ND	ND	NA	ND	104	NA	135	322	40.9	ND	ND	NA	ND	ND	NA	40.9
m-Diethylbenzene	188	160	8.0	106	153	18.1	126	122	1.6	263	355	14.9	501	410	10.0	12.0
n-Butylbenzene	334	265	11.5	55.2	65.9	8.8	134	129	1.9	263	146	28.6	589	486	9.6	15.0
p-Diethylbenzene	225	200	5.9	74.4	91.5	10.3	66.7	50.6	13.7	193	159	9.7	594	487	9.9	10.2
n-Undecane	125	ND	NA	145	123	8.2	371	274	15.0	493	350	17.0	474	488	1.5	12.1

Table 4-3
Summary of Sampling and Analytical Pooled CVs

Compound	Mean Sample Concentration (ppbv)	Pooled Analytical CV (%)	Pooled Sampling CV (%)	Meets Objectives (Y/N)
Ethane	88,900	22.4	24.0	N
Propane	852	4.0	25.8	Y
Chloromethane	73.5	1.2	2.9	Y
Dichlorodifluoromethane	16.3	NC	NC	NA
Isobutane	279	2.7	7.2	Y
Vinyl Chloride	16.9	8.9	38.4	Y
Isobutene + 1-Butene	198	4.5	12.0	Y
n-Butane	495	11.7	13.8	Y
Isopentane	7,270	2.0	5.9	Y
Acetone	929	NC	1.6	NA
Trichlorofluoromethane	42.5	36.8	75.4	N
n-Pentane	2,640	1.7	6.4	Y
1,1-Dichloroethylene	39.7	20.2	24.5	Y
Methylene Chloride	1,780	7.5	74.1	Y
2-Methyl-2-butene	93.5	NC	NC	NA
Neohexane	1,520	2.2	5.3	Y
1,1-Dichloroethane	6.6	NC	NC	NA
Cyclopentane	521	2.0	5.5	Y
2,3-Dimethylbutane	2,350	1.9	5.8	Y
MTBE, Isohexane, c-4-M-2-Pentene	2,850	2.0	5.7	Y
3-Methylpentane	4,700	2.0	5.9	Y
c-1,2-Dichloroethylene	83.9	2.4	38.4	Y
n-Hexane	990	1.8	6.4	Y
Chloroform	1.7	14.3	3.2	Y

Table 4-3, (Continued)

Compound	Mean Sample Concentration (ppbv)	Pooled Analytical CV (%)	Pooled Sampling CV (%)	Meets Objectives (Y/N)
Ethane	88,900	22.4	24.0	N
Methylcyclopentane	1,890	2.3	6.0	Y
2,4-Dimethylpentane	1,890	1.9	5.8	Y
1,1,1-Trichloroethane	27.4	12.6	50.5	Y
Benzene	2,920	1.4	5.4	Y
1-Butanol + Cyclohexane	3,120	2.1	6.0	Y
Isoheptane + 2,3-Dimethylpentane	3,650	2.1	5.9	Y
3-Methylhexane	1,560	2.1	6.1	Y
Trichloroethylene + BromoDCmethane	17.6	3.1	36.8	Y
1,4-Dioxane + 2,2,4-Trimethylpentane	11,200	2.0	6.2	Y
n-Heptane	461	3.5	5.9	Y
Methlycyclohexane	5,180	2.0	6.0	Y
Methylisobutylketone	675	2.6	6.6	Y
2,5-Dimethylhexane	1,280	2.6	5.8	Y
2,2,3-Trimethylpentane	1,720	1.8	6.1	Y
2,3,4-Trimethylpentane	2,930	2.1	6.0	Y
Toluene	4,400	1.4	6.6	Y
3-Methylheptane	732	2.1	5.9	Y
Hexanal	2,710	2.1	5.9	Y
2,2,5-Trimethylhexane	1,760	2.1	4.7	Y
1-Octene	119	9.8	10.6	Y
n-Octane	914	2.0	23.0	Y
Tetrachloroethylene	21.2	2.2	38.3	Y
Chlorobenzene	18,400	2.3	6.0	Y

Table 4-3, (Continued)

Compound	Mean Sample Concentration (ppbv)	Pooled Analytical CV (%)	Pooled Sampling CV (%)	Meets Objectives (Y/N)
Ethane	88,900	22.4	24.0	N
Ethylbenzene	410	14.0	14.1	Y
p-Xylene + m-Xylene	451	7.6	16.5	Y
Styrene	512	11.7	20.5	Y
Heptanal	174	4.0	9.5	Y
o-Xylene	99.9	10.2	18.4	Y
n-Nonane	179	3.1	16.4	Y
Isopropylbenzene	169	5.8	7.1	Y
a-Pinene + Benzaldehyde	679	5.6	5.9	Y
n-Propylbenzene	555	18.7	14.3	Y
m-Ethyltoluene	156	8.0	10.4	Y
p-Ethyltoluene	436	28.4	8.4	Y
1,3,5-Trimethylbenzene	196	30.8	11.8	N
o-Ethyltoluene	158	19.2	9.9	Y
b-Pinene	370	14.4	14.5	Y
1,2,4-Trimethylbenzene	307	9.8	11.2	Y
Benzyl Chloride + m-Dichlorobenzene	514	24.8	18.6	Y
Isobutylbenzene	66.4	NC	0.4	NA
n-Decane + p-Dichlorobenzene	1,130	18.4	21.0	Y
1,2,3-Trimethylbenzene	364	2.2	5.6	Y
o-Dichlorobenzene	3,770	11.6	17.4	Y
Limonene	228	6.5	9.9	Y
Indene	218	2.1	40.9	Y
m-Diethylbenzene	235	17.1	12.0	Y
n-Butylbenzene	243	17.1	15.0	Y

Table 4-3, (Continued)

Compound	Mean Sample Concentration (ppbv)	Pooled Analytical CV (%)	Pooled Sampling CV (%)	Meets Objectives (Y/N)
Ethane	88,900	22.4	24.0	N
p-Diethylbenzene	219	6.2	10.2	Y
n-Undecane	273	19.6	12.1	Y

NC = Not calculated or calculation not meaningful.

VOC Sample Footnotes

The raw data tables contained in the appendices have several laboratory generated footnotes whose meanings or implications may not be clear from the footnote description. The sample wide footnotes include "d", "i", "o", "e" while the compound specific footnotes include "g" and "hh". The "d" footnote has been previously discussed as part of the hold time discussion. This footnote only stipulates that some part of the VOC analysis was performed outside of the 14-day laboratory imposed hold time. This footnote does not have any impact on the data quality.

The "i" footnote states that "detection limits are increased." This footnote is somewhat confusing when applied to source level samples. It was designed for use on ambient samples when insufficient sample was collected to achieve desired detection limits. On these samples, it signifies that the samples were diluted more than once. For low level samples, multiple dilutions will reduce some species below analytical detection limits, but for these very high level samples, the dilutions are necessary to get the analyte concentrations to within sample and linear calibration ranges. While analytes that were present in the original samples at very low concentrations were surely diluted below analytical detection limits, these compounds would have probably been masked by the larger peaks anyway. It should also be noted that several analytical runs were required for most of these samples. In cases of multiple analytical runs, the "best" data were extracted for each run instead of all data being quantitated from the single analytical run.

The "e" footnote denotes that the sample was run using a Nafion membrane. This is sometimes necessary if the samples have a high moisture content. Radian uses a moisture management system that can eliminate these problems in most ambient samples, however, the one sample affected by this (collected May 31, 1994) was collected during a period when large quantities of moisture were being removed from the soil and the moisture management system was unable to handle the large moisture concentration. The effect of using this membrane was that oxygenated compounds are removed along with the moisture. This includes alcohols, ketones, aldehydes, and ethers. Removal for some of these compounds can be up to 90% or better. The membrane does not affect aliphatic, aromatic, or halogenated compounds. When the original test plan was being developed, it was thought the membrane would have to be used on all the samples. The "o" footnote is fairly clear. It denotes duplicate sample analysis and has no impact on data quality.

The two compound specific footnotes "g" and "hh" both indicate that the individual compound's concentration may be biased high. The "g" footnote indicates that there was an interference peak (usually an unidentified compound) or electronic spike that couldn't be fully resolved and prevented unbiased quantitation. The "hh" footnote indicates that this compound's quantitation was biased due to coelution with a known or unknown halogenated compound. Since the majority of halogenated compounds are quantitated on the ELCD, which has no interferences from non-halogenated species, e.g., aliphatic or aromatic compounds, coelution on the FID column can be determined. The problem is that halogenated compounds have vastly different responses on the FID than they have on the ELCD and since they are only quantitated on the ELCD, their exact response on the FID column is not precisely know. Therefore, an exact subtraction of the halogenated compounds concentration from the non-halogenated compound's concentration is not possible. Compounds with this footnote should considered to be biased slightly high.

4.2 SVOC Quality Control Procedures

The QC procedures associated with the SVOC analysis include collection of field blanks, field duplicates, surrogate spiking of media prior to sampling, and surrogate spiking prior to sample extraction. SVOC samples were collected six times during the sampling program with three field blanks being collected and one duplicate sampling run being performed. The SVOC sampling train consisted of a ⅜-inch O.D. teflon tube, inserted into the centroid of the SVE exhaust line. Sample was extracted from the exhaust line into the sample condenser followed by the XAD-2 resin cartridge. The length of the teflon line was kept as short as possible (approximately 3 feet) to minimize gas contact prior to the resin. Following sample collection, this sample line, along with the sample condenser, was rinsed with methylene chloride. The methylene chloride rinse was added to the XAD-2 resin during extraction.

The results of the field surrogate (the surrogates added to the sampling media prior to sample collection) sample recoveries are shown in Table 4-4 while the results for the laboratory surrogates (the surrogates added after sampling and prior to extraction) are shown in Table 4-5. In some cases, surrogate recoveries were not calculable due to the very high levels of analytes present in the samples, requiring dilution factors of up to 500 times for the samples. These high deletion factors deleted the surrogates to concentrations below the analytical detection limits.

Three field blanks were collected during the monitoring program. The field blanks were spiked prior to being taken to the field, were spiked with laboratory surrogates prior to extraction, and analyzed using the same protocols as the other field samples. Table 4-6 shows the field blank analytical results. One field duplicate sample was collected and analyzed during the program. This sample consisted of identical sampling trains collecting sample from the same sample port by using a tee connector. The results of these analyses are presented in Table 4-7.

Table 4-4
Summary of Field Surrogate Analytical Recovery

Sample ID	Surrogate Recovery (%)		
	Dibenzofuran-d_8	Isophorone-d_6	Pyrene-d_{10}
SC-02-040894-R-009	76	69	78
SC-02-040894-B-010	102	98	100
SC-02-050694-R-011	93	87	91
SC-02-053194-R-016	69	NC	NC
SC-02-053194-B-017	100	97	125
SC-02-060794-R-020	NC	NC	NC
SC-02-060794-D-021	NC	NC	NC
SC-02-061494-R-023	78	77	80
SC-02-061494-B-024	106	103	110
SC-02-062494-R-025	106	96	93

NC - Recovery not calculable due to high dilution factors required to bring SVOC analytes into calibration range which diluted surrogates below detection limits.
Note: For samples where multiple sample dilutions were performed, table presents recovery from lowest sample dilution.

Table 4-5
Summary of Laboratory Surrogate Recovery

Sample ID	Surrogate Recovery (%)					
	2-Fluorobiphenyl	2-Fluorophenol	Nitrobenzene-$_5$	Phenol-d_5	Terphenyl-d_{14}	2,4,6-Tribromophenol
SC-02-040894-R-009	71	77	134	84	75	59
SC-02-040894-B-010	95	100	106	108	100	113
SC-02-050694-R-011	88	84	76	90	91	42
SC-02-053194-R-016	NC	78	NC	NC	NC	NC
SC-02-053194-B-017	93	76	90	86	141	85
SC-02-060794-R-020	NC	NC	NC	NC	NC	NC
SC-02-060794-D-021	NC	NC	NC	NC	NC	NC
SC-02-061494-R-023	76	87	80	87	81	65
SC-02-061494-B-024	97	97	101	99	106	86
SC-02-062494-R-025	NC	NC	NC	NC	NC	NC

NC - Recovery not calculable due to high dilution factors required to bring SVOC analytes into calibration range which diluted surrogates below detection limits.
Note: For samples where multiple sample dilutions were performed, table presents recovery from lowest sample dilution.

Table 4-6
Summary of SVOC Duplicate Analytical Results

Compound	Sample Concentration ($\mu g/m^3$)		Percent Difference (%)
	SC-02-060794-R-020	SC-02-060794-R-021	
Acenaphthene	ND	ND	N/A
Dibenzofuran	ND	ND	N/A
1,2-Dichlorobenzene	24,800	25,600	3.1
1,3-Dichlorobenzene	2,060	2,120	2.7
1,4-Dichlorobenzene	7,030	7,210	2.6
Diphenylamine/N-NitrosDPA	ND	ND	N/A
Fluorene	ND	ND	N/A
2-Methylnaphthalene	83.2	79.2	4.8
N-Nitroso-di-n-propylamine	ND	ND	N/A
Naphthalene	177	175	1.6
Phenanthrene	ND	ND	N/A
1,2,4-Trichlorobenzene	ND	ND	N/A

ND - Analyte not detected.
N/A - Not applicable or calculation not meaningful.

Table 4-7
Summary of SVOC Field Blank Analytical Results

Compound	Sample Concentration (μg)		
	040894-R-009	053194-R-017	061494-R-024
Acenaphthene	ND	ND	ND
Dibenzofuran	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND
1,3-Dichlorobenzene	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND
Diphenylamine/N-NitrosDPA	ND	ND	ND
Fluorene	ND	ND	ND
2-Methylnaphthalene	ND	ND	ND
N-Nitroso-di-n-propylamine	ND	ND	ND
Naphthalene	ND	ND	ND
Phenanthrene	ND	ND	ND
1,2,4-Trichlorobenzene	ND	ND	ND

Note: Approximate detection limits for the SVOCs are 1 μg/sample.

5.0 DATA PRESENTATION

This section presents the analytical results from the VOC and SVOC monitoring. Table 5-1 shows the results of the soil vapor samples. The probe depths are shown in Table 5-2 while Figure 5-1 shows the relative location of the vapor probes. Table 5-3 presents the results of the VOC sampling from the SVE system exhaust. The SVOC sample data are shown in Table 5-4 with system flow rate data presented in Table 5-5.

The VOC soil data correlated very well with the SVE vapor exhaust in terms of relative composition and concentration. Eleven compounds were detected in the soil vapor that were not detected in the SVE exhaust stream. These eleven compounds were generally detected in only one or two vapor wells (usually well TD-1). Additionally, the relative vapor concentrations were fairly proportional to the concentrations seen in the SVE exhaust.

Very few of the 8270 compounds were detected in the SVOC samples. The predominate compounds detected in the SVOC samples were the dichlorobenzenes, which are generally considered to be volatile compounds. A comparison of the analytical concentrations for the three dichlorobenzene isomers determined by the two methods is presented in Table 5-6. With one exception, the values determined from the VOC analysis are significantly higher than those determined from the SVOC analysis. There are several reasons for this. One, the collection efficiency of the XAD-2 resin for the dichlorobenzenes is not as high as for it is for higher molecular weight compounds. Two, some of the dichlorobenzene can be lost in the extraction and concentration steps. For these reasons, the dichlorobenzene values determined from the VOC analysis should be considered to be the most representative of actual exhaust conditions.

The remaining SVOCs detected in these samples generally were also relatively low molecular weight compounds, with a trichlorobenzene isomer being the heaviest SVOC detected. Not surprisingly, the highest SVOC sample concentrations were measured during periods of active soil heating.

Table 5-1
Summary of Soil Vapor VOC Concentrations

Compound	Compound Concentration (ppbv)					
	040894-R-001	040894-R-002	040894-R-003	040894-R-004	040894-R-005	040894-R-006
Ethane	14,700,000	225,000	192,000	291,000	278,000	11,900
Chlorodifluoromethane	128	ND	ND	ND	ND	ND
Propane	ND	ND	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	311	ND	ND	ND	ND	ND
Isobutane	21,700	393	ND	ND	ND	ND
Vinyl Chloride	204,000	476	70.0	352	78.8	ND
Isobutene + 1-Butene	16,400	281	782	ND	1,400	ND
n-Butane	279,000	1,250	432	850	903	ND
t-2-Butene	12,200	ND	ND	ND	ND	ND
Chloroethane	312	ND	ND	ND	44.3	ND
Isopentane	2,190,000	13,500	7,920	16,300	19,500	184
Acetone	ND	ND	ND	ND	ND	ND
Trichlorofluoromethane	ND	ND	ND	ND	ND	ND
n-Pentane	277,000	1,990	2,550	2,720	6,090	ND
1,1-Dichloroethylene	3,150	200	95.3	241	207	195
Methylene Chloride	1,630	ND	81.8	19.8	ND	ND
2-Methyl-2-butene	ND	ND	ND	ND	ND	ND
Neohexane	18,500	506	457	349	1,020	ND
t-1,2-Dichloroethylene	50	ND	12.5	ND	29.0	ND
1,2-Dichloroethane	123	ND	36.6	ND	87.3	ND
Cyclopentane	36,900	413	924	634	1,930	ND

Table 5-1, (Continued)

Compound	Compound Concentration (ppbv)					
	040894-R-001	040894-R-002	040894-R-003	040894-R-004	040894-R-005	040894-R-006
2,3-Dimethylbutane	316,000	3,510	5,390	4,980	10,700	85.5
MTBE, Isohexane, c-4-M-2-Pentene	229,000	3,120	7,150	3,820	13,400	98.3
3-Methylpentane	120,000	2,590	5,410	4,320	9,500	70.0
c-1,2-Dichloroethylene	186,000	3,480	209	2,590	39.1	ND
n-Hexane	124,000	1,090	5,520	2,230	8,340	73.8
Chloroform	2,020	ND	ND	ND	ND	ND
Methylcyclopentane	79,100	2,990	10,000	3,490	13,900	100
1,2-Dichloroethane	1,540	25.6	ND	8.0	ND	ND
2,4-Dimethylpentane	157,000	2,780	9,050	3,660	12,400	92.3
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND
Benzene	21,900	589	19,500	665	14,100	120
1-Butanol + Cyclohexane	77,100	3,320	15,500	4,280	18,700	148
Isoheptane + 2,3-Dimethylpentane	176,000	4,150	20,400	5,750	21,600	130
3-Methylhexane	40,400	1,320	11,100	1,490	11,300	81.5
Trichloroethylene + BromoDCmethane	90,400	613	63.2	740	9.6	ND
1,4-Dioxane + 2,2,4-Trimethylpentane	563,000	13,400	91,000	93,700	700	ND
n-Heptane	78,400	669	1,940	1,880	960	ND
Methlycyclohexane	87,400	5,820	40,100	6,710	33,300	260
Methylisobutylketone	ND	354	3,300	354	2,570	ND
2,5-Dimethylhexane	41,900	1,040	11,600	1,590	8,180	59.5
2,2,3-Trimethylpentane	48,100	1,420	13,700	2,060	10,100	77.9
1,1,2-Trichloroethane	89.5	38.6	ND	ND	ND	ND
2,3,4-Trimethylpentane	87,700	3,120	29,100	4,850	18,500	143

Table 5-1, (Continued)

Compound	Compound Concentration (ppbv)					
	040894-R-001	040894-R-002	040894-R-003	040894-R-004	040894-R-005	040894-R-006
Toluene	259,000	10,900	38,400	13,700	23,400	268
Dibromochloromethane	ND	19.7	ND	ND	ND	ND
3-Methylheptane	14,100	424	5,880	723	2,400	ND
Hexanal	20,200	1,770	20,900	1,970	11,000	61.2
1,2-Dibromoethane	8.5	48.0	ND	ND	ND	ND
2,2,5-Trimethylhexane	35,800	1,280	18,400	1,940	9,190	72.5
1-Octene	ND	ND	1,080	ND	523	ND
n-Octane	23,800	700	6,000	1,300	2,680	ND
Tetrachloroethylene	2,470	187	6.5	201	ND	ND
Chlorobenzene	42,800	11,700	168,000	7,950	44,900	583
Ethylbenzene	6,930	395	3,110	612	895	ND
p-Xylene + m-Xylene	22,000	1,240	1,220	2,730	679	61.3
Bromoform	ND	63.0	ND	ND	ND	ND
Styrene	ND	278	2,920	362	718	ND
Heptanal	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	83.3	ND	ND	ND	ND
o-Xylene	6,070	708	792	924	215	ND
n-Nonane	17,100	134	617	713	123	ND
Isopropylbenzene	ND	119	1,910	181	271	ND
a-Pinene + Benzaldehyde	4,560	219	7,130	358	709	ND
n-Propylbenzene	ND	101	3,520	214	363	ND
m-Ethyltoluene	ND	238	494	604	ND	ND
p-Ethyltoluene	4,070	348	4,560	462	496	ND

Table 5-1, (Continued)

Compound	Compound Concentration (ppbv)					
	040894-R-001	040894-R-002	040894-R-003	040894-R-004	040894-R-005	040894-R-006
1,3,5-Trimethylbenzene	7,130	305	2,050	834	741	ND
o-Ethyltoluene	4,290	178	960	417	147	ND
b-Pinene	ND	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene	6,480	344	2,400	995	323	ND
Benzyl Chloride + m-Dichlorobenzene	28,900	8,230	2,680	5,850	653	62.1
Isobutylbenzene	ND	ND	ND	ND	ND	ND
n-Decane + p-Dichlorobenzene	76,900	14,800	2,840	11,500	738	81.4
1,2,3-Trimethylbenzene	ND	ND	ND	ND	ND	ND
o-Dichlorobenzene	441,000	122,000	8,610	90,600	1,300	393
Indene	ND	ND	ND	ND	ND	ND
m-Diethylbenzene	ND	77.4	4,120	ND	ND	ND
n-Butylbenzene	3,140	149	2,050	293	437	ND
p-Diethylbenzene	ND	181	1,170	196	224	ND
n-Undecane	8,680	316	1,010	688	173	ND
Naphthalene	ND	115	366	247	112	ND
Unidentified VOC	558,000	27,000	288,000	122,000	104,000	446
Unidentified Halogenated VOC	397	117	112	285	142	6.6
TNMHC	10,400,000	346,000	1,030,000	453,000	643,000	7,840

Table 5-2
Summary of Soil Vapor Sampling Well Depths

Well Number	Screened Interval (Feet below Ground Level)
TD-1	20.1 - 24.1
TD-2	10.5 - 14-5
TD-3	10.5 - 14-5
TD-4	10.2 - 14.2
TD-5	10.5 - 14.5
TD-6	10.4 - 14.4
TD-7	20.3 - 24.3
TD-8	10.3 - 14.3

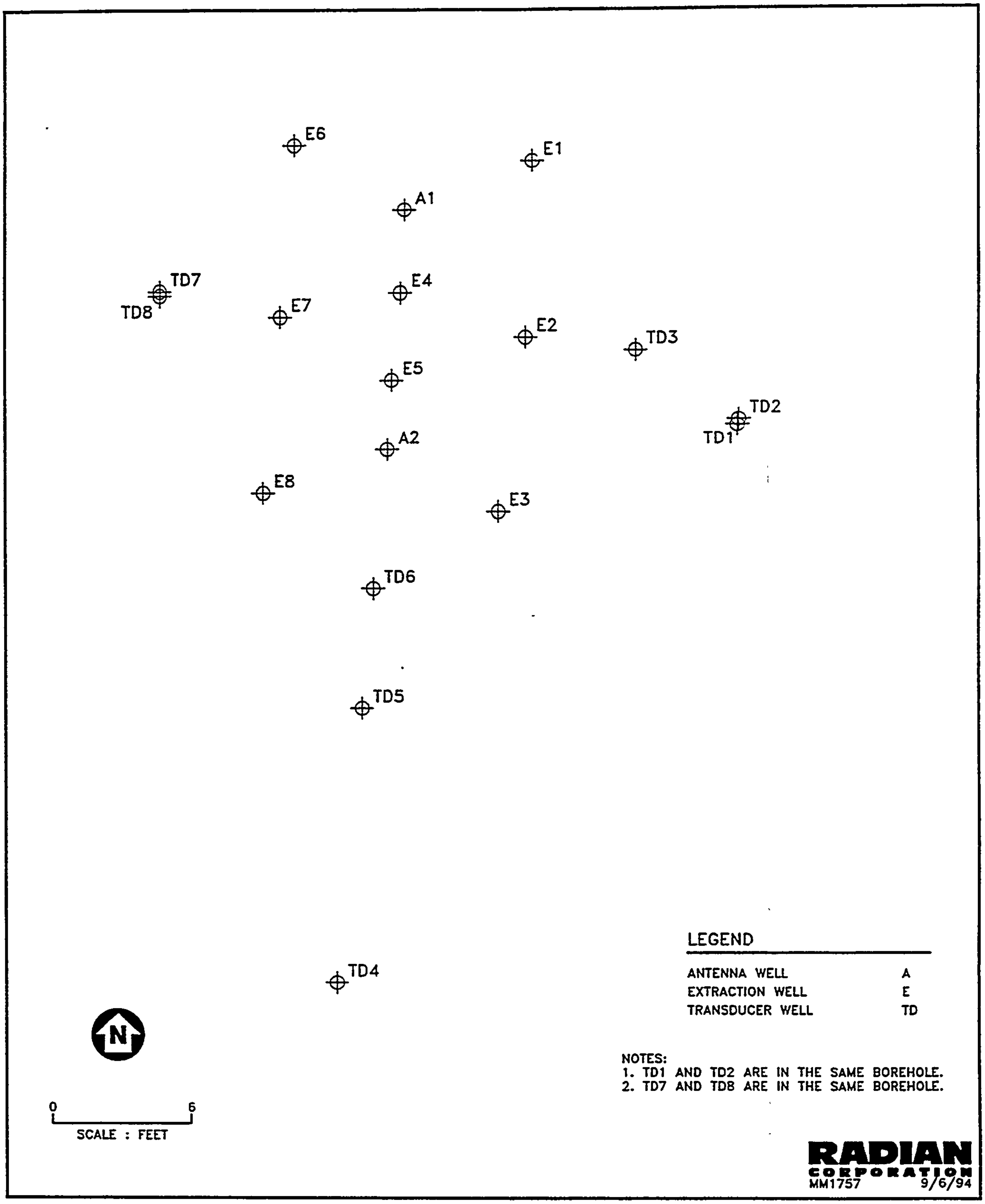

Figure 5-1. Location of SVE Extraction Wells, Heating Antenna, and Soil Vapor Sampling Wells.

Table 5-3
Summary of SVE VOC Vapor Concentrations

Compound	Sample Concentration (ppbv)					
	040894-R-007	050694-R-012	053194-R-014	060794-R-018	061494-R-022	062494-R-026
Ethane	98,700	114,000	16,300	31,300	6,490	122,000
Chlorodifluoromethane	ND	ND	ND	ND	ND	ND
Propane	ND	ND	609	ND	ND	ND
Chloromethane	ND	88.7	60.3	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	16.3
Isobutane	ND	212	ND	ND	ND	340
Vinyl Chloride	34.5	14	10.8	10.5	ND	10.1
Isobutene + 1-Butene	ND	360	ND	ND	ND	158
n-Butane	353	623	307	ND	ND	1,160
t-2-Butene	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND
Isopentane	5,660	8,810	1,820	2,330	529	24,100
Acetone	ND	914	ND	ND	ND	ND
Trichlorofluoromethane	ND	ND	3.5	230	2.5	94.8
n-Pentane	2,240	2,980	715	785	215	8,690
1,1-Dichloroethylene	24.7	48.7	2.2	ND	ND	35.2
Methylene Chloride	ND	ND	3.5	14,000	32.2	81.1
2-Methyl-2-butene	ND	ND	93.5	ND	ND	ND
Neohexane	1,170	1,930	388	466	111	4,930
t-1,2-Dichloroethylene	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND
Cyclopentane	516	552	124	155	35.2	1,640

Table 5-3, (Continued)

Compound	Sample Concentration (ppbv)					
	040894-R-007	050694-R-012	053194-R-014	060794-R-018	061494-R-022	062494-R-026
2,3-Dimethylbutane	2,610	2,530	643	837	174	6,770
MTBE, Isohexane, c-4-M-2-Pentene	3,360	2,600	719	898	196	8,460
3-Methylpentane	4,670	4,890	1,150	1,460	332	14,800
c-1,2-Dichloroethylene	133	33.1	78.7	100	7.9	103
n-Hexane	1,750	1,020	412	446	94.6	1,800
Chloroform	ND	ND	1.6	ND	ND	ND
Methylcyclopentane	2,600	1,580	561	703	149	4,960
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND
2,4-Dimethylpentane	2,740	1,780	668	862	171	4,350
1,1,1-Trichloroethane	ND	62.9	5.3	21.4	ND	70.6
Benzene	3,900	1,480	1,420	1,840	295	6,980
1-Butanol + Cyclohexane	4,040	2,850	994	1,270	251	8,270
Isoheptane + 2,3-Dimethylpentane	5,450	3,250	1,400	1,820	341	8,060
3-Methylhexane	2,520	1,230	614	790	149	3,310
Trichloroethylene + BromoDCmethane	51.0	8	25.7	37.1	3.4	34.0
1,4-Dioxane + 2,2,4-Trimethylpentane	16,800	10,300	5,300	6,930	1,240	21,600
n-Heptane	873	215	326	388	51.7	635
Methlycyclohexane	7,080	3,660	1,980	2,690	465	13,000
Methylisobutylketone	847	759	246	335	67.1	1,620
2,5-Dimethylhexane	1,900	866	577	764	133	2,810
2,2,3-Trimethylpentane	2,470	1,410	803	1,050	183	3,670
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND
2,3,4-Trimethylpentane	4,000	2,480	1,640	2,160	361	5,730

Table 5-3, (Continued)

Compound	Sample Concentration (ppbv)					
	040894-R-007	050694-R-012	053194-R-014	060794-R-018	061494-R-022	062494-R-026
Toluene	5,730	3,720	2,690	3,350	513	8,930
Dibromochloromethane	ND	ND	ND	ND	ND	ND
3-Methylheptane	1,100	458	387	520	82.3	1,460
Hexanal	3,290	2,030	1,190	1,580	274	6,870
1,2-Dibromoethane	ND	ND	ND	ND	ND	ND
2,2,5-Trimethylhexane	ND	1420	1030	1350	226	3,910
1-Octene	171	65.5	ND	73.6	ND	190
n-Octane	1,110	702	576	219	109	2,120
Tetrachloroethylene	8	14.3	21.6	35.7	3.5	62.3
Chlorobenzene	20,500	7110	12700	18600	2,800	40,400
Ethylbenzene	444	328	199	291	37	990
p-Xylene + m-Xylene	701	211	401	475	67.7	752
Bromoform	ND	ND	ND	ND	ND	ND
Styrene	613	183	ND	ND	ND	974
Heptanal	ND	ND	259	60.9	ND	254
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND
o-Xylene	198	ND	38.6	114	ND	ND
n-Nonane	ND	93.9	260	326	40	103
Isopropylbenzene	175	98.3	107	128	19.9	438
a-Pinene + Benzaldehyde	771	256	423	550	80.5	1,710
n-Propylbenzene	302	102	ND	108	ND	1,680
m-Ethyltoluene	ND	101	145	182	ND	271
p-Ethyltoluene	428	191	308	393	56	1,290

Table 5-3, (Continued)

Compound	Sample Concentration (ppbv)					
	040894-R-007	050694-R-012	053194-R-014	060794-R-018	061494-R-022	062494-R-026
1,3,5-Trimethylbenzene	106	149	92.9	321	40.8	226
o-Ethyltoluene	ND	98.2	187	272	ND	102
b-Pinene	ND	173	ND	273	15.3	873
1,2,4-Trimethylbenzene	283	185	290	403	51.2	588
Benzyl Chloride + m-Dichlorobenzene	464	414	450	618	81.8	854
Isobutylbenzene	ND	66.1	ND	ND	ND	ND
n-Decane + p-Dichlorobenzene	470	765	1,470	2250	209	1,640
1,2,3-Trimethylbenzene	ND	ND	225	293	32.3	929
o-Dichlorobenzene	2,040	2,730	5,160	7280	964	5,010
Limonene	ND	ND	ND	ND	ND	339
Indene	ND	ND	135	ND	ND	ND
m-Diethylbenzene	188	106	126	263	ND	501
n-Butylbenzene	334	55.2	134	263	ND	589
p-Diethylbenzene	225	74.4	66.7	193	ND	594
n-Undecane	125	145	371	493	49.9	474
Naphthalene	ND	78.6	60.0	92.3	ND	138
Unidentified VOC	41,400	23,600	26,300	33,900	3,580	98,500
Unidentified Halogenated VOC	60	ND	6.0	ND	ND	96
TNMHC	191,000	137,000	86,400	117,000	17,000	391,000

Table 5-4
Summary of SVOC Sample Concentrations

Compound	Sample Concentration ($\mu g/m^3$)					
	040894-R-009	050694-R-011	053194-R-016	060794-R-020	061494-R-023	062494-R-025
Acenaphthene	ND	22.3	ND	ND	ND	ND
Dibenzofuran	ND	8.7	ND	ND	ND	ND
1,2-Dichlorobenzene	998	17,000	23,400	24,800	928	14,500
1,3-Dichlorobenzene	322	1,480	2,230	2,060	80	1,880
1,4-Dichlorobenzene	1,122	3,880	6,430	7,030	271	6,020
Diphenylamine/N-NitrosDPA	ND	50.7	ND	ND	ND	ND
Fluorene	ND	10.2	ND	ND	ND	ND
2-Methylnaphthalene	10.2	147	59.1	83.2	0.7	ND
N-Nitroso-di-n-propylamine	ND	ND	83.7	ND	ND	ND
Naphthalene	14.7	221	166	177	3.4	ND
Phenanthrene	ND	24.0	ND	ND	ND	ND
1,2,4-Trichlorobenzene	4.1	124	ND	ND	3.9	ND

Table 5-5
Summary of SVE System Flow Rate Data

Date	ΔP ("H_2O)	Pressure ("Hg)	Temperature (°F)	Moisture[1]	Duct Velocity (ft/sec)	ACFM[2]	DSCFM[3]
04/08/94	1.35	28.25	90	2.0	81.91	108.1	96.4
04/08/94	0.30	26.69	105	10.0	40.89	54.0	40.6
05/06/94	0.10	26.69	126	10.0	24.04	31.7	23.0
05/31/94	0.45	27.34	157	32.0	54.08	71.4	38.1
06/07/94	0.40	28.25	157	32.0	50.16	66.2	36.5
06/14/94	0.64	28.47	100	8.2	57.37	75.7	62.6
06/24/94	0.25	28.69	116	5.0	36.00	47.5	39.8

[1] Exhaust gas moisture content estimated based on duct temperature and moisture fraction based on saturation tables.

[2] Actual cubic feet per minute.

[3] Dry standard cubic feet per minute.

Table 5-6
Comparison of Dichlorobenzene Concentrations by GC/MD and 8270 Analysis

Compound	Concentrations in ppb											
	04/08/94		05/06/94		05/31/94		06/07/94		06/14/94		06/24/94	
	SVOC	VOC	SVOC	VOC	SVOC	VOC	SVOC	VOC	SVOC	VOC	SVOC	VOC
1,2-Dichlorobenzene	166	2,040	2,827	2,730	3,891	5,160	4,122	7,280	154	964	2,407	5,010
1,3-Dichlorobenzene	53	464	246	414	371	450	342	618	13	81.8	313	854
1,4-Dichlorobenzene	187	470	646	765	1,070	1,470	1,169	2,250	45	209	1,001	1,640

SVOC Concentrations converted from $\mu g/m^3$ to ppbv.

One data anomaly was noted with these sample data. The lowest SVOC and VOC concentrations were measured on June 14th, one week after the heating system was turned off. These concentrations were lower than those measured prior to soil heating as well as being significantly lower than those measured 10 days later. The soil temperature should have still been relatively warm on June 14th and warmer than on June 24th. Therefore, one would expect that the VOC and SVOC concentrations would have been higher, not lower, on this monitoring day. Since the sample collections methods are vastly different (i.e., the chance two vastly different methods would be compromised) and no anomalies were discovered with the analytical methodologies, process conditions on this day should be closely scrutinized to determine whether any operational parameters could explain these lower concentrations.

APPENDIX B.7

TABLE B.7 - 1
KAI COST SUMMARY - PHASE II
RF SOIL DECONTAMINATION DEMONSTRATION

ITEM	UNIT COST ($)	SUBTOTALS
RF SOURCE		**$884,578**
RF TRANSMITTERS	242,000	
RF CONTROL UNIT	600,000	
ELECTRICITY	42,578	
RF APPLICATION		**$208,000**
ANTENNA	132,000	
ANTENNAE CASING	27,200	
COAXIAL TRANSMISSION LINE	21,600	
ANTENNA TOWERS & BASE PLATES	27,200	
RF SHIELDING & GROUNDING		**$1,104**
MESH SCREEN	256	
GROUNDING	848	
MEASUREMENT/CONTROL		**$20,173**
FIELD MEASUREMENT WELLS (TMW)	377	
PRESSURE MEASUREMENT WELLS (VMW)	254	
THERMOCOUPLES ASSEMBLIES	1,405	
VACUUM/PRESSURE GAUGES	138	
GAS CHROMATOGRAPH	18,000	
VAPOR COLLECTION/TRANSFER PIPING		**$2,102**
VAPOR BARRIER	835	
HORIZONTAL EXTRACTION PIPING	114	
EXTRACTION MANIFOLD	1,153	
VAPOR EXTRACTION/TREATMENT		**$251,700**
REGENERATIVE BLOWER	1,700	
CATOX TREATMENT UNIT	250,000	
SITE SUPPORT		**$68,597**
UTILITY TRUCK	35,000	
CELLULAR TELEPHONE	4,875	
MISCELLANEOUS ODCS	41,815	
FENCING	9,200	
GRAVEL	2,500	
CONCRETE	1,400	
WASTE DISPOSAL	7,108	
LIGHTS	1,700	
SUBCONTRACTOR SUPPORT		**$140,802**
DRILLING FOR SYSTEM INSTALL	8,610	
IN GROUND SYSTEM ABANDONMENT	9,493	
RF CONSULTANTS	80,000	
ANALYTICAL	42,700	
LABOR		**$259,875**
SITE PREPARATION/SET-UP	37,125	
TREATMENT	204,188	
SITE RESTORATION/DEMOBILIZATION	18,563	
	SUBTOTAL	**$1,836,931**
ODC MARKUP	10.60%	**$167,168**
ENGINEERING, PROCUREMENT, & PROJECT MANAGEMENT	15%	**$236,558**
CONTENGENCY	15%	**$236,558**
	TOTAL	**$2,477,216**

TABLE B.7 - 2
KAI COST DETAILS - PHASE II
RF SOIL DECONTAMINATION DEMONSTRATION

INPUT PARAMETERS						
HEATED AREA (FT)	LENGTH	44	ANTENNA TO ANTENNA	16	HEAT TIME, WKS/CELL	8
	WIDTH	32			COOL TIME, WKS	4
	DEPTH	20				
					TREATMENT TIME (WKS)	20
CELL AREA (FT)	WIDTH	16			MOB/DEMOB TIME (WKS)	6
	LENGTH	16				
	DEPTH	20	VAP. BARRIER OVERLAP (FT)	12		

RF SOURCE

RF TRANSMITTERS $242,000.00 CAPITAL

4 - 25kW/240V TRANSMITTERS INCLUDES TRAILER, DUMMY LOAD, ELECTRIC FIELD MEASUREMENT EQUIPMENT, TRANSFORMERS, MATCHING NETWORKS OR TUNERS, INSTRUMENTATION FOR ELECTRICAL/RF/TEMPERATURE DATA MANAGEMENT, AND TOOLS

100	POWER REQUIRED FOR SYSTEM (kW)
25	INDIVIDUAL TRANSMITTER POWER (kW)
$55,000.00	COST PER TRANSMITTER
$22,000.00	COST FOR TRAILER
$242,000.00	TOTAL TRANSMITTER/TRAILER COST

RF CONTROL UNIT $600,000.00 CAPITAL

HOUSED IN 40' SEMI TRAILER WITH COMPUTERIZED INSTRUMENTATION FOR THE MONITORING AND CONTROL OF RF, ELECTRICAL, TEMPERATURE, VAPOR FLOW AND TREATMENT. THIS TRAILER WILL ALSO HOUSE THE SITE OFFICE AND GC LAB AREA.

$600,000.00	COST FOR CONTROL UNIT (EST/KAI)

ELECTRICITY $42,577.92 DISPOSABLES

$0.07	COST PER KILOWATT HOUR
170	POWER USAGE IN KW/H DURING HEATING
3,360	HEATING HOURS (168/WK X TREATMENT TIME)
571,200	KWH USED DURING HEATING
15	POWER USAGE IN KW/H DURING COOLING/OTHER
1,344	COOLING/OTHER HOURS (168/WK X COOLING AND MOB/DEMOB TIME)
20,160	KWH USED DURING COOLING/OTHER
591,360	TOTAL KWH USED FOR PROJECT
$42,577.92	TOTAL COST FOR ELECTRICITY

RF APPLICATION

ANTENNAE $132,000.00 CAPITAL

ANTENNA ARE CONSTRUCTED BY KAI AND ARE PROPRITORY.
OUTSIDE DIA = 4.5 INCHES

8	NO. OF ANTENNAE
16,500	COST PER ANTENNA
$132,000.00	COST FOR TEES/CAPS = EXCITORS PER CELL X COST PER TEE/PLUG

ANTENNAE WELL CASING (SLEEVES) $21,600.00 CAPITAL

8	NO. CASINGS REQUIRED
2,700	COST PER CASING
$21,600.00	TOTAL CASING COST

COAXIAL TRANSMISSION LINE $9,600 CAPITAL

CONSTRUCTED OF 2" SCH 40 COPPER PIPE IN SECTIONS TIED WITH FLANGES
TIES RF TRANSMITTERS TO INDIVIDUAL ANTENNA

$60.00	COPPER ELBOW (EST)

$24.00	COST PER LF - 6" DIAM. SCH 40 COPPER PIPE (EST.)
320	TOTAL LF (EST)
$30.00	2" DIA COPPER COMPATIBLE FLANGES
$9,600.00	TOTAL COST = PIPE, 6 FLANGES, 1 TEE AND 1 ELBOW

ANTENNA TOWERS AND BASE PLATES	$27,200	CAPITAL

CONSTRUCTED FROM PREFABRIATED TOWER SECTIONS AND HARDWARE IN SHEET METAL SHOP.

8	20 FT TOWERS REQUIRED
2000	COST PER 20 FT OF TOWER (2 SECTIONS) SECTION WITH CONNECTORS TOWER SECTIONS
300	COST PER PULLY ASSEMBLY
1000	COST PER BASE PLATE
100	COST PER GUIDE WIRE SUPPORT KIT (EST)
$27,200	

RF SHIELDING AND GROUNDING

MESH SCREEN	$256.00	DISPOSABLE

EXTENDS 5' OUT FROM ANTENNA HOLES

0.32	COST PER SQUARE FOOT OF ALUMINUM MESH
800	SQUARE FEET OF ALUMINUM MESH REQUIRED
$256.00	TOTAL COST FOR ALUMINUM MESH

GROUNDING	$848.00	DISPOSABLE

INTERLINKING SYSTEM OF 2-O COPPER WIRE CONNECTED TO 4 FT 0.05 INCH DIA GOUNDING RODS
DRIVEN INTO THE GROUND

10.00	COST PER GROUNDING RODS
1.25	COST PER LF OF 2-0 COPPER WIRE
4.00	COST PER MECHNICAL CONNECTOR
32	NO. GR RODS
320	LF OF 2-0 COPPER
32	NO. OFMECHNICAL CONNECTORS
$848.00	TOTAL COST FOR ALUMINUM MESH

MEASUREMENT/CONTROL

FIELD MEASUREMENT WELLS (FMW)	$376.74	DISPOSABLE

TMWs ARE CONSTRUCTED OF 3" DIA GREEN THREAD FIBERGLASS PIPE COMPLETED 2' AGL

6	NO. OF FMWs
156	LF OF FMWs= NO. OF TMWs X (24' DEPTH + 2' STICKUP)
$7.30	COST PER 20 LF OF 3" DIA GREEN THREAD FIBERGLASS (ACT.)
$53.30	COST PER COUPLING & CAP (1 PER)
$376.74	COST FOR TOTAL LF OF FMWs = TOTAL LF/20 X COST PER 20 LF

PRESSURE MEASUREMENT WELLS (PMW)	$254.10	DISPOSABLE

PMWs ARE CONSTRUCTED OF 2" DIA GREEN THREAD FIBERGLASS PIPE COMPLETED TO GL

6	NO. OF PMWs
20	LF PER PMW = 20' DEPTH
120	LF OF PMWs= NO. OF PMWs X PMW DEPTH
$5.20	COST PER 20 LF
$37.15	COST PER COUPLING & CAP (1 PER)
$254.10	COST FOR TOTAL LF OF PMWs = TOTAL LF/20FT X COST PER 20 LF

THERMOCOUPLE ASSEMBLIES	$1,404.58	DISPOSABLE

THERMOCOUPLE ASSEMBLIES ARE 20 FT LONG 0.5 INCH DIA PVC PIPE WITH THERMOCOUPLES
THERMOCOUPLES ATTACHED AT 20', 15', & 5' DEPTHS
EACH TC WILL COME WITH 10' OF WIRE, EXTRA WIRE AND PLUG/JACK FOR EACH TC REQUIRED
WIRE REQUIRED TO EXTEND 50' FROM TOP OF WELL

3	TOTAL TC ASSEMBLIES REQUIRED
3	TC's PER ASSEMBLY
$19.50	COST PER TC (EST.)
$175.50	TOTAL TC COST = TOTAL TCs X COST PER TC
6.60	COST PER 20 FT PVC PIPE SECTION
19.80	TOTAL COST PVC

$584.00	COST PER 1000 LF OF WIRE (EST.)
$1,168.00	COST FOR 2000 LF
$4.30	COST OF PLUG/JACK FOR EXTRA WIRE (EST.)
12	TOTAL FOR PLUG/JACKS
$41.28	TOTAL COST FOR PLUG/JACKS = TOTAL PLUG/JACKS X COST PER X 20% DISCOUNT (EST.)

VACUUM/PRESSURE GAUGES $138.00 CAPITAL

MAGNAHELIC 0-10" AND 0-40" GAGES

46.00	COST PER GAUGE
3	GAUGES REQUIRED
$138.00	TOTAL COST FOR GAUGES

GAS CHROMATOGRAPH $18,000.00 RENTAL

PORTABLE GC

3000.00	MONTHLY RENTAL RATE FOR PORTABLE GC
6.00	TOTAL MONTHS NEEDED
$18,000.00	TOTAL COST FOR PORTABLE GC RENTAL

VAPOR COLLECTION/TRANSFER PIPING

VAPOR BARRIER $835.20 DISPOSABLE

3 LAYER BARRIER, TWO LAYERS OF REINFORCED PLASTIC AND ONE LAYER OF 2" INSULATION
BARRIER WILL EXTEND 12' BEYOND EDGE OF CELL IN ALL DIRECTIONS

2880	PLASTIC BARRIER DIMENSIONS (SQ. FT) = (CELL WIDTH + 24') X (CELL LENGTH + 24')
$0.13	COST PER SQ. FT. FOR REINFORCED PLASTIC BARRIER MATERIAL (EST.)
$0.16	COST PER SQ. FT. FOR 2" FIBERGLASS INSULATION (MCM CARR)
$835.20	COST FOR BARRIER = (.13/SQ. FT. X 4320 SQ. FT.) X 2 LAYERS + (.16/SQ. FT. X 1600 SQ. FT.) X 2 BARRIERS

HORIZONTAL EXTRACTION PIPING $113.70 CAPITAL

TWO SECTIONS OF HORIZONTAL PIPING OF 10 FT SECTIONS OF 2" GREEN THREAD FIBERGLASS PIPE
EACH SECTION CONSTRUCTED WITH AN END CAP AND 1 90/ELBOW

28.00	COST FOR 2" FIBERGLASS END CAP
0.26	COST PER LF. FOR 2" GREEN THREAD FIBERGLASS PIPE
23.65	COST FOR 2" 90 DEG. ELBOW
20	LENGTH OF PIPE IN FT (INDIV. SECTIONS)
56.85	COST FOR ONE HORIZ. EXT. SECTION (PIPE 1 90/ELBOW, & 1 END CAP)
2	NO. REQUIRED
$113.70	TOTAL COST = HORIZ. EXT. SECTIONS X CELLS INSTALLED

EXTRACTION MANIFOLD $1,152.70 CAPITAL

TIES TOGETHER ALL VAPOR EXTRACTION COMPONENTS
COMPONENTS FOR 3 EXTRACTION & 3 PMW AND 2 HORIZ. EXTRACTION SECTIONS
MANIFOLD CONSTR. WITH FLANGE DIVIDING EACH CELL AND VALVE BETWEEN EACH COMPONENT
FLEXIBLE VACUUM HOSE TIES MANIFOLD TO INDIV. EXTRACTION COMPONENTS & TREATMENT UNIT

15.50	COST FOR 2" FLANGE 15.50 (VEE)
0.26	COST PER LF FOR 2" GREEN THREAD FIBERGLASS PIPE
5.00	COST FOR THREADED FIBERGLASS ADAPTER (VEE)
9.15	COST FOR 2" HOSE COUPLING (1 MALE/1 FEMALE) (VEE)
2.94	COST PER LF OF VACUUM HOSE (VEE)
19.90	COST FOR 2" BRONZE BALL VALVE (ESCO)
23.65	COST FOR 2" 90 GREEN THREAD 90/ELBOW
250	LENGTH OF PIPE(EST)
8	VALVES REQUIRED = 3 ELECTRODE ROWS + 3 HORIZ, EXT. SECTIONS
8	NUMBER OF 25' HOSE SECTIONS WITH 2 COUPLING SETS REQUIRED
$1,152.70	TOTAL COST = PIPE, 2 FLANGES, 3 ELBOWS, 6 TEES, 6-3' HOSE SECTIONS WITH COUPLINGS

VAPOR EXTRACTION/TREATMENT

REGENERATIVE BLOWER $1,699.80 CAPITAL

HOUSED ON 40' FLATBED TRAILER WITH CAT/OX UNIT

1053.00	REGENERATIVE BLOWER COST - GAST MODEL R6350A-2
56.80	VACUUM GAUGE
109.80	MUFFLER

307.50	FILTER
172.70	RELIEF VALVE
$1,699.80	TOTAL COST FOR BLOWER AND ACCESSORIES

CATALYTIC OXIDATION TREATMENT UNIT WITH NaOH PRECIPITATION $250,000.00 CAPITAL

HOUSED ON A 40' FLAT BED TRAILER. UNIT INCLUDES AMBIENT AIR CONDENSER, WATER SEPARATOR, CATALYTIC OXIDIZER,D NaOH PRECIPITATION UNIT, & MANIFOLD FOR FLEXIBLE HOSES

$250,000.00	TOTAL COST FOR TRAILER-MOUNTED TREATMENT UNIT

LABOR

GENERAL LABOR

	SALARY	HR RATE	
PROJECT MANAGER	60,000	28.85	
SR ENGINEER	55,000	26.44	
JR ENGINEER	45,000	21.63	
FIELD TECHNICIAN	35,000	16.83	
		93.75	
		117.19	OVERHEAD (125%)
		21.09	G&A (10%)
		232.03	CREW HOUR

SITE PREPARATION/SET-UP $37,125.00 LABOR

INCLUDES FENCING, MATERIAL RECEIPT, TRAILER/SITE SETUP, ELECTRICAL, DOGHOUSE FAB., MISC. ACTIVITIES

4-MAN CREW WORKING 8 HR DAYS, 5 DAYS PER WEEK

4	TIME REQUIRED IN WEEKS
232.03	LABOR RATE FOR 4 MAN CREW (INCLUDES ALL INDIRECTS)
40	CREW HOURS PER WEEK
160	TOTAL CREW HOURS REQUIRED FOR SITE PREPARATION/SET-UP
$37,125.00	TOTAL COST FOR SITE PREPARATION/SET-UP

TREATMENT $204,187.50 LABC

INCLUDES RF/SVE OPERATION, PROJECT MANAGEMENT, AND REPORTING

DOES NOT INCLUDE INITIAL 4 WEEK SET-UP OR FINAL DEMOBILIZATION

2 MEN ON SITE 11.5 HOURS PER DAY 7 DAYS PER WEEK (=40 CREW HRS)

0.1	CONTINGENCY FACTOR FOR LOST TIME
232.03	LABOR RATE FOR 4 MAN CREW (INCLUDES ALL INDIRECTS)
40	CREW HOURS PER WEEK
20	TOTAL WEEKS OF TREATMENT
800	TOTAL CREW HOURS REQUIRED FOR TREATMENT
$204,187.50	TOTAL COST FOR TREATMENT CREW

SITE RESTORATION/DEMOBILIZATION $18,562.50 LABOR

2	TIME REQUIRED IN WEEKS
232.03	LABOR RATE FOR 4 MAN CREW (INCLUDES ALL INDIRECTS)
40	CREW HOURS PER WEEK
80	TOTAL CREW HOURS REQUIRED FOR SITE RESTORATION/DEMOBILIZATION
$18,562.50	TOTAL COST FOR SITE RESTORATION/DEMOBILIZATION

SITE SUPPORT

TRUCKS AND TRAILERS $35,000 CAPITAL

ONE TON UTILITY TRUCK WITH OVERHEAD WINCH, HYDRAULIC LIFT, AND SMALL TRAILER

CELLULAR TELEPHONE $4,875.00 SERVICES

750.00	MONTHLY RENTAL RATE
7	MONTHS NEEDED
$4,875.00	TOTAL RENTAL COST FOR CELLULAR TELEPHONE

MISCELLANEOUS ODCS $41,814.72 DISPOSABLES

		UNIT	UNIT COST	EST. QTY
21.10	ALUMINUM FOIL	ROLL	2.11	10
39.84	BARRIER TAPE	ROLL	9.96	4

116.10	BOOT COVERS	PAIR	11.61	10
455.00	CHEMICAL TOILET	MONTH	65.00	7
204.00	COTTON GLOVES	PAIR	0.68	300
6.00	DECON TUB	EACH	3.00	2
375.00	16-GAL EYEWASH	EACH	375.00	1
205.00	DRAEGER PUMP	EACH	205.00	1
132.00	DRAEGER TUBES	EACH	33.00	4
546.20	FULL FACE RESP.	EACH	136.55	4
53.00	HARD HATS	EACH	5.30	10
4929.80	HNU DETECTOR	EACH	4,929.80	1
78.85	HPLC (4L)	4L	15.77	5
1253.00	LEL/O2 METER W/ ACC.	EACH	1,253.00	1
146.32	LIQUINOX DETERGENT	GAL	18.29	8
86.34	METHANOL (4L)	4L	28.78	3
2000.00	MILEAGE (TRUCK)	MILE	0.50	4000
84.60	MSA COMB. CARTRIDGES	EACH	2.82	30
113.00	NITRILE GLOVES	PAIR	1.13	100
5046.00	OVA	EACH	5,046.00	1
28.10	PACKING TAPE	ROLL	2.81	10
74.00	PAPER TOWELS	ROLL	0.74	100
23284.80	PROPANE (CAT/OX)	GAL	0.63	36960
10.08	PIN FLAGS (BDL50)	BDL	2.52	4
209.60	SAFETY GLASSES	EACH	5.24	40
21.60	SAMPLE BOWL/TROWEL	EACH	7.20	3
74.20	SPAN GAS (HNU)	TANK	37.10	2
72.08	SPAN GAS (LEL/O2)	TANK	36.04	2
1850.00	STEAM CLEANER	EACH	1,850.00	1
43.45	SURGEONS GLOVES	BOX	8.69	5
127.00	TRASH BAGS	BOX	6.35	20
104.76	TYVEK COVERALLS	EACH	2.91	36
23.90	ZIPLOCK BAGS	BOX	2.39	10

$41,814.72 TOTAL MISCELLANEOUS ODC COST

FENCING **$9,200.00** CAPITAL

FENCE DIMENSIONS ARE 300' BY 200', INSTALLED WITH TWO GATES

11.50	COST PER LINEAR FOOT FOR FENCING, INCLUDES GATES
800	TOTAL LINEAR FOOTAGE REQUIRED
$9,200.00	TOTAL COST

GRAVEL **$2,500.00** DISPOSABLE

USED TO REGRADE SITE DURING RESTORATION

$2,500.00 TOTAL COST FOR GRAVEL (EST)

CONCRETE **$1,400.00** DISPOSABLE

TRANSFORMER PAD

$1,400.00 8' X 8' CONCRETE PAD WITH FENCING (EST.)

LIGHTS **$1,700.00** DISPOSABLE

PERIMETER LIGHTS FOR SITE SECURITY AND NIGHT OPERATIONS

85.00	EST. COST PER LIGHT INCLUDING POST AND ELECTRICAL HOOKUP
20	NUMBER OF LIGHTS REQUIRED
$1,700.00	TOTAL COST FOR LIGHTING

WASTE DISPOSAL $7,107.50 SERVICES

SLUDGE FROM NaOH PRECIPITATION UNIT, LIQUID FROM AMBIENT AIR CONDENSER, EXCESS SOIL, AND MISCELLANEOUS (PPE, USED HOSE, ETC.)

2.50	COST PER MILE FOR HAZWASTE TRANSPORT (EST)
25.00	COST FOR BULK DRUM TRANSPORT (EST)
0.40	COST FOR INCINERATION PER POUND (EST)
150.00	COST PER DRUM FOR HANDLING DURING INCINERATION PER POUND (EST)
350.00	COST PER DRUMFOR LANDFILL (EST)
300.00	COST PER DRUM FOR LANDFILL PICK-UP & HANDLING (EST)

0.25	COST PER GALLON FOR WATER TREATMENT (EST)

6,000	NaOH SLUDGE (LB) - (10 DRUMS)
$4,150	COST TO DRUM, TRANSPORT, & INCINERATE

5,000	LIQUID (GAL)
630	DECON WATER (GAL)
$1,533	COST TO TRANSPORT (50 MILES) & TREAT

3	MISC. (DRUMS)
$1,425	COST TO TRANSPORT & LANDFILL

SUBCONTRACTOR SUPPORT

DRILLING AND ABANDONMENT	**$8,609.80**	SERVICES

SYSTEM INSTALL

1.00	COST FOR 100 LB. BAG SAND BACKFILL (1 CUBIC FOOT)
10.50	COST FOR 50 LB BAG BENTONITE CHIPS (0.79 CUBIC FEET)
13.00	COST PER FOOT FOR BORING (4.25" HS AUGER)
15.00	COST PER FOOT FOR BORING (8" HS AUGER)
100.00	COST PER HOUR FOR STANDBY, SITE RESTORATION, MISC. CREW TIME
30.00	COST PER HOUR FOR DECON
250.00	MOB/DEMOB RATE EACH MOBILIZATION
30.00	COST PER BORING FOR SAMPLING
8	ANTENNAE BOREHOLES
26	DEPTH OF ANTENNA BOREHOLES (=2 FT)
208	TOTAL LF OF ANTENNAE BOREHOLES
4	FIELD MEASUREMENT WELLS
80	TOTAL LF OF FIELD MEASUREMENT WELLS (4.25' AUGER)
3	THERMOCOUPLE ASSEMBLIES
60	TOTAL LF OF THERMOCOUPLE ASSEMBLIES (4.25' AUGER)
6	PRESUURE MEASUREMENT WELLS
120	TOTAL LF OF PRESSURE MEASUREMENT WELLS (4.25" AUGER)

$3,120.00	ANTENNAE BOREHOLE DRILLING COST AT $15 PER FOOT

200	LF OF PRESSURE/FIELD MEASUREMENT WELLS
$2,600.00	DRILLING COST AT $13 PER FOOT

12	NUMBER OF BORING REQUIRING SAMPLING
$312.00	COST FOR SAMPLING ($30 EACH)

$780.00	COST OF BOREHOLES FOR THERMOCOUPLE ASSEMBLIES

23	REQUIRED AUGER DECONS (BEFORE EACH SAMPLE AND AT END)
1	TIME FOR EACH DECON (HRS)
$690	COST FOR DECON

164	100 LB. BAGS OF SAND REQUIRED (7 BAGS PER 20' OF BORING)
$163.80	TOTAL SAND COST

168	50 LB. BAGS OF BENTONITE REQUIRED (2 BAGS PER BOREHOLE) FOR INSTALLATION
$1,764.00	TOTAL BENTONITE COST

1	MOBILIZATIONS FOR ENTIRE TREATMENT AREA
250.00	COST PER MOBILIZATION/DEMOBILIZATION
$250.00	TOTAL MOBILIZATION COST

4	STANDBY HRS (EST)
$400.00	COST PER HR FOR STANDBY

SYSTEM ABANDONMENT (DISMANTLE)	**$9,492.50**	SERVICES

100.00	COST PER HR FOR RIG TIME
10.50	COST OF 50 LB BAG BENTONITE CHIPS (0.79 CUBIC FEET)
30.00	COST PER HOUR FOR DECON
250.00	MOB/DEMOB RATE

30.00	COST PER BORING FOR SAMPLING
2.00	TIME IN HOURS TO ABANDONE AN ANTENNA WELL (PULL & BENTONITE FILL)
2.50	TIME IN HOURS TO ABANDONE A PMW, FMW, OR TC ASSEMBLY (PULL & BENTONITE FILL)
15.00	COST FOR EACH ABANDONMENT REPORT
5.00	CUBIC FT BENTONITE PER HOLE (EST)
20	NUMBER OF BORING REQUIRING SAMPLING
$600.00	COST FOR SAMPLING ($30 EACH)
20	NUMBER OF SOIL SAMPLE HOLES
12	AVERAGE DETPH IN FT OF BOREHOLE (8" DIA)
$3,600.00	COST OF DRILLING
8	NUMBER OF ANTENNAE
$1,720	COST TO ABANDONE
3	NUMBER OF THERMOCOUPLE ASSEMBLY
$795	COST TO ABANDONE
12	NUMBER OF PMW's AND FMW's
$3,180	COST TO ABANDONE
43	NUMBER OF HOLES
$2,258	BENTONITE COST
23	REQUIRED AUGER DECONS (BEFORE EACH SAMPLE AND AT END)
1	TIME FOR EACH DECON (HRS)
$690	COST FOR DECON
1	MOBILIZATIONS FOR ENTIRE TREATMENT AREA
250.00	COST PER MOBILIZATION/DEMOBILIZATION
$250.00	TOTAL MOBILIZATION COST

NALYTICAL	$42,700.00	SERVICES

850.00	ANALYTICAL COST PER SAMPLE FOR VOCs, SVOCs, TPH, MOISTURE, AND SIEVE
22	NUMBER OF SAMPLES TO BE ANALYZED (20 SOIL & 2 WATER)
6.00	NUMBER OF INDEPENDENT VAPOR SAMPLES
4000.00	COST PER VAPOR SAMPLE
$42,700.00	TOTAL ANALYTICAL COST

TABLE B.7 - 3
KAI CAPITAL AMORTIZATION COST DETAILS - PHASE II
RF SOIL DECONTAMINATION DEMONSTRATION

CAPITAL EQUIPMENT ITEM	EQUIPMENT COST	SALVAGE VALUE	ANNUAL CAPITAL COST	ANNUAL MAINTENANCE COST*		ANNUAL COST
RF TRANSMITTER	242,000	$48,400.00	$51,071	10%	$24,200	$75,271
RF CONTROL UNIT	600,000	$120,000.00	$126,623	10%	$60,000	$186,623
COAXIAL TRANSMISSION LINE	9,600	$480.00	$791	25%	$2,400	$3,191
ANTENNAE	132,000	$6,600.00	$33,080	10%	$13,200	$46,280
ANTENNAE CASING	21,600	$1,080.00	$5,413	33%	$7,128	$12,541
TOWER AND BASE PLATES	27,200	$1,360.00	$6,817	25%	$6,800	$13,617
HORIZONTAL EXTRACTION PIPIN	114	$0.00	$30	50%	$57	$87
VACUUM/PRESSURE GAUGES	138	$0.00	$36	50%	$69	$105
BLOWER	1,700	$339.96	$359	10%	$170	$529
CATOX TREATMENT UNIT	250,000	$50,000.00	$52,759	10%	$25,000	$77,759
TRUCK & TRAILER	35,000	$7,000.00	$7,386	25%	$8,750	$16,136
FENCING	9,200	$0.00	$2,427	50%	$4,600	$7,027
TOTAL	$1,319,352	$235,260	$284,366		$123,574	$432,140

* OPERATION COSTS INCLUDED IN ODC's

APPENDIX C

DRILLING, SOIL SAMPLING, AND IN-GROUND COMPONENT INSTALLATION

APPENDIX C

DRILLING, SOIL SAMPLING, AND INGROUND COMPONENT INSTALLATION

I. INTRODUCTION

Drilling included pre- and post-demonstration phases. The pre-demonstration drilling included soil sampling at designated depths and the installation of the in-ground RFH/SVE components. Post-demonstration drilling also included collecting soil samples at designated locations and abandonment of wells and borings installed during the pre-demonstration phase. Sampling was performed by a registered geologist according to protocal specified in the Sampling and Analysis Plan. (Halliburton NUS, 1993 and 1994) A Mobile B-61 drill rig was used during drilling, sampling, and well installation and abandonment. The IITRI demonstration was conducted in 1993 and the KAI demonstration in 1994.

II. IITRI DEMONSTRATION

Pre-Demonstration Drilling and Sampling

Drilling activities for the IITRI demonstration began with the installation of 3 dewatering wells on January 22, 1993. A dewatering system was required in order to keep groundwater levels below the tips of the excitor electrodes (see Appendix A.8. for Dewatering System details). The dewatering system consisted of a total of 4 dewatering wells, 1 existing well (PW04) and the 3 installed wells (DW01, DW02, and DW03). The dewatering wells were constructed of 6-inch diameter PVC screen and casing and installed in a 14-inch diameter boring. A clean sand backfill was installed around the screen and a bentonite seal placed on top of the sandpack.

Soil sampling and electrode and thermowell installation began on January 26, 1993, and was completed on February 6, 1993 (see Appendix A.1. for details). A total of 3 dewatering wells, 16 ground electrodes, 4 exciter electrodes, and 7 thermowells were installed for a total of 916.5 feet drilled. Hollow-stem augers were used for soil sample collection and to install electrodes and wells. Table C-1 provides auger sizes used for the different types of borings. Soil samples were collected at designated depths using 3-inch diameter split spoons with stainless steel liners. The liners were removed from the split spoon, sealed with a Teflon film and a plastic cap, labeled and recorded on a chain of custody form, transferred to EPA representatives along with the chain of custody form, prepared for shipment, and shipped to the Radian (Austin) laboratory for analysis. A total of 54 soil samples during the pre-demonstration sampling.

TABLE C-1
DRILLING DATA
IITRI DEMONSTRATION

BORING TYPE	NUMBER OF BORINGS	AUGER SIZE I.D. (inch)	BOREHOLE DIAMETER (inch)	FEET DRILLED	SOIL VOLUME (ft^3)	NUMBER OF DRUMS
PRE-DEMONSTRATION						
DEWATERING WELL	3	10	14	117.5	125.6	
GROUND ELECTRODE	16	4.25	8	446	155.7	
EXCITER ELECTRODE	4	4.25	8	112	41.2	
THERMOWELL	7	4.25	8	241	84.1	
TRACER TEST WELL	1	4.25	8	15	5.6	
SUBTOTALS				**814**	**286.6**	**16**
POST DEMONSTRATION						
SOIL BORING	21	4.25	8	366.5	127.9	
ABANDONMENT	27	3.4	8	719	251	
SUBTOTALS				**1085.5**	**378.9**	**16**

All sampling equipment was decontaminated between samples. The hollow-stem augers used during drilling were taken to the decontamination area established at the Kelly AFB EPCF for decontamination between borings. Stainless steel liners and plastic caps used to collect the soil samples were thoroughly cleaned and wrapped in aluminum foil prior to being used.

The electrodes were placed as specified by IITRI based on site conditions. Some of the electrode borings were drilled deeper than the depth required to set the electrodes. This was necessary to collect soil samples from the designated depths. Boreholes where this occurred were backfilled with bentonite to the depth required to set the electrodes, after the soil samples were collected. Electrodes were set in open boreholes and a special hand-mixed backfill was placed around the electrodes to the surface. Some boreholes required setting the electrodes through the hollow-stem augers to ensure the integrity of the borehole. The sand/clay backfill was prepared on site by mixing sand and clay in the appropriate proportions. A sand backfill was added to the thermowells where the special sand/clay backfill was not required.

At boring EC05 an obstruction was encountered at a depth of 3.8 feet that the augers could not penetrate. A backhoe was used to excavate the obstruction which consisted of 12 pieces of concrete in the fill material. Some of the concrete pieces measured up to 2 feet wide and 2 feet long. The pit that the concrete was excavated from measured 8 feet long, 2.3 feet wide, and 6.5 feet deep. The pit was backfilled with excavated soil and the drilling resumed.

The 286.6 cubic feet of soil cuttings generated during drilling were placed on a plastic liner adjacent to the work area. Approximately 198 cubic feet of soil cuttings were placed and compacted in a one foot thick layer over the heated zone. The remaining 89.6 cubic feet of soil cuttings were placed in 15 drums, labeled, and transported to the Kelly AFB Drum Storage Lot for ultimate disposal.

Post-Demonstration Drilling and Sampling

Post-demonstration drilling and soil sampling began on August 16, 1993 and was completed on August 23, 1993. Soil samples were collected from boreholes drilled adjacent to borings sampled in the pre-demonstration sampling event. The new borings were drilled as close as possible to the existing borings and soil samples were collected from the same depth interval when possible that the sample was collected at in January. In some instances poor sample recovery or obstructions at the original sample depth precluded sampling at the exact same interval. Where this occurred the sample was collected just below the original sample depth where possible. Twenty-one (21) soil borings were drilled for a total of 366.5 feet during the post-demonstration drilling in order to collect soil samples. Hollow-stem augers were used to collect the soil samples.

Additional fieldwork in the post-demonstration drilling phase included abandonment of the soil borings used to collect soil samples as well as abandoning the electrodes and thermowells installed for the demonstration. The electrodes and thermowells were pulled out of the ground using the drill rig and the boreholes were reamed using hollow-stem augers. Of 16 ground electrodes 14 were reuseable. The excitor electrodes were melted inplace and could not be reused. The boreholes were then backfilled with bentonite as approved by the TNRCC. The soil borings were also backfilled with bentonite.

The TNRCC agreed that according to the CAMU concept all soils cuttings could remain on site after the demonstration. Soil cuttings from the post-demonstration drilling were placed on plastic liners when there were no organic vapors detected using an FID. These cuttings were used for site grading backfill during demobilization. For site safety reasons when organic vapors were detected the soil cuttings were drummed. Sixteen (16) drums of soil cuttings were generated and were transported to the Kelly AFB Drum Storage Lot for ultimate disposal.

III. KAI DEMONSTRATION

Pre-demonstration Drilling and Sampling

Fieldwork for the KAI demonstration began on January 10, 1994 with site preparation and pre-demonstration drilling and soil sampling. Three existing wells at the site (S1TW10, S1TW11, and S1PW04) were pulled and abandoned in accordance with TNRCC regulations. The wells were within the demonstration area and required removal.

Pre-demonstration drilling and soil sampling began on January 11, 1994 and was completed on January 19, 1994. A total of 2 antenna, 8 SVE wells, 5 field measurement wells, 6 transducer wells, and 3 thermocouple wells were drilled and installed for a total of 583 feet drilled. Hollow-stem augers of various diameters depending on the type of boring were used (see Table C-2). Soil samples were collected at depths specified in the Sampling and Analysis Plan (Halliburton NUS, 1993). The soil samples were collected using the same methodology used in the IITRI demonstration. A total of 70 soil samples were collected during the pre-demonstration sampling.

The KAI system was installed in the boreholes according to the specifications provided in Appendix B.3. Bentonite and sand backfill were added to the different types of wells as specified. Wells were set inside the hollow-stem augers where the integrity of the borehole was suspect and directly in the boreholes where the boreholes remained open.

Soil cuttings were drummed, labeled, and transported to the Kelly AFB Drum Storage Lot for ultimate disposal. No soil cuttings remained on site except those treated in place. Approximately 203.4 cubic feet of soil cuttings were generated in the pre-demonstration drilling (see Table C-2). Forty (40) drums were used to containerize and transport these cuttings.

Post-demonstration Drilling and Sampling

Post-demonstration drilling and soil sampling began on July 6, 1994 and was completed on July 14, 1994. Post-demonstration drilling and soil sampling activities began on and involved soil sampling and abandonment of the KAI system that was installed in January. Soil samples were collected from boreholes drilled adjacent to borings sampled in the pre-demonstration sampling event. Eighteen (18) new soil borings were drilled adjacent to the boreholes that were sampled in January during the pre-demonstration sampling. A total of 73 soil samples were collected during the post-demonstration sampling. Soil samples were collected from the same depth intervals as the earlier pre-demonstration samples or as close as possible. A total of 434.4 feet was drilled during the sampling phase.

The soil borings were abandoned using the same methodology employed during the IITRI demonstration. The KAI antennae sleeves and various wells were pulled and abandoned. The boreholes were reamed and backfilled with bentonite. The extraction wells and most of the pressure measurement wells had to be overreamed with the piping still in the borehole before the piping could be pulled free of the borehole.

The TNRCC agreed that according to the CAMU concept all soils cuttings could remain on site after the demonstration. Soil cuttings from the post-demonstration drilling were placed on plastic liners when there were no organic vapors detected using an FID. These cuttings were used for site grading backfill during demobilization. For site safety reasons when organic vapors were detected the soil cuttings were drummed. Thirty-five (35) drums of soil cuttings were labeled andtransported to the Kelly AFB Drum Storage Lot for ultimate disposal. Post-demonstration field activities were completed on July 19, 1994.

TABLE C-2
DRILLING DATA
KAI DEMONSTRATION

BORING TYPE	NUMBER OF BORINGS	AUGER SIZE I.D. (inch)	BOREHOLE DIAMETER (inch)	FEET DRILLED	SOIL VOLUME (ft^3)	NUMBER OF DRUMS
PRE-DEMONSTRATION						
ANTENNA SLEEVE	2	6.6	10	55.2	19.3	
VAPOR EXTRACTION WELL	8	4.25	8	193.6	67.6	
FIELD MEASUREMENT WELL	5	4.25	8	126.7	44.2	
TRANSDUCER WELL*	6	4.25	8	143.3	50.0	
THERMOCOUPLE WELL	3	4.25	8	64	22.3	
SUBTOTALS				**582.8**	**203.4**	**40**
POST DEMONSTRATION						
SOIL BORING	18	4.25	8	434.4	151.6	
ABANDONMENT BORING	24	4.25	8	503.5	175.6	
SUBTOTALS				**937.9**	**327.2**	**35**

* Pressure Measurement Well

APPENDIX D

VT DESIGN AND OPERATION

SOIL VAPOR EXTRACTION AND VAPOR TREATMENT SYSTEM DESIGN

I. DESIGN BASIS

The in situ RFH of soil for the enhancement of SVE requires a method of applying a vacuum to extract soil vapor and transfer that vapor to a flare or other treatment system for destruction. The system design incorporated an ejector assembly with transfer piping and operation procedures for integration of the SVE and vapor treatment components.

Design Criteria

Design criteria were estimated from existing site characterization data, assumptions based on past RFH test results, and requirements of air discharge regulations.

Estimated

Maximum vapor flow rate	7,200 scfh
Average vapor flow rate	3,500 scfh
Maximum hydrocarbon concentration	17,000 ppm
Average hydrocarbon concentration	9,500 ppm

Assumed

Maximum vapor temperature	350°F
Normal vapor temperature range	60-300°F
Ejector pressure	-30 inches H_2O vacuum

Required

Maximum flare velocity	60 fps (43 expected)
Hydrocarbon emissions	1 lb/hr (0.07 expected)
Maximum chlorinated hydrocarbon emission rate	24 ppm (6.7 expected)

Design Considerations

The design incorporated an existing flare owned by Kelly AFB. An ejector assembly was designed with few moving parts to be inherently simple, rugged, reliable, and mobile. Uninterrupted operation was required, so all equipment was designed to operate over a 180-day period without major maintenance or repair. Basic flow, temperature, and pressure instrumentation were provided along with vapor sampling ports for process monitoring. There were no provisions to cool the vapor stream or condense water and hydrocarbon vapor removed from the treatment volume. The entire vapor stream was flared. Some condensation occurred within the ejector assembly and flare, particularly during the lower temperature stages of the demonstration. Condensate was captured and transported to the Kelly AFB EPCF for treatment. Site personnel coordinated the deliveries with EPCF personnel to assure the availability of treatment capacity.

Safety Considerations

The concentrations of hydrocarbon vapors generated by the RF source in the infiltrating air might have reached the explosive range. The likelihood was very small, but worthy of consideration. The vapor collection manifold and the inlet section of the ejector assembly posed the greatest risks. The anticipated average hydrocarbon content was less than one percent, well below the lower explosive limit (LEL) of the identified hydrocarbons.

Compressed air (75 psig) served for both motive force and vapor stream dilution. This dilution effect kept the composition of the total stream well below the LEL of any hydrocarbons removed from the ground. The additional air reduced hydrocarbon concentrations approximately 50 percent downstream of the ejectors. The all-steel construction of the ejector assembly can withstand overpressures in excess of 200 psig, and should not have been damaged by ignition of the vapors in the system.

II. PROCESS DESCRIPTION

Extracted vapors flowed from the SVE manifold to an ejector assembly. The ejector assembly consists of a collection header piping, a pair of particulate strainers, and a pair of venturi-type air ejectors. A pipeline transferred the vapors from the ejectors to a flare for destruction.

Collection Header

The collection header piping directed the vapors from the SVE manifold through the strainers and ejectors to the transfer pipeline. The collection header is a mobile, skid-mounted unit that includes and supports the strainers and ejectors.

Strainers

Two strainers are provided to remove any particulates larger than 80 microns. Smaller particles will not harm downstream equipment. The line strainers require periodic cleaning. All flow may be routed to one strainer so one may be cleaned while the other remains in service. A drip leg provided in the piping upstream of the strainers allowed condensate in the collection header to be drained and collected for disposal.

Ejectors

A pair of ejectors, powered by a diesel air compressor, supplied the vacuum to remove vapors from the treated zone. Each was located just downstream of the strainers. Each was sized for one half of the maximum design flow. Only one ejector was operated initially to conserve propane fuel and compressed air. The second ejector was available to increase vapor flow rate and/or vacuum as conditions required. A local rental company was able to assure compressor replacement in an hour or two in case of failure. Each ejector could produce a vacuum of 30 inches H_20.

Transfer Piping

The vapor stream from the ejectors flowed to a seal pot at the flare. The piping was elevated and sloped slightly toward the seal pot so condensed vapors flowed to the seal pot and did not collect in low spots in the transfer line. The line was insulated for 20-foot runs on both ends, and the balance of the line was uninsulated.

Seal Pot

The seal pot was mounted on the trailer with the flare system. The seal pot used water as a seal liquid to prevent back flash to the piping from the flare. During the early stages of the test, some water vapor and hydrocarbons in the extracted vapor condensed and collected in the seal pot. Excess liquid flowed into a collection drum for disposal. Seal water evaporated as vapor temperatures rose during the test. Make-up water was added as necessary to maintain the liquid seal level.

Flare

The flare is an existing package unit supplied by Kelly AFB. Vapors from the seal pot flowed through a flame arrestor to the flare stack. Propane gas was added to the mixed vapor stream before combustion at the flare tip. The flare is equipped with an ignitor and an air blower that provides extra combustion air for smokeless operation.

Instrumentation and Control

The ejector assembly is not designed to operate unattended for extended periods. All instrumentation is local and all controls are manual. Vapor stream pressure and temperature indicators are located at the inlet to the ejectors and at the inlet to the flare seal pot. There is also a pressure indicator on the compressed air line at the inlet to the ejectors. Local flow indicators are provided for compressed air flow to the ejectors and total flow at the flare (extracted vapor plus ejector motive air). Vapor flow was calculated as the difference between the two flows. Compressed air and propane flow are controlled by manual valves located upstream of the flow indicators. A vapor sampling port is located at the inlet to the ejectors. Conditions were expected to change gradually over the test period, requiring regular monitoring and adjustments by the operator on site.

III. SYSTEM DESCRIPTION

Equipment Description

The major elements of the SVE and vapor treatment systems are as follows:

- SVE wells and manifold

- a skid-mounted ejector assembly,

- approximately 150 feet of 3-inch carbon steel transfer pipe (supported every 20 feet, minimum),

- a packaged flare system

See Figure C-1, Process Flow Diagram (PFD) for details (Figure 1).

Utilities Requirements

The system is designed to operate with the following minimum utility support:

- A 185 scfm, 100 psig, diesel-driven air compressor is required to provide motive force to the ejectors.
- 220-volt AC electric power is required to operate the sampling pump and the ignition system at the flare.
- Propane gas is required at the flare for supplemental fuel. Two 1000-gallon liquid propane storage tanks were used during the tests.
- Diesel fuel was required to power the air compressor for the ejector assembly. A 600-gallon storage tank was provided on site during the tests.
- Potable make-up water for the flare seal pot was obtained from a faucet located near the northeast corner of the site.

IV. OPERATING PROCEDURE

Pre-Operation Checks

Flare

Flare Systems, manufacturer of the flare, modified the flare piping system and performed a system check-up.

Fuel Levels

Diesel and propane fuel levels were checked before testing. Only small quantities of fuel are required for air compressor and flare tests.

Air Compressor

The oil level in the compressor and the air hose connections at the compressor and ejector assembly must be checked before starting the compressor.

Pre-Operation Testing

Air Compressor

Start the air compressor and monitor the air pressure. The compressor was designed to deliver 100 psig and 185 scfm. Check the air line for leaks.

Flare

1. Press the "push power on" button on ignition control panel. The fuel solenoid will energize immediately. Ignition will occur in 20 seconds (or as set on control panel).
2. Open the air blower control damper.
3. Push the "push blower on" button.

Note: Additional air supplied by the blower is required only during flare testing. During normal RF system operation, air flow from the ejectors is sufficient for combustion. The damper should be closed and the blower should be turned off.

Shutdown Alarm

1. Disconnect the waterproof plug to ignition control box on flare.
2. The system should go into alarm mode in approximately three minutes.
3. The ignition, blower, and solenoid should shut down in this mode.
4. Reconnect the plug to the ignition control box. The system should restart within 20 seconds.

Ejector Assembly

Note: Test each ejector independently. The valves on the skid are tagged.

1. Open both the upstream and downstream valves to the selected strainer.
2. Open the valve to the selected ejector.
3. Open the compressed air valve to direct air from the compressor through the selected strainer and ejector. Observe the air pressure and adjust to 75 psig. One strainer will be on stream.
4. The vapor and air mixture will flow through the ejector and 3-inch transfer line to the flare system.

System Start-Up

Air Compressor

Start the air compressor. The compressor is oversized to operate in intermittent mode. Adjust the compressor to provide 75 psig.

Ejector Assembly

1. Open the valves upstream and downstream of the strainer(s) to supply air to one or both ejectors, as desired.
2. Adjust the compressed air supply valve to supply approximately 140 scfm (or desired flow) to the ejector(s).
3. Ejector operation can be confirmed by observing the Magnehelic gauges provided to monitor pressure drop across the strainer(s).
4. Vapor extraction can be confirmed by observing the combined air/vapor flow meter at the flare; the combined flow should be substantially greater than the compressed air flow to the ejectors.

Flare

1. Ensure the air blower control damper is shut.
2. Press the "push power on" button on ignition control panel.
3. Turn the propane valve on until flame is visible.
4. If smoke is observed, adjust propane flow until smoking is eliminated.

Miscellaneous Operating Criteria

Diesel and Propane Supply

In order to prevent a fuel shortage, the diesel fuel and propane storage tanks were monitored twice daily and the suppliers were given timely delivery notification of fuel needs. Propane consumption varies with the volume and calorific value of the total vapor mixture. Diesel fuel consumption varies with operating conditions. Usage rates must be closely tracked and storage capacity increased, if required.

Strainer Cleaning

The strainer(s) must be cleaned when the vacuum difference across the strainer exceeds 15 inches H_2O (The pressure difference between the pressure gauge upstream and downstream will indicate the total pressure drop). Use the ejector assembly valves to isolate the clogged strainer. Unplug the strainer cap using a wrench, gloves and respirator (Level C). Remove the screen to a plastic pot. Wash it with potable water at the condensate drum by the flare system. Place the wash water in the condensate drum after cleaning a strainer.

Air Flow Control

The air flow must be monitored to maintain the desired pressures through the system. A globe valve is furnished to throttle the system to maintain the desired air flow rate. A local flow meter is furnished. If the valve is wide open and the vacuum level is not being maintained to at least the minimum requirements of approximately 18 inches H_2O, the second ejector should be brought on stream to maintain the vacuum. The vapor flow rate is determined by the difference between the mixed air and vapor flow meter (F1-004) and the compressed air flow meter (F1-013). To maintain the vacuum level at a minimum of 22 inches H_2O, the compressed air volume should be approximately equal to the vapor volume. Due to specific project requirements for continuous operation, arrangements for a standby compressor were made.

Vapor Sampling

The system is furnished with a peristaltic sampling pump to draw the sample vapor to the gas bag furnished by the laboratory. The pump requires 115-volt power. A modular drive system is furnished as a part of the sampling system to control the motor speed and, accordingly, the pump flow rate to fill the gas bag. The samples were analyzed by a certified laboratory.

Safety

Site-specific Health and Safety Plans addressed safety procedures for each test. In addition to site-specific requirements, the following basic procedures are recommended for any operation of the SVE/VT system.

- An exclusion zone must be maintained around the soils being treated, the SVE and vapor treatment systems, and fuel supply tanks.
- Site personnel must be trained in accordance with 29 CFR 1910 and site-specific requirements.
- Smoking on the site is prohibited. The use of open flame inside the secure area is prohibited during flare operation.
- The surface of the piping system may reach a temperature of 300°F or higher. Gloves are recommended during RFH heating operation.
- Safety shoes and hard hats are required all the times around the equipment.
- Goggles or safety glasses are required.

Condensate

The compressed air flows through the ejector to create up to a 30 inches H_2O vacuum at the ejector to draw the vapor from the main manifold. Downstream of the ejector(s), the air and vapor mixture has a pressure of approximately 2 psig and a temperature range of 200°F to 250°F at the peak of soil heating. Condensate may form as heat is lost in the transfer piping. The condensate drains to the seal pot at the flare system, and overflow from the seal pot is collected in a 55-gallon drum. A drum pump is furnished to transfer the condensate from the drum to a wastewater storage tank. During tests at Site S-1, the storage tank contents were periodically transferred to the Kelly AFB EPCF for disposal. Condensate upstream of the ejectors was collected in 5-gallon bottles and transferred to the wastewater storage tank as required.

Electric Tracing

The piping system on the skid is electric traced and insulated to maintain the skin temperature of the piping to compensate for the heat losses and minimize condensation. The electric tracing control is mounted at the piping surface to monitor the skin temperature. The control maintains the selected temperature automatically. The electric tracing is designed for temperatures up to 250°F.

Flare

A modification of the flare piping at the seal pot was required to allow gravity flow of condensate from the transfer line. The seal pot has a sight glass to monitor the level of the water. The level was controlled manually.

APPENDIX E

BIOASSAY DATA

THE UNIVERSITY OF TEXAS AT SAN ANTONIO
6900 North Loop 1604 West
SAN ANTONIO, TEXAS 78249-0662
(210) 691-4458
FAX: (210) 691-5658

COLLEGE OF SCIENCES AND ENGINEERING
Division of Life Sciences

25 August 1994

Mr. Clifton Blanchard
Brown & Root
800 Oak Ridge Turnpike, Suite A600
Oakridge, TN 37830

Dear Mr. Blanchard:

We have completed the bacterial analyses of soil samples collected on July 12, 1994, at Kelly AFB (NUS Project No. 3688). The results are tabulated on the accompanying page, along with the results from the first sampling at that site.

Compared to samples taken in February, 1993, microbial levels were reduced for all classes of bacteria enumerated in the July samples. However, the soils are not "sterile". The lack of recovery of oil-degrading bacteria from two of the samples is surprising in light of the fact that both total heterotrophic bacteria and phenanthrene-toluene degrading bacteria were recovered. Suspecting a problem with the oil agar used in the original assay, we repeated this analysis with plates from a different medium lot; however, results again showed very low numbers of bacteria growing on oil agar plates.

If can provide any additional information, you may reach me at [210] 691-4473.

Respectfully,

Barbara E. Moore, Ph.D.

enc.

NUS Project 3688
Kelly Air Force Base
San Antonio, Texas

Date	Sample No.	Colony-forming units/gm of soil Total Heterotrophs	Degraders on: Oil	 P-T*
19 Feb 1993	KS1-BM01-U0406	6.3×10^5	5.5×10^5	6.0×10^5
	KS1-BM01-U1416	9.0×10^5	1.3×10^6	1.2×10^6
	KS1-BM01-U1719	1.7×10^7	2.1×10^7	2.0×10^7
12 Jul 1994	KRF-BS1-U0608	1.0×10^3	$<1.0 \times 10^2$	1.3×10^3
	KRF-BS2-U1416	1.5×10^5	5.0×10^2	7.2×10^5
	KRF-BS3-U2022	1.2×10^4	$<1.0 \times 10^2$	3.1×10^4

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* Phenanthrene-Toluene

SOIL SAMPLING FOR BIO - MASS CHARACTERIZATION

Procedures for soil sampling for bio - mass characterization are presented as discussed and outlined by Mr. Harlan McLaughlin of the University of Texas San Antonio, as follows:

1. Three samples will be collected above the saturated zone by conventional soil boring techniques.
2. The samples will be collected at depths of 6, 14, and 20 feet (above the saturated zone and/or gravel).
3. Soil will be placed in new quart (large) zip lock baggies with the minimum of handling.
4. Samples will be immediately transported to the UTSA laboratory and turned over to laboratory personnel ~~(Dr. Neal Gintzel or Mr. Harlan McLaughlin~~ at [210]691-4473. Proper chain of custody procedures will be followed. Dr. Barbara Moore
5. Health and safety procedures for soil sampling will be followed.
6. Trip blanks, rinsate blanks and field duplicates are not required
7. Soil will be examined for total heterotropes, oil degraders, and Phenathene/toluene degraders. Sufficient soil will be stored for 60 days for possible further examination.

Contact ~~Dr.~~ Moore to set-up delivery. & get directions to the lab.

APPENDIX F

GROUNDWATER ANALYSIS

cc: CFB

SAIC®
Science Applications International Corporation
An Employee-Owned Company

March 21, 1994

Mr. Clif Blanchard, P.E.
Brown & Root Environmental
800 Oak Ridge Turnpike, Suite A-600
Oak Ridge, TN 37830

Re: EPA Contract No. 68-C0-0048, WA 0-49
<u>SAIC Contract No. 01-0832-07-1123-xxx</u>

Dear Mr. Blanchard:

Enclosed are the results of groundwater sampling conducted on January 14-19, 1994 at Kelly AFB. These data have not been through the complete quality control review process and should be considered draft.

I have also enclosed an agenda for the March 31st Visitor's Day for the KAI radio frequency heating process. Please note the Brown & Root representative will speak between 9:40 and 10:00.

If you have any questions or comments, please call be at (513) 723-2600, ext. 2608.

Sincerely,

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

Peggy Groeber

Margaret M. Groeber

MMG/kml

Enclosure

cc: C. Dial, SAIC
L. Drees, SAIC

s9b:blanchard.ltr

635 West Seventh Street, Suite 403, Cincinnati, Ohio 45203 • (513) 723-2600 • FAX: (513) 723-2605
Other SAIC Offices: Albuquerque, Boston, Colorado Springs, Dayton, Huntsville, Las Vegas, Los Angeles, McLean, Oak Ridge, Orlando, Palo Alto, Seattle, Tucson

DRAFT

Results of groundwater samples from SAIC-KAI project

The following summarizes the results from the groundwater samples submitted to Radian for analysis. The sampling dates were 1/14/94, 1/18/94 and 1/19/94. Attached to each SAIC result summary and critique, are the actual lab summary sheets and any comments the lab had for the analysis. Specific comments concerning the individual groundwater samples appear as separate line items in these comments.

The SAIC summary contains the results that are considered to be usable. Reasons that some results appear in the laboratory summary sheets but not on the SAIC summary sheet is discussed following each sample.

DRAFT

Sample ID: KRF-10-GW114

Lab IDs: 9401253-14A (TRPH)
9401254-11A (Volatiles)
9401255-10A (Semi-volatiles)

Test Parameter	Result
TRPH	4.92 mg/L
Volatiles (all results are as ug/L)	
Acetone	61.9
Benzene	782
Chlorobenzene	25,500
Trans-1,2-Dichloroethene	14.0
Methyl Ethyl Ketone	16.4
4-Methyl-2-Pentanone (MIBK)	11.5
Toluene	51.2
Vinyl Chloride	28.0
Semi-volatiles (all results as ug/L)	
2,4-Chlorophenol	36.3
2-Chlorophenol	193
1,2-Dichlorobenzene	11,200
1,3-Dichlorobenzene	760
1,4-Dichlorobenzene	2160
2-Methylnaphthalene	16.2
Naphthalene	121
Phenol	22.3
1,2,4-Trichlorobenzene	51.4

There is no concern about the TRPH result.

Concerning the volatile results, the laboratory raw data sheets have results for ethylbenzene and xylene as 101 ppb and 276 ppb respectively. The reasons that they are not included are as follows. First, the internal standard used to quantitate these compounds did not pass QC requirements. This is also the reason the one surrogate compound was out of limits (see lab comments). Secondly, the sample was diluted and rerun, but the dilution results do not match up with the undiluted sample. These two compounds are probably present since they appear in amounts well over the detection limits. The actual result can only be guessed at from the lab data presented. Any other results that appear in the raw data sheets, but do not appear in the SAIC summary, were judged to be too near detection limits to be reliable.

For the semi-volatile analysis of this sample, one of the six surrogate compounds (nitrobenzene-d5) added prior to sample extraction did not pass QA/QC requirements. The lower limit for recovery of this compound is 59%. Analysis of the sample and a rerun of the sample yielded 56% and 58%. This is not cause to question the validity of the results for this sample. Any other results that appear in the raw data sheets, but do not appear in the SAIC summary, were judged to be too near detection limits to be reliable.

Sample ID: KRF-09-GW118

DRAFT

Lab IDs: 9401310-11A (TRPH)
9401311-06A (Volatiles)
9401312-05A (Semi-volatiles)

Test Parameter	Result
TRPH	0.834 mg/L
Volatiles (all results are as ug/L)	
Benzene	596
Chlorobenzene	12,000
Ethylbenzene	91.9
Toluene	5.65
Vinyl Chloride	10.2
Xylenes	12.0
Semi-volatiles (all results as ug/L)	
2-Chlorophenol	37.4
1,2-Dichlorobenzene	163
1,3-Dichlorobenzene	23.5
1,4-Dichlorobenzene	183
2-Methylnaphthalene	59.2
Naphthalene	71.1
Phenol	3.58

There is no concern about the TRPH result.

Concerning the volatile results, one of the three surrogate compounds (bromofluorobenzene) added to the sample prior to analysis exhibited high percent recovery. The upper acceptable limit is 115%, and the sample had a recovery of 130% for this compound. Since the rest of the QA for the analysis was acceptable, the results are judged to be usable. Any other results that appear in the raw data sheets but do not appear in the SAIC summary were judged to be too near detection limits to be reliable.

There are no concerns with the semi-volatile analysis of this sample.

DRAF

Sample ID: KRF-DW02-GW119

Lab IDs: 9401349-05A (TRPH)
9401350-05A (Volatiles)
9401351-04A (Semi-volatiles)

Test Parameter	Result
TRPH	267 mg/L
Volatiles (all results are as ug/L)	
Chlorobenzene	15,500
Semi-volatiles (all results as ug/L)	
Acenaphthene	7.79
2-Chlorophenol	22.1
1,2-Dichlorobenzene	1820
1,3-Dichlorobenzene	152
1,4-Dichlorobenzene	529
bis (2-ethylhexyl) phthalate	218
Fluoranthene	29.3
Fluorene	7.51
2-Methylnaphthalene	124
Naphthalene	86.8
Phenanthrene	7.17
1,2,4 Trichlorobenzene	15.5

There is no concern about the TRPH result.

Concerning the volatile results, the only usable result is chlorobenzene. The laboratory only analyzed a dilute portion of this sample. This dilution may have brought other compounds that were present to below detectable levels. The laboratory states in the comment section that the sample had a strong "fuel" odor. It is assumed the laboratory did not want to damage their analytical instrumentation by analyzing the sample undiluted. Other compounds that appear at elevated levels are methylene chloride and carbon disulfide. These compounds were also found in the laboratory and field blanks for this day. After this is accounted for, the results become too close to the detection limits of the analysis.

For the semi-volatile analysis of this sample, one of the six surrogate compounds (2,4,6 Tribromophenol) added prior to sample extraction did not pass QA/QC requirements. The upper limit for recovery of this compound is 123%. Analysis of the sample yielded 151%. Since all other QA criteria for this analysis were acceptable, the results are considered usable. Any other results that appear in the raw data sheets, but do not appear in the SAIC summary, were judged to be too near detection limits.

APPENDIX G

AIR FORCE TECHNICAL ORDER 31Z-10-4, CHAPTER 6

CHAPTER 6

RF POWER DENSITY/HAZARD DISTANCE

SECTION I - RF PROPAGATION

6-1. GENERAL.

a. Hertzian, or radio, waves propagated into space are considered to be a radiant form of energy, similar to light and heat. The waves travel at a speed of approximately 300,000,000 meters per second, or 186,000 miles per second. The radio-frequency portion of the electromagnetic spectrum is theoretically considered to include all frequencies from 0.01 megahertz to 3,000,000 megahertz. This theoretical concept includes a portion of the infrared band, as shown in figure 6-1. However, from the practical standpoint, the radio-frequency spectrum is assumed to extend from 0.01 megahertz (very low frequency) to 300,000 meghertz (extremely high frequency).

b. The wavelength of any radio wave in free space can be determined by using the equation:

$$\lambda = \frac{v}{f}$$

where λ is the wavelength in meters, f is the frequency of the radiation in hertz, and v is the velocity (speed) in meters per second (300,000,000). Thus, a 3-MHz radio wave has a wavelength of 100 meters, while a 30,000-MHz radio wave has a wavelength of 0.01 meter, or 1 centimeter.

c. The radio-frequency spectrum includes frequencies with other designations such as radar, microwave, infrared, etc.

d. The term "microwave" applies to a somewhat arbitrary range or band of frequencies, but is generally intended to mean a band of frequencies between 300 MHz (1 meter in wavelength) and 300,000 MHz (0.1 cm in wavelength), and includes frequencies normally used by radar. The fact that the shorter wavelengths of the microwave band approach the wavelengths of infrared rays is important. It suggests that the biological effects which result from exposure to microwaves are related to the thermal effects associated with the infrared spectrum.

6-2. PROPAGATION OF ELECTROMAGNETIC ENERGY.

a. Wave Theory. Assume that an alternating current is applied to a closed loop of wire of infinite length, i.e., an infinite line. At the instant the current begins to flow, a magnetic field builds up around the conductor, with its lines of force circling the conductor and traveling in the direction given by the right-hand rule (assuming conventional current flow). The magnetic field continues to build up, until maximum strength is reached when the current reaches its maximum value. The field then begins to decrease as the current decreases to zero. As the current begins to increase in the negative direction during the second half cycle of the alternating current, the magnetic field again builds up about the conductor, but with the lines of force traveling in the reverse direction. Thus, the lines of force expand and collapse along the conductor, in phase with the current flowing through it. This is illustrated in (a) and (b) of figure 6-2.

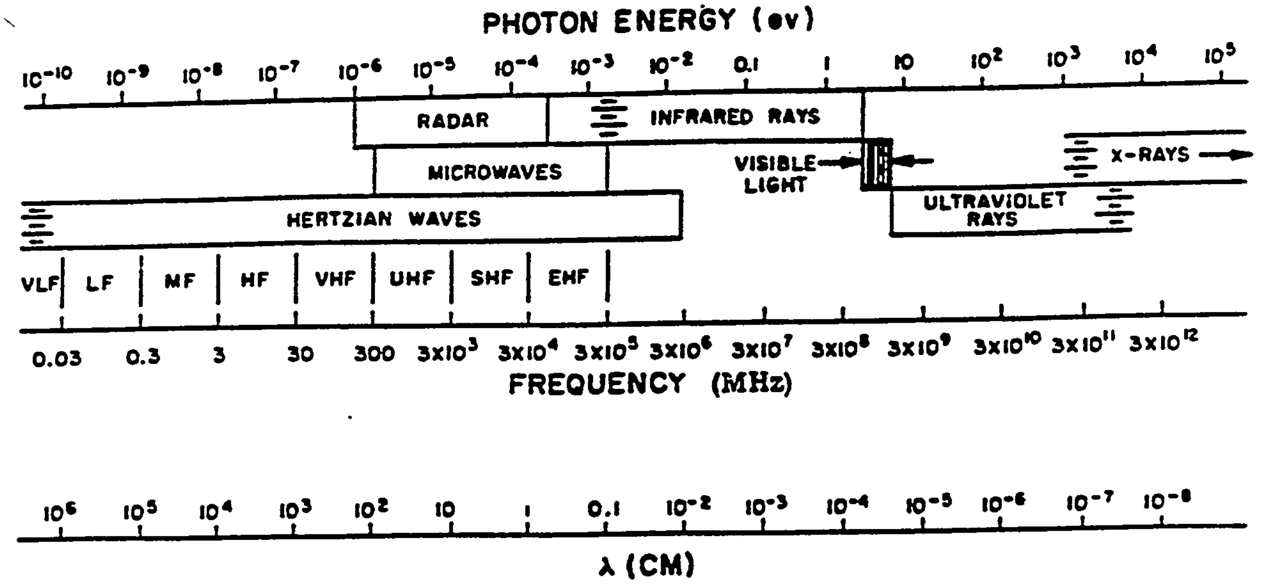


Figure 6-1. Portion of Electromagnetic Spectrum, Showing Relationship of Microwave Radiations to Other Electromagnetic Radiations

b. Induction and Radiation Fields.

(1) It would be expected that, when the lines of force had reached a maximum value, all of them would begin to collapse toward a zero value as the current decreases to zero at the end of the half cycle. For some unknown reason, however, not all of the lines of force collapse. Instead, a small percentage of the lines of force, or magnetic field, continues outward from the conductor, into space. The percentage of the field which does not return to the conductor is extremely small at low frequencies of the alternating current, but as the frequency is increased, the percentage increases to a point where, at extremely high frequencies nearly all of the field continues outward from the conductor.

(2) The percentage of the field which returns to the conductor at the end of each half cycle is known as the "induction field," while the remainder of the field which does not return is termed the "radiation field."

c. Electric and Magnetic Fields.

(1) Although nothing has been said about the characterisites of a particular antenna, it is obvious that this element should be used in describing the principles of radiation. When power is applied to an antenna, two fields are set up by the applied energy; the induction field, which is associated with the stored energy, as described in paragraph 6-2b(2), and the radiation field, which moves through space at approximately the speed of light. At the antenna the intensities of these fields are large, and are proportional to the amount of power being delivered to the antenna. At a short distance from the antenna, and beyond, only the radiation field prevails. The radiation field is made up of an electric component, known as the "electric

field" (E field), and a magnetic component, which is termed the "magnetic field" (H field). These two fields (E and H) vary together in intensity, but their directions are at right angles to each other in space, and both are at right angles to the antenna from which they were radiated. The relative directions of the E and H fields, and their relation to the alternating current in an antenna of infinite length, are shown in (b) and (c) of figure 6-2. It should be kept in mind that the illustration shows the fields which exist about the antenna at a single instant of time. As time progresses, from the left side to the right side of the illustration, the applied current will fall to a negative value, with corresponding changes in the polarity of the magnetic and electric fields along the antenna.

(2) As time passes, the lines of force, or flux lines, shown in (b) and (c) of figure 6-2, expand radially with the velocity of light, and new flux lines are generated at the antenna to replace those that travel outward, as in (d) and (e) of figure 6-2. In this manner oscillating electric and magnetic fields are produced along the path of travel. The variations in the magnitude of the electric component (E field) and those of the magnetic component (H field) are in time phase, so that at every point in space the time-varying magnetic field induces a difference in voltage, which is the electric field. The electric field also varies with time, and its variation is equivalent to a current which is called the "displacement current." This displacement current establishes a magnetic field in precisely the way that a conduction current does. In summary, the varying magnetic field produces a varying electric field, and the varying electric field, through its associated displacement current, sustains the varying magnetic field. Each field supports the other, and neither can exist by itself, without setting up the other. Together, they are termed the "electromagnetic field."

d. Polarization.

(1) At a distance from the radiating antenna, the circular pattern of the lines of force of the electric field becomes less apparent, and the lines appear to be straight lines, as in (e) of figure 6-2. It should be noted that these lines of the electric field (E lines) are in effect parallel to the radiating antenna. When these lines are in a horizontal plane, being radiated from an antenna which is horizontal in space, the electric wave is said to horizontally polarized, as are the lines in (e) of figure 6-2. If the antenna is vertical in space, and the E lines of the electric field are in a vertical plane, the electric wave emitted from the antenna is said to be vertically polarized. The reference in both cases is taken from the earth's surface.

(2) Another type of polarization, which has found application in many radar equipments, is known as "circular polarization." In electronic countermeasures and telemetry systems, circularly polarized antennas are used to permit equal reception of signals without regard to their plane of polarization. They are used in ground radar systems for the reduction of rain and snow return. A circularly polarized wave has two components which are simultaneously at right angles in space and in phase quadrature. At a given instant of time, when the vertically polarized component is at +E max, the horizontally polarized component is at zero and rising in a positive direction. The electric field produced at points along the axis of propagation is the vector sum of the two waves. Since the vertical component leads the horizontal component, the resultant field rotates in a clockwise direction, and since both fields vary at the same frequency, the resultant field rotates at one complete revolution per cycle.

(3) When the vertical and horizontal components are equal in amplitude, the resultant field vector describes a perfect circle, and the resultant wave is said to be circularly polarized. If the vertical and horizontal components are not equal in amplitude, the resultant rotating field vector will describe an ellipse, and the resultant wave is said to be elliptically

polarized. In spite of its apparent rotation, the circularly polarized field consists of, not one wave, but rather two waves. Because of their phase and frequency requirements, both waves must obviously be developed by the same generator.

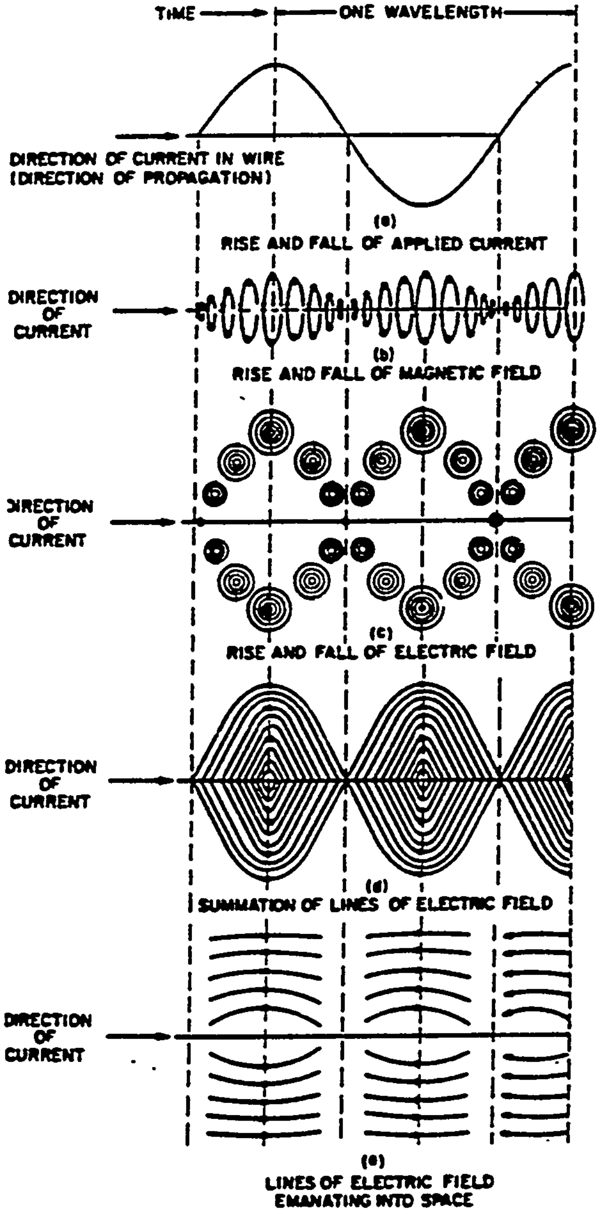


Figure 6-2. Creation of Electric and Magnetic Fields About a Conductor Carrying an Electric Current

(4) Four common methods are used to develop a circularly polarized wave. First, vertical and horizontal dipoles are spaced a quarter wavelength apart and fed, in phase, from the same source. Second, vertical and horizontal dipoles are crossed at the same point, and one is fed directly while the other is fed through a 90-degree phase-shifting network. Third, a circular waveguide flared into a feedhorn is fed by two probes located at right angles in phase quadrature. Fourth, a 45-degree lens is used to divide the incident wave into two perpendicular components while advancing the phase of one component by 90 degrees.

(5) It is important to note that, in discussing circular polarization, a circularly polarized antenna which radiates a clockwise rotating field will not receive a counterclockwise rotating field. Circularly polarized reflections from conducting surfaces retain the direction of rotation of the transmitted signal, but those from dielectric boundaries such as precipitation have their direction of rotation reversed.

(6) Occasionally it is desired to measure circular polarization. This may be done using either a conical horn or a conventional dipole antenna to pick up the signal. If a conical horn is used, no regard need be paid to horizontal or vertical polarization. The horn is directed toward the radiating source so that maximum power is picked up, and the power is indicated directly by the meter in the conventional manner. If a conventional dipole antenna is used, the vertical polarization component and the horizontal polarization component must be measured separately, and the total power calculated. The dipole should be held with its axis parallel with the ground, and its elements should be slowly rotated while the meter is carefully observed. If the wave is truly circular, the meter indication will remain constant throughout the full 360 degrees of dipole rotation, and equal powers in both horizontal and vertical polarization may be read. If the wave is elliptical then maximum and minimum readings will be noted, displaced at 90-degree intervals. The maximum and minimum may not necessarily occur when the dipole elements are exactly horizontal or vertical with respect to the earth, because the ellipse may be tilted. This is the reason for rotating the antenna slowly, so that the highest and lowest readings may be noted and recorded.

(7) The meter readings obtained in the preceding paragraph may be used to calculate the total power in the following manner: Assume that a circularly polarized wave is indicated, by obtaining a constant reading of 0.02 watt per square centimeter as the antenna is rotated. The reading is 0.02 watt/cm^2 with the dipole held in a horizontal plane; it remains at 0.02 watt/cm^2 with the dipole in a vertical plane. Solving for total power:

$$P_t = 0.02 + 0.02 = 0.04 \text{ watt/cm}^2$$

The total power in the circularly polarized wave is therefore 0.04 watt/cm^2. It should be noted that the accuracy of this measurement is based on the assumption that the field density meter (densiometer) used in taking the measurements is calibrated for use with the dipole.

(8) If an elliptically polarized wave is indicated by maximum and minimum meter readings as the antenna is rotated, the total power may be calculated in the same manner as that used for circular polarization in the preceding paragraph. For example:

Assume maximum reading = 0.04 watt/cm^2

Assume minimum reading = 0.015 watt/cm^2

$$P_t = 0.04 + 0.015 = 0.055 \text{ watt/cm}^2$$

e. Field Intensity.

(1) The conventional measure of the field intensity of a radiated wave is a measure of the intensity of the electric field. This intensity usually is expressed in microvolts per meter, and is a measure of the dielectric stress produced by the electric field, or the voltage induced in a conductor 1 meter long when positioned so that it lies in the direction of the electric field and at right angles to both the direction of the magnetic field and to the direction of propagation. For example, assume that a conductor which is 100 feet long and has constant conductivity throughout its length is energized with a battery of 100 volts. If the leads of a voltmeter are touched to the conductor at points exactly 1 foot apart, the meter will indicate 1 volt. Therefore, the voltage drop along the conductor is 1 volt per foot. This is in accordance with Kirchhoff's law, which states that the sum of the voltage drops around any closed circuit is equal to the applied voltage.

(2) In a similar manner, suppose that a transmitter excites a dipole antenna, and that another dipole 1 meter long is placed some distance away to receive the transmitted energy. If a voltmeter is used to measure the voltage drop across the receiving dipole and the voltage reads 1 volt, the field intensity at this point in space is 1 volt per meter.

(3) The relationship of voltage, current, and power to area may be seen as follows: If two very sharp metallic points are used as a spark gap, a potential of 40,000 volts will easily leap across a 1.5 inch gap. If however, two brass balls 1.5 inches in diameter are used as the spark gap electrodes, the spacing will have to be reduced to approximately 1/2 inch before 40,000 volts will jump across the gap. The reason for this is that the increase in the surface area of the electrodes reduces the voltage per square inch of surface. Considering the aspect of power, a figure of 1000 amperes per square inch of cross-sectional area is sometimes used in selecting the size of copper bus bars for power distribution. On the basis of this figure, a bus bar which measures 2 inches wide by 2 inches thick, or has a cross-sectional area of 4 square inches, can carry a current of 4000 amperes.

(4) Now that the relationship between voltage, current, or power and the length or area of a conductor has been shown, the power in an rf field may be considered. Suppose that a horn antenna which has an aperture of 5 centimeters by 10 centimeters is 100 percent efficient and that the physical and effective apertures are identical. The area is then 50 square centimeters. If 50 watts of power is fed to the horn, the power may be considered to distribute itself evenly across the aperture (this may not be absolutely true in practice, but is assumed to be true in this case for a theoretical explanation), and the power density across the aperture will be 1 watt per square centimeter. If a person should inadvertently stand directly in front of this horn, he would be exposed to a power density of 1 watt per square centimeter, which is an extremely high and hazardous power level.

(5) The field intensity of a radiated wave falls off in direct proportion to distance between the transmitting and receiving antennas. For example, if the received field intensity of a signal is 50 microvolts per meter at a distance of 25 miles, then at 50 miles, or twice the distance, the field intensity is one-half as much, or 25 microvolts per meter. Thus, electric field intensity (when measured in terms of voltage, e.g., microvolts per meter) varies inversely with the distance from the transmitting antenna.

(6) In order to understand this variation of the field intensity of a radiated wave, it is essential to consider the relationship between the power radiated and the field intensity. The power of a radiated wave, such as a light wave, falls off as the square of the distance between the source of light and the point of measurement. A sheet of paper held perpendicular to the

rays of a candle at a certain distance from it will be lighted four times as brightly as one held at twice this same distance, because the given amount of light must spread out to cover four times as great an area on the paper which is only twice as far from the candle as the first one. This law is expressed by the formula:

$$A = 4\pi r^2$$

where A is the area of the portion of the surface of a sphere of radius r, having its center at the source of the light. This same law holds for the field intensity of electromagnetic waves when the power intercepted per unit area is considered. However, since electric power expressed in terms of the voltage present is propotional to E^2 (because $P = E^2/R$), then the square of the voltage falls off as the square of the distance, or the voltage itself falls off directly as the distance.

(7) The power flow through a unit area at a distance D from an isotropic antenna is found by dividing the total radiated power by $4\pi D^2$. However, if a directive antenna is used, the energy is concentrated in certain directions, and the distribution over the sphere is not uniform. In this case, the power flow through a unit area at a given distance differs by a factor, G, from that which would be produced by an isotropic antenna. This factor G is called the "gain" of the antenna. The greater the concentration of energy in a given direction, the greater the gain will be in that direction. By definition, an isotropic antenna has a gain of 1 in all directions. A directive antenna has a gain greater than 1 in some directions and less than 1 in other directions. However, the average of the sum of the gains in all directions, or the total gain taken over the entire sphere, must be equal to 1.

(8) Antenna gain may be calculated from the formula $G = 4\pi A/\lambda^2$, where A is the area of the antenna aperture, and λ is the wavelength of the transmitted signal. The units for A and λ must be the same. This formula is derived as follows: Using an aperture with dimension L in both directions, the angular width of the beam determined by diffraction is approximately λ/L radians. The radiated power is then concentrated in a solid angle beam of λ^2/L^2. An isotropic antenna should spread the same power over a solid angle of 4π. Therefore, the gain in concentration of energy is equal to:

$$\frac{4\pi}{\lambda^2/L^2} = \frac{4\pi L^2}{\lambda^2}.$$

Since L^2 equals the area of aperture A, then the gain $G = \frac{4\pi A}{\lambda^2}$.

(9) Before an equation for the attenuation of radio waves in free space can be derived, one other factor, known as the effective receiving cross-section of the antenna, must be defined. The effective cross-section is equal to the total signal power available at the antenna terminals divided by the power density (power per unit area) of the incident wave. In most cases, this cross-section is different from the actual physical area of the antenna. The effective cross-section is a quantity which tells the effectiveness of the antenna in capturing the power in the incident wave. If all of the energy incident on aperture A is absorbed, then the effective cross-section is equal to the area of the aperture. The formula for effective cross section is:

$$A_R = \frac{G\lambda^2}{4\pi}$$

(10) All of the discussion so far concerning free-space propagation can be summarized by providing the equation for power received over a free-space circuit. This equation is:

$$P_R = P_T\left[\frac{G_T A_R}{4\pi D^2}\right]$$

where: P_R = total power at the output terminals of the receiver antenna
P_T = power input to the transmitter antenna
A_R = effective cross-section of the receiver antenna
G_T = gain of the transmitter antenna
D = distance between antennas

This equation shows the inverse relationship between the received power and the distance. It also shows that the received power is directly dependent upon the amount of power transmitted, the gain of the transmitter antenna, and the effective cross-section of the receiving antenna. Assuming that isotropic antennas are used, G_T is equal to 1 and A_R is equal to $\lambda^2/4\pi$.

f. Transmission in Free Space.

(1) There is a certain amount of attenuation, or loss, of energy for radio signals transmitted in free space. This loss is due to the spreading of energy over a greater area as the transmission distance is increased. The loss is directly related to the frequency and transmission distance. The formula for free-space loss is:

$$L_{FS} = 37 + 20 \log F + 20 \log D$$

where: L_{FS} = ratio of transmitter power to receiver power, in dB
F = frequency, in MHz
D = transmitted distance, in miles (statute)

An understanding of the above formula is necessary in order to understand all other propagation losses. This important formula is developed and explained in the following paragraphs.

(2) Theoretically, free space transmission can be realized only if the transmitting and receiving antennas are isolated in unbounded, empty space. For practical purposes, however, it is realized if the following conditions are fulfilled: No large obstacles intervene between the two antennas along an optical line of sight; no alternate transmission path can be followed by a substantial fraction of the radiated energy; the intervening atmosphere has a constant index of refraction, so that no bending of the wave occurs at the particular frequency used; the intervening atmosphere does not absorb energy from the wave at the frequency used. If these conditions are fulfilled, the transmitted wave will have spherical wavefronts, and these wavefronts will spread out so that the intensity of radiated energy varies inversely as the square of the distance. The intensity of energy is the power per unit of area on the spherical wavefront.

(3) The relationship between intensity of energy and distance is illustrated in figure 6-3, which shows part of the pattern of radiated energy from an isotropic antenna in free space. An isotropic antenna both radiates energy uniformly in all directions and receives energy uniformly from all directions. In figure 6-3, let A be a given unit of area on the surface of a sphere at a distance D_1 from the isotropic antenna. The total area of the entire sphere at this distance is $4\pi D_1^2$. Since power is distributed uniformly over the entire area of the sphere, the fraction of the total power which falls on area A is equal to $A/4\pi D_1^2$. Now increase the distance D_2 and consider the intensity of energy on the same area A on the sphere has increased, the area A has now become a smaller fraction of the total area. Thus, the fraction of total power incident to A decreases with increased distance from the free-space circuit, the total received power is calculated according to the formula:

$$P_R = P_T \left[\frac{\lambda^2/4\pi}{4\pi D^2} \right] = P_T \left[\frac{\lambda^2}{4\pi} \right] \left[\frac{1}{4\pi D^2} \right] = P_T \left[\frac{\lambda^2}{16\pi^2 D^2} \right]$$

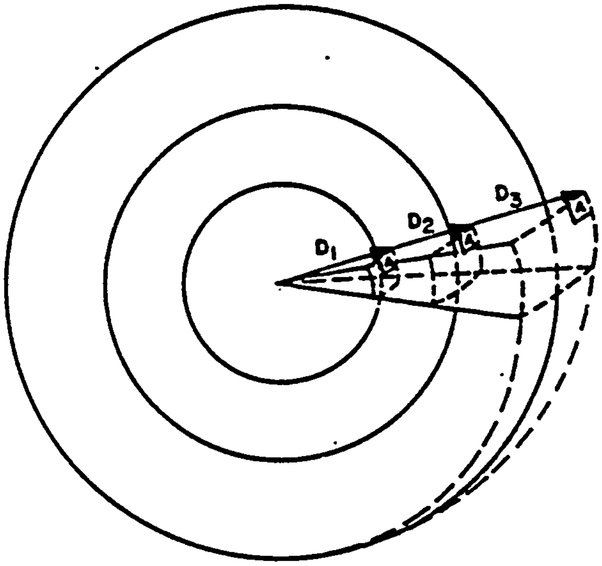


Figure 6-3. Change in Intensity of Radiated Energy with Distance in Free Space Over a Given Area

(4) Free-space loss, or attenuation, is the difference between the input power to the transmitting antenna and the output from the receiving antenna, or $P_T - P_R$, assuming isotropic antennas in both cases. This free-space loss in decibels is equal to $10 \log \frac{P_T}{P_R}$. Using the expression developed in the preceding paragraph for received power with isotropic antennas, the formula for free-space loss is developed as follows:

$$\frac{P_T}{P_R} = \frac{16\pi^2 D^2}{\lambda^2}$$

If the frequency, F, is expressed in megahertz, and the speed of radio waves, C, in miles per second, then:

$$\lambda = \frac{C}{F} = \frac{186000 \times 10^{-6}}{F} = \frac{0.186}{F}$$

Therefore:

$$\frac{P_T}{P_R} = \frac{16\pi^2 D^2}{\left[\frac{0.186}{F}\right]^2} = \frac{16\pi^2 D^2 F^2}{0.186^2}$$

In decibels, free-space loss is given by the following formula:

$$L_{FS} = 10 \log \left[\frac{16\pi^2 D^2 F^2}{0.186^2}\right]$$

$$= 10 \log 16 + 20 \log \pi + 20 \log D$$

$$+ 20 \log F - 20 \log 0.186$$

Removing the constants $10 \log 16 + 20 \log \pi - 20 \log 0.186$, which equals 37, the final expression for free-space loss in dB, with F in megahertz and D in miles (statute), is:

$$L_{FS} = 37 + 20 \log D + 20 \log F$$

NOTE

This is only applicable in the far field of an antenna. Refer to paragraphs 6-3h and 6-7 for information on near field, far field and near-field gain reduction.

(5) To illustrate the usage of the above formula, consider the following example:

Find the free-space loss over a circuit covering a distance of 100 miles between the transmitting and receiving antennas, using a transmitting frequency of 1000 megahertz.

$$L_{FS} = 37 + 20 \log 100 + 20 \log 1000$$

$$= 37 + (20 \times 2) + (20 \times 3)$$

$$= 37 + 40 + 60 = 137 \text{ dB}$$

> This means that the output from the receiving antenna will be down 137 dB from the power input to the transmitting antenna because of free-space loss alone, assuming isotropic antennas. Expressed in another way, the received power is approximately 0.00000000000001 of the transmitter power input.

It can be seen from this example that free-space loss introduces a substantial attenuation to the transmitted signal. This is the basic loss which occurs for all types of radio transmissions. For line-of-sight circuits where the conditions for propagation in free space are closely approximated, the total loss can be considered to be free-space loss. However, for long-distance transmission, where either ground wave, sky wave, or scatter propagation is used, other losses are introduced by the effects of the earth and the atmosphere. Each of these losses must be added to the free-space loss, to find the total loss or attenuation to the transmitted signal.

6-3. TRANSMISSION OF RF ENERGY.

a. General. The radiated waves from an antenna travel through space in all directions. Some of the waves travel along the surface of the earth, and are greatly affected by the earth and its terrain. These waves are collectively called "ground waves." Other waves travel upward and away from the earth's surface, and may or may not return depending upon the conditions in the upper atmosphere and beyond. These waves are called "sky waves."

b. Ground-Wave Propagation. Generally, ground wave propagation refers to the transmission of energy which does not make use of reflections from the ionosphere. Ground waves may take a direct or reflected course from the transmitter to the receiver, or they may be conducted by the surface of the earth or reflected in the troposphere. The resulting ground wave, therefore, may be composed of one or more of the following components: the direct wave, the ground- reflected wave, the surface wave, and the tropospheric wave.

(1) Direct-Wave Component. The direct wave is that component of the entire wave front which travels directly from the transmitting antenna to the receiving antenna. It is limited only by the distance from the transmitter to the horizon, or line-of-sight, plus the small additional distance due to atmospheric diffraction of the wave around the curvature of the earth. The intensity of the electric field of the direct wave varies inversely with the distance. The direct wave is not affected by the ground or by the earth's surface, but it is subject to refraction in the tropospheric air between the transmitter and receiver.

(2) Ground-Reflected Component. The ground-reflected wave is that component of the entire wave that reaches the receiving antenna after being reflected from the ground or from the sea. Upon reflection from the earth's surface, the reflected wave is reversed 180 degrees in phase; this fact is important in determining the resultant effect when the reflected wave combines with the direct wave at the point of reception. Since the ground reflected wave travels a longer time in reaching its destination than does the direct wave, its phase is displaced an additional amount over and above the 180-degree shift caused by reflection.

(3) Surface-Wave Component. The surface wave is that component of the entire wave that is affected primarily by the conductivity and dielectric constant of the earth, and is able to follow the curvature of the earth. When both the transmitting and receiving antennas are either on, or close to, the ground, the direct wave and the ground-reflected wave tend to cancel each other, and the remaining field intensity is principally that of the surface wave. The surface wave extends to considerable heights above the earth's surface, diminishing in

field strength with increased height. Part of its energy is absorbed by the ground, resulting in a greater rate of attenuation than the rate due to the inverse of the distance. The surface-wave component generally is transmitted as a vertically polarized wave, retaining this polarization at appreciable distances from the antenna. This polarization is chosen because the earth has a short-circuiting effect on the electric intensity of a horizontally polarized wave, but offers resistance to the electric component of a vertical wave. The ground currents of the vertically polarized surface wave do not short-circuit a given electric field, but rather serve to return part of the stored energy to the following field. The better the conducting surface, the more energy returned and the less energy absorbed.

(4) Tropospheric-Wave Component. The tropospheric wave is that component of the entire wave which is refracted in the lower atmosphere by relatively rapid changes in humidity with respect to height, and sometimes by rapid changes in the density and temperature with respect to height. At heights between a few thousand feet and approximately one mile, huge masses of warm and cold air exist near each other, causing abrupt temperature differences and changes in density. As a result, reflection and refraction in the troposphere make possible the propagation of the ground wave over distances far greater than can be covered by the ordinary ground wave.

c. The Ionosphere. The earth's atmosphere extends up to a distance of over 200 miles. Since the density of the gases which compose the atmosphere decreases with height, the air particles at a height of 250 miles are so rare as to be almost nonexistent. The atmosphere is in a constant state of bombardment by radiation and particle showers from the sun, and by cosmic rays from an unknown source. The radiation from the sun includes the components of the entire spectrum, ranging from infrared rays to ultraviolet rays, and and particle showers composed of positrons and electrons moving at nearly the speed of light. As these different forms of radiation approach the earth's atmosphere, they reach certain critical levels where the gases are of such density as to be particularly susceptible to ionization, and at these levels ionized layers are formed. It has been found that there are four distinct layers of the ionosphere, which are called, in order of increasing heights and intensities, the D, E, F_1, and F_2 layers. The four layers are present only during daylight hours, when the sun is directed toward that portion of the atmosphere. During the night, F_1 and F_2 layers seem to merge into a single F layer, while the D and E layers fade out, due to the recombination of the ions composing them. It has been found, in addition, that the actual number of layers, their heights above the earth, and the relative intensity of ionization present in them vary from hour to hour, from day to day, from month to month, from season to season, and from year to year. These layers in the ionosphere are commonly referred to as the Kennelly-Heaviside layers, in honor of the two men who were first to propose the idea of the existence of the ionosphere.

d. Sky-Wave Propagation.

(1) Sky-wave propagation generally refers to the transmission of electromagnetic energy which depends upon, and makes use of, reflections from the layers in the ionosphere. The principal ionosphere characteristics which control the reflection of electromagnetic waves back toward the earth are the height and the ionization density of each of the layers. The higher the frequency, the greater the density of ionization required to reflect waves back to earth. In other words, the shorter the length of the waves, the denser, or more closely compacted, must be the medium to refract them. Therefore, the upper layers, which are the most highly ionized, reflect the highest frequencies, whereas the D layer, being the least ionized does not reflect frequencies above approximately 500 kHz. Thus, at any given time for each layer there is a value of highest frequency, called the "critical frequency," at which

waves sent vertically upward are reflected directly back to earth. Waves of frequencies higher than the critical frequency pass on through the ionized layer and are not reflected back to earth, unless they are reflected from an upper layer. Waves of frequencies lower than the critical frequency are reflected back to earth, unless they are absorbed by, or have been reflected from, a lower layer.

(2) Although the critical frequency, when determined by vertical propagation as explained in the preceding paragraph, marks a boundary condition in that all frequencies at or below the critical frequency will be returned to earth, it is to be noted that other frequencies above the critical frequency also will be returned to earth if they are propagated at certain angles of incidence. At angles of incidence near the vertical, a given frequency may pass on through the ionosphere. But as the angle of incidence is decreased, an angle is reached at which the wave is reflected back to earth. This angle is called the "critical angle." The distance, on the earth's surface, to the point at which the wave returns is called the "skip distance;" as the angle of incidence decreases, the wave returns at greater and greater distances, or, in other words, the skip distance increases.

(3) The distance at which the wave returns to the earth depends on the height of the ionized layer and the amount of bending of the path while traversing the layer, the latter depending on the frequency of the wave as compared to the ion density of the layer required to refract or bend the wave. Upon return to the earth's surface, part of the energy enters the earth and is rapidly dissipated, while part is reflected back into the ionosphere again, where it may be reflected downward again at a still greater distance from the transmitter.

e. Directed Radiation.

(1) In present day radio transmission, utilizing frequencies that are extremely high, it is necessary to concentrate the transmitted energy into a narrow beam and to direct this beam toward the desired receiver, much like the headlamp of an automobile focuses a light beam. This is necessary for two reasons: to realize a greater signal at the receiving antenna, and to avoid transmission of the signal in undesired directions where unfriendly receivers may be loacted. At extremely high frequencies, single-wire antennas, or arrays, become less efficient because of the small physical size for a half wavelength and consequently high radiation resistance. Since the radiation properties of extremely high, or microwave, frequencies approach those of light waves, their propagation can be directed by reflecting surfaces placed in their path. These reflecting surfaces can be properly spaced elements acting in parasitic fashion, additional driven elements properly spaced or oriented, or a parabolic-shaped reflecting device.

(2) A reflecting surface in the shape of a parabola, having at its focal point the source of rf energy, will focus most of the radiated power in more or less parallel lines, forming a relatively narrow beam in which the rf energy is of high concentration. Some of the energy, however, does escape from the main beam and is dispersed at various angles in the immediate vicinity of the reflector.

f. Power Densities in a Typical Radar System.

(1) Significantly different levels of electromagnetic energy exist in each radar system. In the typical radar system shown in figure 6-4, the highest power density exists within the transmission line, which normally is closed and therefore not readily accessible. Power density, expressed in terms of average watts per square centimeter, is given approximately by the equation:

$$W = \frac{P_t}{A_{tl}}$$

where: W = power density, in average watts per cm^2

P_t = average power output of transmitter, in watts

A_{tl} = cross-sectional area of transmission line, in cm^2

It should be noted that the power is not distributed uniformly over the entire area of the transmission line, as implied by the equation above, but the equation gives a close approximation.

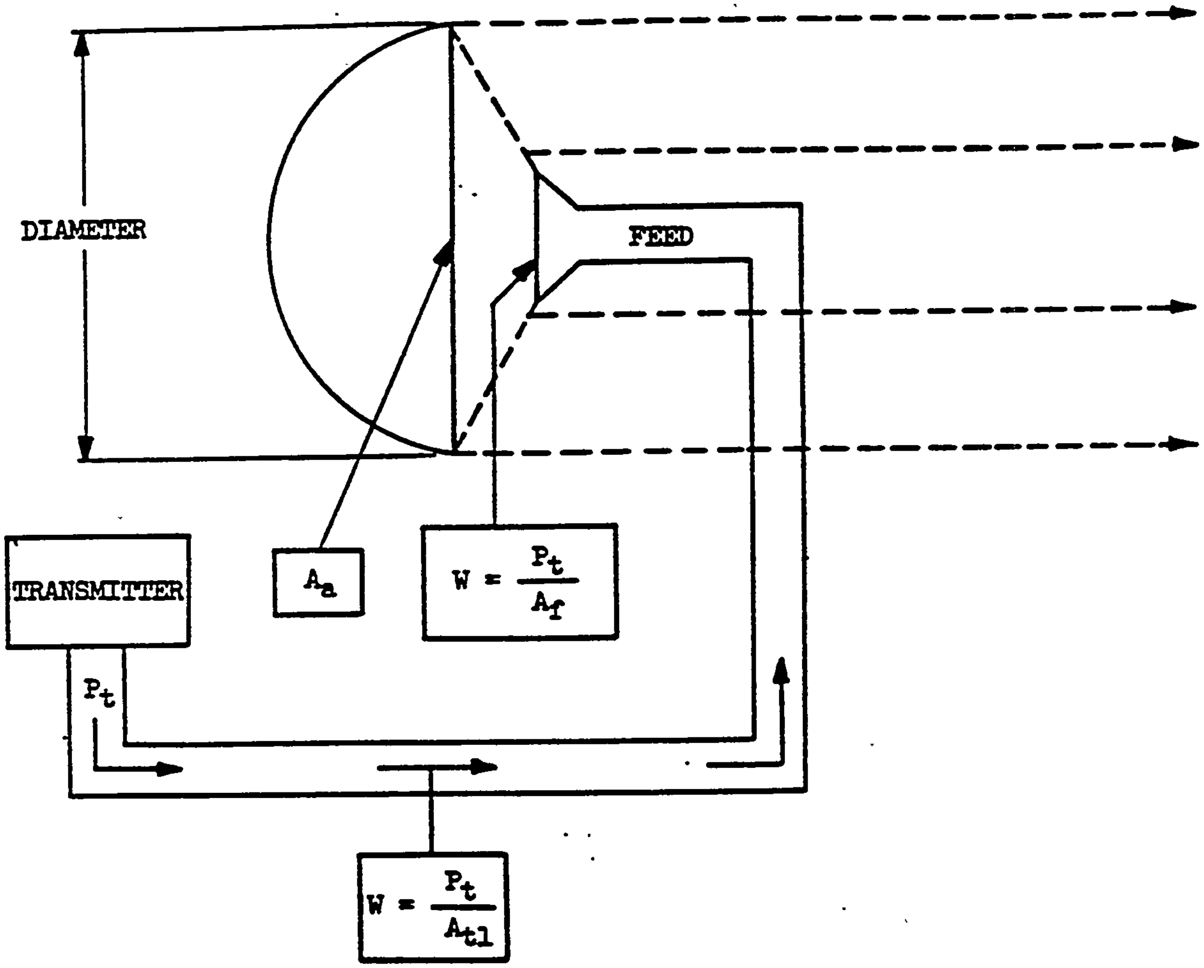


Figure 6-4. Power Densities in a Typical Radar System

(2) The transmission line conveys the power to an antenna feed, which in turn feeds the energy on to the antenna. Before reaching the antenna, the energy from the feed is propagated through space which ordinarily is not enclosed, and is therefore more accessible to personnel than is the inside of the transmission line. The power density in the aperture of the feed is given, again approximately, by the equation in the preceding paragraph, except that the feed aperture A_f is now used instead of A_{tl}. Since the feed aperture, A_f, is usually larger than the cross-sectional area of the transmission line, A_{tl}, the power density in the feed aperture is usually less than that in the line.

(3) From the antenna, the electromagnetic energy is radiated into free space, to enable the system to perform its function. While the energy is traveling through space, it cannot be controlled; this fact constitutes one of the biggest problems in combatting the possible hazards due to this radiation.

(4) The manner in which a parabolic antenna radiates its energy is somewhat complicated and is subject to many variations. For purposes of simplicity and generalization, this process may be depicted as shown in figure 6-4. The available power, P, furnished by the transmitter through the transmission line and the antenna feed to the antenna itself, is radiated outward from the antenna in a direction normal to the antenna aperture in most cases (but with very important exceptions in other cases). In order to obtain useful beams with low side lobes, the energy is "tapered" across the aperture in a manner illustrated in figure 6-5 for different type antennas. The taper decreases the applied energy smoothly from a maximum at the center of the aperture to a typical value of 10 dB (one-tenth) down from maximum at the aperture extremities. This distribution of energy across the antenna aperture is commonly called the antenna illumination. Paragraph g below provides the general space distribution of the transmitted power leaving the antenna for the more common antenna illuminations of cosine or $(1-r^2)$ with a typical taper of 10 dB.

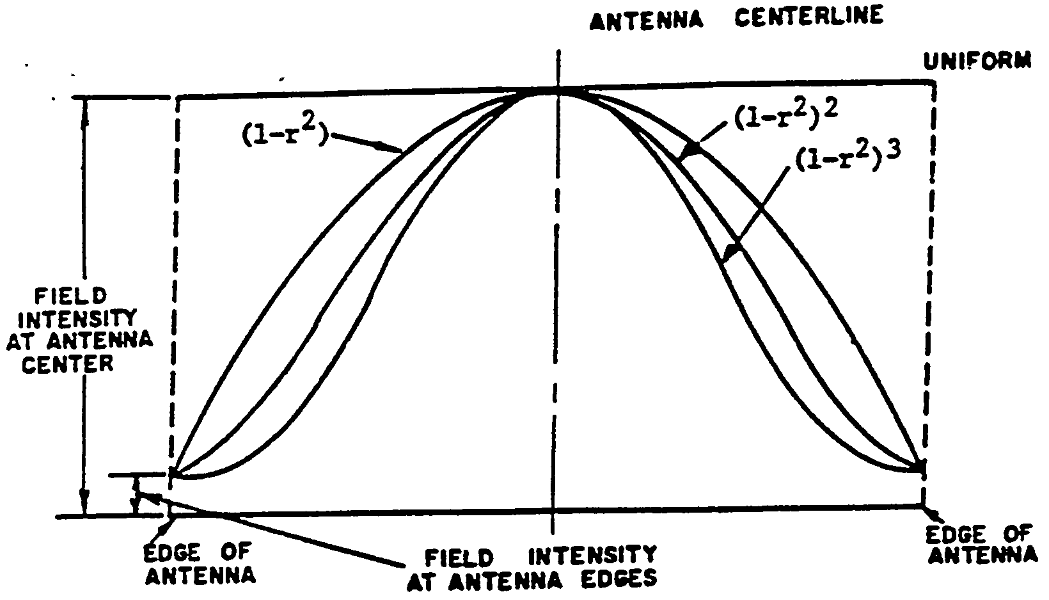
g. <u>The Fresnel Region, or Near Field</u>. After the electromagnetc energy leaves the aperture, its intensity varies with distance from the antenna as shown in figure 6-6. At distances relatively close to the antenna, in the area known as the "Fresnel" (or near field) region as given approximately by the equation below, the power remains fairly constant with distance, and is collimated in a beam of about the same size as the projected area of the aperture.

$$D_{Fresnel} = D < \frac{1}{4}\left[\frac{L^2}{\lambda}\right]$$

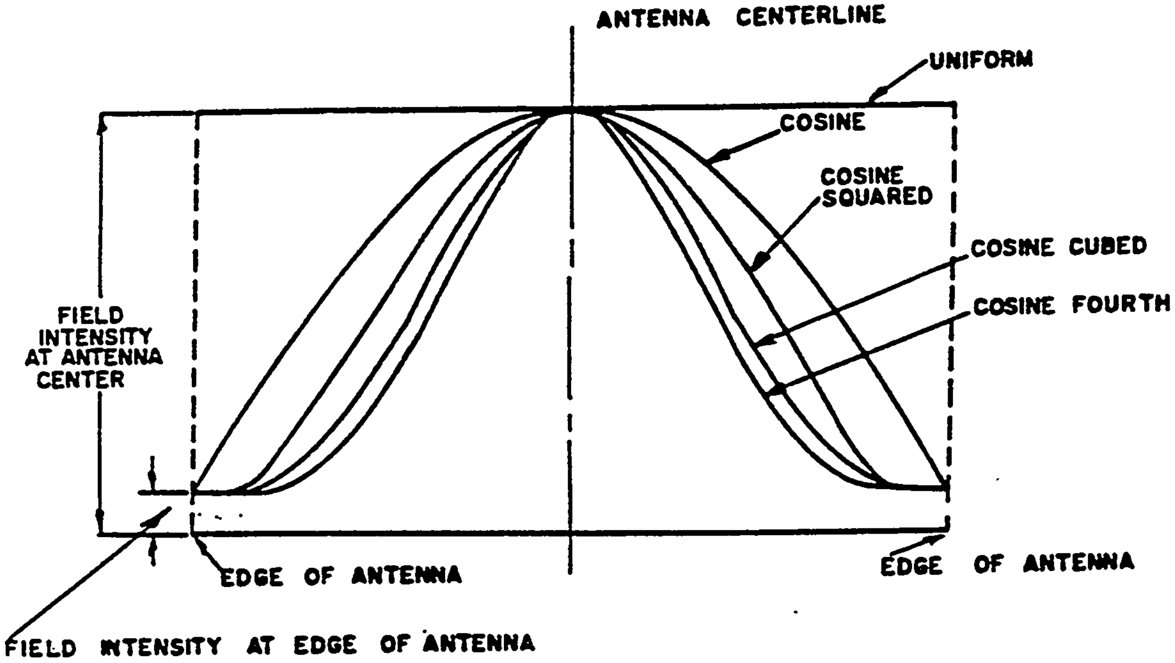
where: D = distance from antenna, in feet

L = antenna aperture dimension, in feet

λ = wavelength, in feet



(A)
ILLUMINATION OF ANTENNAS WITH CIRCULAR APERTURES



(B)
ILLUMINATION OF ANTENNAS WITH ELLIPTICAL OR RECTANGULAR APERTURES

Figure 6-5. Field Intensity Distribution Across an Antenna

As indicated in figure 6-6, the energy is not distributed uniformly across the beam because of the taper described in the paragraph above. The approximate power densities at the beam center and beam edges are:

$$\left.\begin{aligned} W_{\text{beam center}} &\approx \frac{3P_t}{A_a} \\ W_{\text{beam edges}} &\approx \frac{P_t}{3A_a} \end{aligned}\right\} \text{inside Fresnel region}$$

where: A_a = antenna aperture projected area

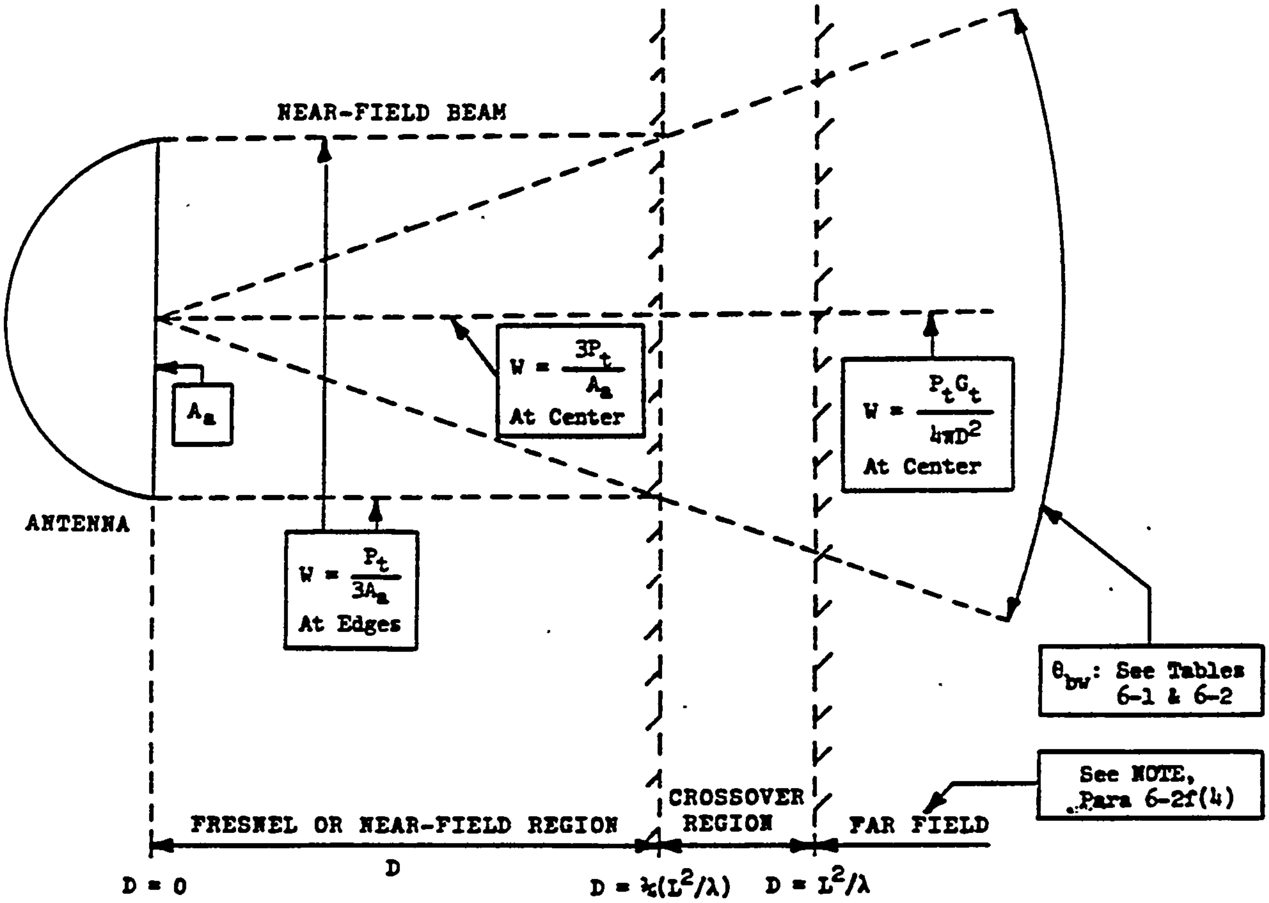


Figure 6-6. Distribution of Energy in Transmitted Beam

h. The Fraunhofer Zone, or Far Field. Beyond the Fresnel region, the radiated beam begins to spread out and the power density along the beam axis decreases with distance. At some distance the antenna appears to be a point source and the power density obeys the inverse square law. This is where the "Fraunhofer Zone," or far field begins. The distance to the far-field boundry (D_f) can be designated as:

$$D_f = \frac{2L^2}{\lambda}$$

where the actual on-axis power has reached 99% of the value obtained from the inverse square formula, or:

$$D_f = \frac{L^2}{\lambda}$$

where the actual on-axis power has reached 94% of the value obtained from the inverse square formula.

NOTE

D_f is limited to a minimum of 3 λ

A region of transition exists between the Fresnel and Fraunhofer fields, as shown in figure 6-6, this is known as the "quasi-Fresnel," or cross-over region. In the Fraunhofer region, the radiation is in a diverging beam shape, where the intensity is maximum at the beam center, and decreases away from the beam center as the angle of divergence increases. If the antenna is made larger or the antenna illumination is made more uniform, the radiated beam is made narrower and the beam center power density is made higher. Tables 6-1 and 6-2 express the half-power beamwidths for the different antenna illuminations in terms of the antenna diameter and the wavelength of the radiated wave. Another way of expressing the concentrating action of an antenna is by "its gain." Thus, a large antenna with a narrow beam has a large gain. The effects of the beam broadening due to antenna illumination is a Fraunhofer gain reduction. This "gain factor" is listed in tables 6-1 and 6-2 and normalizes the gain of ideal antennas with the different illuminations to the gain of an ideal uniformly illuminated antenna. In terms of gain, which is a pure number and can be furnished for each antenna, the power density at the beam center in the Fraunhofer region is given by the equation:

$$W_f = P_t G_t / 4\pi D^2$$

where: G_t = antenna power gain
W_f = Far-field power density

Table 6-1. Beamwidths, Gain Factors, and Side lobes of Rectangular and Elliptical Antennas with Various Illuminations

ILLUMINATION	GAIN FACTOR	HALF-POWER BEAMWIDTH θ (DEGREES)	FIRST SIDELOBE DB BELOW MAIN BEAM INTENSITY
Uniform	1.00	$\frac{50.4\lambda}{L}$ to $\frac{68.7\lambda}{L}$	13.2
Cosine	0.81	$\frac{68.7\lambda}{L}$ to $\frac{83\lambda}{L}$	23
Cosine Squared	0.667	$\frac{83\lambda}{L}$ to $\frac{95\lambda}{L}$	32
Cosine Cubed	0.575	$\frac{95\lambda}{L}$ to $\frac{110\lambda}{L}$	40
Cosine Fourth	0.515	$\frac{110\lambda}{L}$ to $\frac{116\lambda}{L}$	48

Table 6-2. Beamwidths, Gain Factors, and Side Lobes of Circular Antennas with Various Illuminations

ILLUMINATION	GAIN FACTOR	HALF-POWER BEAMWIDTH θ (DEGREES)	FIRST SIDELOBE DB BELOW MAIN BEAM INTENSITY
Uniform	1.00	$\frac{58.5\lambda}{L}$ to $\frac{72.8\lambda}{L}$	17.6
$(1-r^2)$	0.75	$\frac{72.8\lambda}{L}$ to $\frac{84.2\lambda}{L}$	24.6
$(1-r^2)^2$	0.56	$\frac{84.2\lambda}{L}$ to $\frac{94.5\lambda}{L}$	30.6
$(1-r^2)^3$	0.44	$\frac{94.5\lambda}{L}$ to $\frac{103.5\lambda}{L}$	—

i. Power Level on the Main Beam Axis.

(1) Some of the information given in previous paragraphs of this section may be summarized as follows: First, the power level radiated by a typical beam-forming antenna remains in a beam of approximately the same area as the projected area of the aperture, as far as the limit of the Fresnel, or near-field region. Within this region, the power along the axis of the beam is highly concentrated, having a power density of approximately three times the power density measured across the aperture of the antenna, expressed in average watts per

quare centimeter, due to the concentrating effects of the reflector. Beyond the Fresnel region and as far as the limit of the quasi-Fresnel region, or between the distances of $1/4(L^2/\lambda)$ and L^2/λ (antenna aperture diameter squared divided by wavelength, both in feet), the beam spreads out and the concentration of power along the axis of the beam begins to decrease from the value given above. The power density decreases until it reaches a value, at the beginning of the Fraunhofer zone (which is at a distance of L^2/λ), where the power density is approximately equal to the total average power P_t multiplied by the power gain G_t of the antenna, divided by the quantity 4π times the square of the distance from the antenna. This is given by the formula:

$$W_f = P_tG_t/4\pi D^2$$

At greater distances, it can be seen that the power level, or density, along the main beam axis, continues to fall off in proportion to the square of the distance.

(2) Figure 6-6 provides a convenient picture of the near field and cross-over region beam power distribution. In practice the transfer from collimated beam radiation to linear beam divergence would not be so abrupt. The beam cross-section would start spreading slowly at a point at a distance of $1/6(L^2/\lambda)$ to $1/4(L^2/\lambda)$ and would gradually diverge at a larger angle until linear divergence is nearly reached at L^2/λ. Therefore, in the near-field and cross-over region, the transmitter power is distributed over a greater area than that presented by a discrete antenna center point radiating at the divergent angle present in the Fraunhofer region. The beam is less concentrated than indicated by the formula $W_f = P_t G_t /4\pi D^2$. The antenna gain is then less than in the Fraunhofer region and a gain reduction factor must be applied to the antenna Fraunhofer gain.

j. Power Level off the Main Beam Axis.

(1) The power level, or density, off the main beam axis depends upon a number of variables, so that only an approximation can be given by calculations. For the different illuminations of the type antennas noted in tables 6-1 and 6-2, the narrowest beamwidth of the beamwidth range would apply to an ideal antenna. The beamwidth of the actual antenna will be broadened from that of an ideal one, due to imperfect illumination, imperfect reflector surface, and aperture illumination phase errors. Centered about the main beam are separate and individual beams of energy of lesser amplitude called "side lobes." The forward side lobes can be attributed to illuminated energy in proximity to the antenna edge discontinuity. Note the relation of the side-lobe levels to the energy in the area near the antenna edge as shown for different illuminations of tables 6-1 and 6-2 (reference can be made to figure 6-5 for energy near the antenna edge for the different illuminations). The diffraction of the spill-over energy at the antenna edge and the energy transmission through the imperfect reflector contribute to like back lobes from the antenna. The result of the above combined effects is a loss of a portion of the transmitter power in directions other than that of the main beam axis. The relation of the main beam axial power concentration (antenna gain) to the theoretical antenna gain is referred to as the "antenna efficiency." The antenna efficiency varies from 50% to 90% for antennas designed to concentrate all the transmitter power within a narrow beam along the vertical and the horizontal axis. For antennas where reflector shape is made to form a cosecant-squared pattern along the vertical axis, this antenna efficiency varies from 35% to 60%. The theoretical antenna gain will vary with the type illumination employed. The theoretical antenna gain will be greatest for uniformly illuminated antennas where the

narrowest beamwidth is developed. The "antenna gain factor" is the factor by which the theoretical antenna gain of a uniformly illuminated antenna must be multiplied to obtain the theoretical antenna gain of an antenna with an illumination other than uniform along an axis. This gain factor must be separately applied for each axis illumination when applied to elliptical or rectangular antennas. The gain factors for different antenna illuminations are shown in tables 6-1 and 6-2.

(2) Due to the effects of paragraph (1) above further clarification of figure 6-6 is necessary. Since the illumination energy in the vicinity of the antenna edge is diffused, diffracted, and radiated in a direction governed by the antenna edge discontinuity, energy along the edge of the collimated radiation region cross-section decreases to a very low figure in a short distance from the antenna. Decrease of the antenna illumination level becomes less in the near field when progressing from the collimated area edge toward the center of the area. More specific calculations for finding the approximate power density at the center and at various distances off the center of the main beam axis within the close-in region are given in Section II of this chapter.

k. Reflection, Refraction, and Scattering.

(1) As previously pointed out in this chapter, the two principal ways in which radio waves radiated from a transmitter travel to a receiver are by means of ground waves and sky waves. The propagation of the ground wave is affected by the electrical characteristics of the earth (soil or sea), and by diffraction, or bending, of the wave with the curvature of the earth. Although these characteristics differ in different localities, they remain practically constant with time in any one given locality under most conditions. Skywave propagation, on the other hand, is variable, since the state of the ionosphere is always changing and, therefore, affects both the reflection and refraction of the sky wave.

(2) A radio wave may be reflected in a manner similar to that of any other type of wave. For instance, when a beam of light falls on the surface of a mirror, nearly all of it is reflected. In a similar manner, the efficiency with which reflection of radio waves occurs depends on the material of the reflecting medium. Large, smooth metal surfaces of good electrical conductivity, such as copper, are very efficient reflectors of radio waves, reflecting nearly all of the energy carried by the incident waves. The surface of the earth itself is a fairly good reflector of radio waves, particularly for waves that are incident at small angles from the horizontal. The ionosphere, even though it does not have a surface like that of a mirror, is also a fairly good reflector of radio waves.

(3) Reflection of waves is of importance in several ways. First, it provides a way of measuring the properties of material. A study of the constitutive properties of matter is often made by studying the fractional reflection and transmission of electromagnetic waves through matter. The reflectivity depends on the angle at which the wave strikes the boundary between the two media.

(4) The second important aspect of reflection is the standing-wave pattern in which the field intensity is greater or less than that in either separate traveling wave. A field with an intensity just at the threshold of safety (with respect to human exposure) in the absence of reflections can become hazardous at certain points when reflection occurs. Reflection is associated with dimensional resonance phenomena where the field amplitude builds up because the dimensions are such that successive reflections from walls or boundaries just overlay one another properly in space and time. Such dimensional resonances can occur in structures like the eyeball; the determining factor is the ratio of the wavelength (in the medium constituting

the eyeball) to the dimensions of the eyeball. The seriousness of the effect depends on the reflecting properties of the walls.

(5) The third important aspect of reflection is its bearing on any discussion of dosage. Consider a body, say a mouse, placed in a field whose intensity is known in the absence of the mouse. The free-space value may have little relevance to establishing a tolerance level for other animals, for what is important is the field within the mouse. To determine the latter, it is necessary to determine the reflectivity of the hair and skin.

(6) In addition to its ability to be reflected, a radio wave may also be refracted, in a manner similar to a beam of light. When a beam of light shines on a smooth surface of water, some of the light is reflected, and the remaining portion penetrates the water. The direction of travel of that portion which penetrates the water is different from that of the light beam incident to the surface of the water. This is so because the light passes from a less dense medium (air) to a more dense medium (water). In a similar manner, a radio beam is refracted when it passes through media of different densities. The amount that a wave is refracted as it passes from one medium to another, expressed by the ratio of the velocity of an electromagnetic wave through a perfect vacuum to its velocity through the denser medium, is called the "index of refraction."

(7) In somewhat recent years, extensive experiments have indicated that radio waves not only are reflected and/or refracted, but also are scattered, under certain conditions in the troposphere and in the lower ionosphere. The exact reason for, or the mechanism which causes, this scattering is not yet fully known. "Scattering" is the term given to the dispersing of the radio waves in various directions, in a sense similar to the manner in which the lens on the tail light of an automobile directs the light in all directions.

(8) Fluctuations in the humidity of the air are believed to play an important part in scattering, because of the large index of refraction of water vapor. Fluctuations in temperature at various altitudes may also contribute to the scattering phenomena. In the atmosphere there are layers in which the index of refraction changes as much as 30×10^{-6} over a distance of 100 meters, and rates of change of 10^{-2} to 10^{-3} per meter are quite common.

l. Absorption of RF Energy.

(1) In traveling through space, radio waves may be reflected, refracted, or scattered, as pointed out in previous paragraphs. Whenever the radio waves are so affected, some of the energy is absorbed at the point where the change of direction occurs. If conditions are favorable to the particular wavelength of the radio wave, it may happen that most, if not all, of the rf energy may be absorbed.

(2) When rf energy is absorbed by a body, using the term "body" in its broad sense to include any obstruction to the transmitted wave, the rf energy is converted into heat. The total amount of heat developed depends upon the field intensity of the rf energy and upon the area of the surface receiving the energy. The heat developed per unit area may, or may not, be in direct proportion to the actual size of the unit area. This is especially so when the unit becomes so small that it approaches the size of one wavelength. To explain this, it is necessary to consider how the electromagnetic field interacts with matter. Atoms and molecules are complexes of charge, and when placed in an electric field, their charge distribution becomes polarized. Some molecular systems, such as many molecules in living

tissue, already have charge distributions which are polar; that is, the center of gravity of the negative charge is displaced from that of the positive charge. All membranes have polar structure. In a time-varying field the polarization vibrates and, by virtue of interaction between different elements of the molecular system, the electrical energy is transformed into heat. This is the dominant phenomenon in what may be termed the low-amplitude region. The hazard of radiation in this region is purely thermal. The destruction of tissue is a secondary process resulting from the generation of heat. If the intensity of radiation is low so that the rate of generation of heat can be handled by the distribution processes in the organism, the result is only discomfort. When the intensity of radiation increases, not only does heat generation increase, but also another effect comes into play. The enforced redistribution of electric charge under the applied field can be so great that a complete reorganization results. This is the so-called process of field-induced transitions.

(3) Man, a biped, when in the erect position is potentially a long cylindrical antenna. Quadruped mammals, such as dogs, likewise may be expected to act more or less like antennas depending upon their size, length of head, tail, and body, and the manner in which they stretch out in a polarized electromagnetic field. Results of experiments indicate that when the longitudinal axis of the body corresponds, in its position, more or less to the plane of polarization, heating occurs more rapidly and more extensively than when the longitudinal axis is 90° away from the plane of polarization. Since more heat is developed within the body, it is apparent that more rf energy is absorbed.

(4) Sometimes it is necessary to intentionally absorb rf energy, in order to shield an area from radiation. Commercial materials such as impregnated hair, absorbent foam, and resistive cloth are available for this purpose.

(5) There are occasions when it is desirable to know to what degree electromagnetic energy will be attenuated in passing through various materials. Tests have been performed at Rome Air Development Center on some representative materials to determine such attenuation. Results of some of these tests are listed in the following paragraphs, along with the test conditions.

(a) Wood Frame Building. Tests were made on a portion of a wood frame building, of the following construction:

5-1/2" x 3/4" tongue-and-groove inner siding
5-1/2" x 7/8" clapboard outer siding (no tar paper between layers)
Inner wall unfinished
2" x 4" studding, spaced on 16" centers

At three test frequencies, power absorption was found to be as follows:

Frequency (MHz)	dB Down (Power)
1300	2.0
2800	3.1
9200	1.3

Since the inner wall of this building was unfinished, and since no tar paper was used between the two layers of wood siding, additional tests were made at one frequency (9200 MHz) on several interior finishing materials, as follows:

Material	dB Down (Power)
Plain tar paper (lightweight) 0.074" thick	2.5
Pressed cardboard 0.351" thick	2.8
Plaster board 0.362" thick	1.0

(b) Cinder-Block Wall. Power absorption tests were made on a wall built of cinder blocks which individually measured 16 inches long, 8 inches high, and 7-1/2 inches thick. The tests were made at three frequencies, with the following results:

Frequency (MHz)	dB Down (Power)
1300	11.4
2800	14.5
9200	20.5

(c) Microwave Absorbent Material. Power absorption tests were made at two frequencies on microwave absorbent material (Hairflex-Sponge Rubber Product), 2' x 2' x 4" thick. The power absorption was found to be as follows:

Frequency (MHz)	dB Down (Power)	
	(wet)	(dry)
1300	13.6	13.8
9200	25.0	25.0

(d) Copper Wire Screen. Tests were made at two frequencies on the power absorption of copper wire screen, having 19 wires (0.018" diameter) per inch. Absorption was found to be as follows:

Frequency (MHz)	dB Down (Power)
1300	20
9200	24

m. Transmission Through Waveguides.

(1) Transmission of electromagnetic waves by reflection from layers in the ionosphere was discussed previously, in paragraph 6-3d. After reflection in the ionosphere, the wave, returning to earth, may again be reflected back to the ionosphere. This process may continue, under ideal conditions, until the wave completely encircles the earth. This can be visualized by considering that the wave is guided by two conducting layers --- the earth and the

ionosphere --- in its travel. Instead of the earth and the ionosphere, two flat metal plates separated by only an inch or so may be used as conducting layers to guide an electromagnetic wave. If an electromagnetic wave of very short wavelength is fed between the plates by means of a very small dipole antenna, the wave will be confined and will be reflected back and forth between the plates in its travel. If two more metal plates are added to make a long, rectangular tube which completely confines the wave and prevents it from moving sideways out of the confines of the two original plates, the result is an efficient conductor of very short electromagnetic waves. This tube, which can also be of cylindrical cross-section instead of rectangular, is called a "waveguide."

(2) It is necessary that the wavelength of the electromagnetic wave applied to the waveguide be sufficiently short in order to be conducted through the guide. For a waveguide of given internal cross-sectional dimensions, a particular value of wavelength called the "cutoff wavelength" may be calculated. Any wavelength shorter than the cutoff wavelength will pass through the waveguide, while any longer wavelength will not pass through. This value of cutoff wavelength, for a rectangular waveguide, is approximately equal to twice the internal width dimension of the waveguide.

(3) The transmission of electromagnetic waves may be accomplished in either of two ways: by radiating them from an antenna or by conducting them through a waveguide or similar type of transmission line. When radiated from an antenna, the waves are unguided in that they spread out after leaving the antenna, because the rays of the beam are not parallel. Even though the waves may be concentrated into a narrow beam by means of a directional antenna, the energy is distributed over an increasingly large cross-sectional area as the distance from the antenna increases. When conducted through a waveguide, on the other hand, the energy is restricted to the constant cross-sectional area within the waveguide. Except for the attenuation of the energy due to copper loss along the walls of the waveguide, nearly all of the transmitted energy reaches its destination.

n. Standing Waves.

(1) When radio waves are fed to a wire conductor of infinite length, the rf waves of electromagnetic energy move along the wire. Because of the electrical resistance of the wire, the amplitude of the waves gradually diminishes, but the waves continue to travel as long as the wire does not come to an end. These waves of energy are called "traveling waves."

(2) In practice, however, a wire conductor (such as an antenna) has a finite length. Therefore, the traveling waves stop abruptly when they reach the end of the wire. At this point, since the current has stopped flowing, the magnetic field surrounding the wire collapses, and in doing so, the collapsing lines of force cut across the wire and induce a voltage in the wire, according to Lenz's law. This voltage causes a current to flow back toward the initial source. If a continuous succession of waves is fed to the wire, they will be continually reflected back toward the source. The waves moving from the transmitter toward the end of the wire are called "incident waves," while those which are reflected back are called "reflected waves."

(3) With a continuous flow of incident waves away from the transmitter and a continuous flow of reflected waves returning toward the transmitter, it is obvious that these waves, traveling in the same conductor, must pass each other. At certain points along the conductor both the incident and reflected waves will reach their maximum positive (or negative) values, at the same instant. At these points they reinforce each other. At certain other points along the conductor both of the waves reach a zero value at the same time; here

the resultant wave is zero. In a conductor, such as an antenna, which has a finite length, the points at which the resultant wave reaches its maximum (positive or negative) and its zero values are stationary. This is so, even though both the incident and reflected waves are moving. Since the resultant wave, in effect, stands still on the line, with only its amplitude changing from maximum positive, through zero, to maximum negative values, the wave is referred to as a "standing wave."

(4) When electromagnetic energy is transferred from a transmitter to an antenna, especially when they are located some distance apart, a transmission line of some form is used to conduct the energy. At the input end of the transmission line, the ratio of voltage to current is termed the "input impedance." At the output end of the line the ratio of voltage to current is termed the "output impedance." If the transmission line is of infinite length, the input impedance is called the "characteristic impedance" of the line. If the infinite line is now shortened to some finite length, and the line terminated by a load whose impedance is equal to the characteristic impedance of the line, the same impedance will appear at the input end of the line, or, in other words, the input impedance will remain the same. No matter how short the line is made, provided the line is terminated by its characteristic impedance, the input impedance will remain the same as if the line were an infinite line. Since an infinite line cannot contain standing waves, neither can a line of any length contain standing waves if the line is terminated by its characteristic impedance.

(5) When a line of a given length is terminated in its characteristic impedance, with the result that no standing waves appear on the line, and either the line or the termination is changed, then standing waves will again appear on the line, because the impedance has been changed. This may happen if a joint or point of coupling in a waveguide becomes loose. The loosened joint causes the impedance at this point to increase, giving an effect similar to a change in termination. The line impedance no longer matches the load (termination) impedance, and the result is a mismatch in impedance, and standing waves on the line.

o. Directional Antennas.

(1) Electromagnetic energy can be reflected in a similar manner to light energy, and under the same condition in that the physical dimensions of the reflector must be large compared to the wavelength of the energy to be reflected. Metallic reflecting surfaces in the shape of a parabola may be used to beam the energy in a manner similar to the beaming of light rays by the headlamp of an automobile. This type of beam transmission finds most use at the ultrahigh frequencies, where the physical dimensions of the radiating elements are small. By the use of two or more antennas properly spaced and phased, directional transmission may also be realized, by causing the radiated signals from the antennas to add in the preferred direction and to subtract, or cancel, in other directions.

(2) Two-Element Array. If two antennas A and B, such as dipoles, positioned vertically and parallel to each other, and spaced a half-wavelength apart, are excited in phase, the radiation from them is concentrated along a line passing between them at right angles to their plane. This is so because the radiation from each dipole will add, in phase, in the directions at right angles to their plane. The radiation in the plane of the two antennas, however, is negligible, because the energy from dipole A, in traveling the half-wavelength to dipole B, arrives at dipole B exactly reversed in phase by 180 degrees (a half-wavelength), and the two fields cancel each other.

(3) If the two antennas A and B, still positioned vertically and parallel to each other, are now spaced one-quarter wavelength apart and excited with equal currents which differ in phase by 90 degrees, the radiation from them will be concentrated in one direction along a line

in the plane of the antennas. If antenna A radiates toward antenna B a current which, instantaneously, is at zero degrees in phase, the current will reach antenna B a quarter-wavelength, or 90 degrees, later. If, at this instant, antenna B is fed and radiates a current which is 90 degrees later in phase than the current fed to antenna A, the two radiated currents will be in phase in this direction from A to B, and the fields will add to each other. In the reverse direction, however, if antenna B radiates its current, which is 90 degrees later in phase, in the direction toward antenna A, the current from antenna B will reach antenna A delayed another quarter-wavelength or 90 degrees, which means it will be exactly 180 degrees out of phase with the current from antenna A, and thus will cancel any radiation in the direction from B to A. At other angles the waves will add vectorially to give intermediate values of radiation.

(4) Broadside Array. If two, or multiples of two, horizontal antennas, each a half-wave long, are located in line and fed in phase at the point between each pair, with additional groups of these antennas stacked a half-wavelength apart above and below the first group, the result is called a "broadside array." Without a reflector this antenna would radiate a narrow beam of energy in the two directions at right angles to the plane of the antennas. If a similar array of parasitic reflectors, or a metal sheet or metal screen reflector, is located between one-tenth and one-quarter wavelength behind the antenna elements, the radiation will be confined in a narrow beam approximately 20 degrees wide in the single direction away from the reflector. The pattern of the radiated energy will become narrower in the horizontal plane as the number of pairs of elements alongside each other is increased. The radiated pattern will become narrower in the vertical plane as the number of stacks, one above the other, is increased. Arrays of sixteen elements, arranged in four rows of four each, have been commonly used in the past in heavy ground radar equipments, and much larger arrays are being used at the present time, radiating tremendous amounts of power, often at very low angles above the horizon.

p. Transmission from Microwave Antennas.

(1) When electromagnetic energy of frequencies in the microwave region is to be transmitted, the waveguide becomes the principal means of transmission. Waveguides are used, basically, in three applications, namely, to transmit energy, to radiate energy, and to obtain resonance under certain conditions. The transmission of energy through waveguides has already been discussed in a previous paragraph. In addition to transmitting the energy from the source to the load, a waveguide which is being fed electromagnetic energy will radiate energy if the end of the waveguide is left open. However, the termination is seldom of the proper impedance, resulting in mismatch and the creation of standing waves; therefore, a waveguide has low efficiency as an antenna.

(2) Waveguide Antennas. Electromagnetic energy may be put into, or may be removed from, waveguides by the same means. In the case of waveguides which are transmitting energy, the output end may be left open. Some of the energy is radiated into space, but a considerable portion of the energy is reflected because of the mismatch of impedances between the open end of the waveguide and the space beyond, causing standing waves to be set up within the waveguide. In order to eliminate the reflections and terminate the waveguide properly for maximum transfer of energy, the opening at the end of the guide may be flared in the shape of a horn. If the flaring is of the proper shape and dimensions, it will effectively match the impedance of the waveguide to the impedance of free space.

(3) Electromagnetic Horns. Horn radiators are often used to obtain directive radiation when the wavelength is in the microwave region. At this range of frequencies they are very practical because the physical dimensions, which must be large compared to the operating

wavelength, are not unduly large. Since horn radiators do not contain resonant elements, they are usable over a wide frequency band. In operation as a means of directing electromagnetic waves, an electromagnetic horn is similar to an acoustical horn. They differ in one respect, however, in that the physical dimensions of the throat of an acoustic horn are usually much smaller than the sound wavelengths for which it is used, while the dimensions of the throat of an electromagnetic horn are comparable to the wavelength being transmitted. The application of horn radiators is not confined to waveguide operation, although they are readily adapted for use with waveguides. A horn radiator serves not only to match the impedance of the waveguide to that of the external space, but also to produce directed radiation. The shape of the horn, along with the dimensions of the mouth, measured in wavelengths, determines the shape of the radiated field pattern for a given magnitude and distribution of phase across the mouth of the horn. In general, as the opening of the horn is increased in size, the more directive is the resulting field pattern. With an aperture of approximately five wavelengths, a radiated major lobe of approximately 30 degrees is produced. The flare angle, which is the included angle across the sides of the horn, determines in large part the major lobe of the radiated field pattern. With a rectangular waveguide and horn, a very narrow lobe, or highly directive pattern, is produced when the flare angle is 60 degrees. Reducing the angle to 20 degrees approximately doubles the width of the lobe, while at zero degrees (which is the open-ended waveguide) the lobe is approximately four times the width at 60 degrees.

(4) Lenses. In the same manner as a lens made of glass is used to focus a beam of light, so can a lens made of plastic be used to focus a beam of electromagnetic energy. A lens made of metal may also be utilized for this purpose. The metal lens is actually composed of a large number of small waveguides, arranged symmetrically in concentric circles, to give the general over-all shape of a convex lens. At the focal point a dipole with reflector, or a horn, is located. The rays of electromagnetic energy that are emitted from the dipole or horns, diverge toward the lens, where the waveguides composing the lens act to refract the rays to form a highly directional, concentrated beam in which the rays are essentially parallel. This action is similar to that of a convex lens, which when placed at a distance equal to its focal length from a point source of light, refracts the divergent light rays from the source to form a beam of light in which the rays are parallel.

(5) Pencil-Beam Antennas. Very directive, or pencil, beams of radiated energy, in which the radiation is restricted to small angles in both elevation and azimuth, may be produced by building up arrays of pairs of dipole elements (broadside arrays). When properly phased and equipped with reflectors and, in some cases, director elements, considerably narrower radiated beams may be obtained. Limitations to the directivity result from mechanical problems brought about in meeting the requirement of physical dimension versus wavelength ratio.

(6) To produce pencil beams when the wavelength is in the microwave region, the simplest and most practical method is to locate a point source of electromagnetic energy at the focal point of a symmetrical reflector (or lens). In the microwave region, the over-all size of the reflector (or lens) and the distance between the reflector (or lens) and the feed point can be made physically large enough so that the feed operates essentially as a point source.

(7) Fanned-Beam Antennas. While a pencil-beam antenna has the advantage of concentrating its radiated energy in a very narrow beam, this fact may become a disadvantage in an application such as radar target interception, because the beam covers a very limited area in space at a given instant. For use in the latter application it is often necessary to sacrifice some of the advantage in directivity, usually in a vertical plane, but still retain the directivity of the narrow beam in the horizontal plane. This is achieved by flaring, or

broadening, the beam vertically, by the use of a fanned-beam antenna. By maintaining a narrow beam in the horizontal plane, resolution of the target on the scope presentation is retained, while flaring the beam vertically increases the possibility of intercepting a target return in a random search scan. The resultant beam may be a simple fanned beam, with the original symmetrically circular beam "distorted" into a symmetrically elliptical beam, or it may take a form which is highly "distorted" from circular. The latter types are called "shaped-beam" antennas.

(8) Fanned-beam antennas may appear in several forms: a point source feeding an oval section of a parabolic reflector at its focal point; a line source from a rectangular aperture feeding a parabolic cylindrical reflector or portion of a cylinder; a point source between parallel plates to produce a rectangular aperture which is located at the focal point of, and feeds, a parabolic cylindrical reflector.

(9) Shaped-Beam Antennas. In order to reduce to a single scan the amount of scanning time required to completely cover, or explore, a region covering a wide angle in elevation, while at the same time holding to a narrow angle in azimuth, and to accomplish these requirements without wasting the transmitted power, a shaped-beam is necessary. Shaped-beam antennas are used on shipboard for surface scanning in azimuth; they provide a broad elevation pattern, to allow for the roll and pitch of the beam due to an unstabilized antenna. The beam must spread slightly downward from the antenna to the surface of the water, but then should follow the surface rather than continue in a fanshape toward a position beneath the water's surface, in order to conserve the power that would be wasted should the beam tend to penetrate the water. In azimuth the beam must be sharp, for accurate target location. This type of beam may be called a "sector-shaped beam."

(10) Shaped-beam antennas are also used on ground or aboard ship for height-finding. In this case the azimuth pattern of the beam must be relatively broad, so that the target will remain in the beam long enough to obtain elevation information. In elevation the beam must be sharp, for accurate height measurement. In order to allow relatively close targets traveling across the path of the beam to remain within the beam for the necessary period of time, a close-in broadening of the azimuth beam, equally on both sides of center, is required. This type of beam is called a beavertail-shaped, or double cosecant theta, beam.

(11) Cylindrical Reflector Antennas. The cylindrical reflector antenna is a type of fanned-beam antenna, utilizing a line source to produce a rectangular aperture which feeds a parabolic cylinder. The beam from this type of antenna is broad in one plane and narrow in the other. When used in the conventional position with the axis of the cylinder in a horizontal plane, the beam is broad in that plane and narrow in the vertical plane. The reflector is in the form of a cylindrical parabola, with either open or closed ends. Cylindrical parabolic reflectors have a parabolic curvature in one plane, usually the horizontal plane, with no curvature in any plane perpendicular to this horizontal plane. The antenna which excites the parabola is normally placed parallel to the cylindrical surface, and located at the axis of the parabola. The focus should lie well within the mouth of the parabola, so that most of the energy radiated by the antenna will be intercepted by the reflecting surface, to produce the desired spread of the radiated beam.

(12) Spherical Reflector Antennas. The spherical reflector antenna is a type of pencil-beam antenna; when fed with a point source of electromagnetic energy located at the focal point of the reflector, it will produce a very directive or pencil-shaped beam in which the radiated energy is highly concentrated. The spherical reflector is often "shaped" to purposely broaden the radiated beam in a particular plane, as previously described in the discussion of shaped-beam antennas.

(13) Phased Array Antennas. The phased array antenna has an aperture that is constructed from many individual radiating elements such as horns, dipoles, slots, etc. The energy emitted from each element adds or subtracts according to the relative phase and amplitude to form the overall radiated pattern. The characteristics of the antenna are determined by the geometric position of the elements in the array and by the relative phase and amplitude of their exitation. The development of electronically controlled phase shifters and switches which can be controlled by a computer allows precise beam positioning without movement of the array. In addition to beam steering the radiation pattern can be controlled. Electronically controlling both beam position and pattern allows the phased array to perform multifunctions (tracking several targets while it continues to search).

(14) The fixed phase array allows the rf generator(s) to be physically located adjacent to the radiating element. Having multiple rf generators located at the radiator allows efficient radiation of very high power without the problems encountered in a single transmitter system with extensive waveguides and rotating joints.

(15) Some general characteristics of the phased array with the elements in a single plane (planar-array) are:

(a) The beam can be steered approximately 60 degrees from broadside in both azimuth and elevation.

(b) The number of radiating elements (N) which can be used in the array is limited by the maximum 3-dB bandwidth to be utilized.

(c) The maximum antenna gain (G) is in the broadside direction and is related to the number of radiating elements (N).

(d) The gain is reduced in relation to the angle (θ) by which the beam is steered away from broadside. "G" is approximately equal to broadside gain ($\cos \theta$).

(e) The 3-dB beamwidth increases in relation to the angle (θ) by which the beam is steered away from broadside. The 3-dB beamwidth is approximately equal to the broadside beamwidth/$\cos \theta$.

APPENDIX H

AFOSH STANDARD 161-9

DEPARTMENT OF THE AIR FORCE
Headquarters US Air Force
Washington DC 20330-5000

AFOSH STANDARD 161-9

12 February 1987

Occupational Health

EXPOSURE TO RADIOFREQUENCY RADIATION

Supersedes AFOSH Std 161-9, 12 October 1984. (See signature page for summary of changes.)
No of Printed Pages: 49
OPR: HQ AFOMS/SGPR (Lt Col David Wood)
Approved by: HQ AFMSC/SGP (Brig Gen Rufus Dehart)
Distribution: F

2. Acts as a single point contact for the unit on RF radiation safety matters and maintains active liasion with BES and EHS personnel.

3. Coordinates medical or other consultant RF radiation survey or hazard evaluation activities with command and supervisory personnel. Keeps these individuals informed of the status of all such activities, particularly during investigations of suspected or alleged overexposures.

4. Keeps track of all unit actions needed to eliminate RF radiation hazards to personnel. Make sure corrections are being done in a timely manner.

(f) Supervisors of persons using or working on RF radiation emitting equipment:

1. Make sure workers under their supervision follow procedures blished in equipment technical orders d manuals, unit OIs etc. for protection of personnel from overexposure to RF radiation.

2. Make sure personnel do their jobs in the way that keeps their exposures to RF radiation as low as practical, but in all cases below the PEL.

3. Make sure workers are properly trained in safe work practices and are told about specific hazards in their work place and the procedures to be followed to avoid those hazards.

4. Make sure that any suspected or alleged overexposures are immediately reported to the unit RPO, Commander and the supporting EHS and that persons involved are promptly transported to the nearest supporting medical facility for examination.

(g) Individuals using or workng on RF radiation emitting equipment have a responsibility for protecting themselves from possible harm from RF radiation by:

1. Following procedures for safe work given in equipment technical orders and manuals, unit OIs, etc.

2. Asking supervisors to explain any instruction that is not understood.

3. Making sure required warning signs and safety devices are in place or properly set before beginning work.

4. Making sure, when working with others, that everyone understands the procedures and signals to be used for the task being done.

5. Promptly telling their supervisor of any suspected accidental exposure.

B. TERMS EXPLAINED

1. Average Power. The time average rate of energy transfer.

$$P_{avg} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P\,dt$$

Where P is the power as a function of time.

2. Permissible Exposure Limit (PEL). That exposure level, expressed in power density, to which an individual may be exposed, which in light of present medical knowledge, will not cause detectable bodily injury under the conditions of exposure.

3. Power Density. The power per unit area. It is normally expressed in milliwatts per square centimeter (mW/cm^2).

4. Radiofrequency (RF) Radiation. For purposes of this standard, electromagnetic radiation at frequencies between 10 kHz and 300 GHz.

5. Restricted Area. Any area where access is controlled for the purpose of excluding entry of persons of less than 140 centimeters (55 inches) in stature. (NOTE: Includes those areas from which members of the general public are normally excluded, such as industrial work areas, flight lines,

communications compounds, etc.).

6. Unrestricted Area. Any area where access is uncontrolled. (NOTE: Includes typical public areas of the base, base housing, recreational areas, etc.).

7. A glossary of technical terms is provided as Attachment 1 to this standard.

C. REQUIREMENTS

1. Permissible Exposure Limits (PELs):

a. The biological effects of RF radiation on humans depend on the frequency of the incident radiation field, the polarization of the field, the size and shape of the person and his or her ability to dissipate by normal biological mechanisms, the energy absorbed.

b. The PELs listed in Tables 1 and 2 are based upon limiting the total body absorbed power to a specific absorption rate (SAR) of 0.4 watts per kilogram or less as averaged over any six-minute period. These PELs represent conditions under which it is believed that humans may be repeatedly exposed without adverse effects regardless of age, sex or child bearing status. The PELs are expressed as the maximum average plane wave power density, in milliwatts per square centimeter; electric field strength squared, in volts squared per meter squared; and magnetic field strength squared, in amps squared per meter squared, to which individuals may be continuously exposed. For the purposes of this standard, the average power of a device is the peak output power reduced by all duty factors associated with transmitter modulation and cyclic antenna motion. (The motion of a rotating antenna may markedly reduce the true average power at any given point.) Averaging is done over the six-minute period of maximum exposure potential. Exposures separated by more than six minutes are essentially separate physiological events with noncumulative effects. Examples of averaging techniques a given in Attachment 2.

c. The limits in Tables 1 and apply directly to far-field (pla wave) conditions where a stric relationship between electric ar magnetic fields exists. In near-fiel conditions, at frequencies below 3 MHz, the electric and magnetic fiel may require separate evaluation. Th individual fields can then be compare with the PELs. Equations fc converting field strength t equivalent power density are als given in Attachment 2.

d. Measurements to evaluate adherence to the PELs should be made a distances of at least 5 cm from ar object. Most probes used for makin RF radiation measurements have a styro foam spacer which provides at leas this amount of separation betwee objects and the sensing elements.

e. RF equipment which radiates a frequencies below 1000 MHz and deliver less than 7 watts of power to th radiating device is considered non hazardous.

f. There are no special R exposure limits for pregnant females Any RF environment safe for the mothe is also safe for the developing embry or fetus.

g. Permissible exposure limits i Table 1 may be increased under specia circumstances provided that all of th following conditions are met:

(1) the SAR does not exceed 0. W/Kg when averaged over the whole bod over any six (6) minute period;

(2) the spacial peak SAR (ho spots) does not exceed 8 W/Kg average over any one (1) gram of tissue;

(3) the maximum (peak) electri field intensity does not exceed 1 kilovolts per meter (kV/m), and;

(4) personnel are adequatel protected from electric shock ar burns through the use of electri

Table 1. Maximum Permissible Exposure Limits (PELs) in Restricted Areas for Human Exposure to Radiofrequency Radiation (Averaged Over any Six-Minute Period).

Frequency(f) (MHz)	Power Density (mW/cm^2)	Electric Field Strength Squared (V^2/m^2)	Magnetic Field Strength Squared (A^2/m^2)
0.01-3	100	400,000	2.5
3-30	$900/f^2$	$4000(900/f^2)$	$0.025(900/f^2)$
30-100	1.0	4000	0.025
100-1000	f/100	4000(f/100)	0.025(f/100)
1000-300,000	10	40,000	0.25

Table 2. Maximum Permissible Exposure Limits (PELS) in Unrestricted Areas for Human Exposure to Radiofrequency Radiation (Averaged Over any Six-Minute Period).

Frequency(f) (MHz)	Power Density (mW/cm^2)	Electric Field Strength Squared (V^2/m^2)	Magnetic Field Strength Squared (A^2/m^2)
0.01-3	100	400,000	2.5
3-30	$900/f^2$	$4000(900/f^2)$	$0.025(900/f^2)$
30-300	1.0	4000	0.025
300-1500	f/300	4000(f/300)	0.025(f/300)
1500-300,000	5.0	20,000	0.125

NOTES:

1. All exposures must be limited to a maximum (peak) electric field intensity of 100 kilovolts per meter (kV/m).

2. In the equations for PELs, "f" is the operating frequency of the emitter in megahertz.

3. Use the PELs under the heading 'Restricted Area' for Air Force workers and workplaces. Use the more restrictive PELs under the heading 'Unrestricted Areas' when assessing potential hazards in areas where the public has unrestricted access.

4. When exposure is to multiple-frequency radiation, the sum of the fractions of the PELs at the separate frequencies must not exceed unity.

5. When an RF emitter operates over a band of frequencies in which the PEL varies, such as between 3 and 30MHz, the lowest PEL shall apply.

6. Values in these tables were derived using a value of the impedance of free space 400 ohms. This value is rounded up from the generally accepted value of 377 ohms allow for ease of calculations.

7. When both the electric field and magnetic field are measured, both values must be equal to or less than their applicable derived equivalent PELs.

safety matting, wear of electrical safety shoes, or other isolation technqiues (primarily applicable for frequencies below 30MHz where the primary hazard is from electric shock and burns).

h. The application or use of PELs greater than those in Table 1 requires:

(1) A coordinated measurement and evaluation study by USAFOEHL and USAFSAM with input from ground safety;

(2) documentation of the findings of the evaluation (maintained locally in the BEE case file per instructions in AFOSH Std 161-17, Standardized Occupational Health Program);

(3) briefing of management, employees, and employee representatives on the findings of the evaluation and the reasons for the exception to the PELs;

(4) posting of the affected area to notify all personnel of the exception to the PELs and what additional protective measures must be taken. Signs should be appropriate Air Force CAUTION warning signs annotated with the protective measures required; should be large enough to be easily read from a distance; and should be located at the entrances to the areas which are affected.

2. Protective Clothing. RF shielded clothing is not acceptable as a method of protecting individuals from hazardous levels of RF radiation and it will not be used. An exception is the use of electrically insulated gloves and shoes for protection against electrical shock or insulation from the ground plane under conditions allowed by C1g.

3. Radiofrequency Hazard Warning Signs:

a. The format to be used for RF radiation warning signs is shown in Figure 1. This is the only format acceptable for use within the Air Force; signs using other formats must be replaced.

b. Signs may be locally reproduc in any size required. Two sizes adhesive backed plastic signs, 5 and 18 in square, respectively, may ordered through local Publicati Distribution Offices from the Defe Logistics Agency (DLA)--DOD Gene Supply Center.

c. RF warning signs are required access points to areas in which radi tion levels may exceed the PEL. Or narily, the BEE will determine locations and sizes of warning si appropriate to a given facility activity, and will recommend suita warning information to be printed the bottom half of the signs. Becau each installation is different, ev uation on an individual basis is nece sary. This determination will be m in coordination with the unit RPO. T organization operating the RF emitt is responsible for getting installing the signs.

d. In cases such as flight li radar maintenance, portable warni signs are needed. Signs on stan such as shown in Figure 2, may used. Units must be sure that stands for the signs are stable that signs are kept in good repai They must be supplied in suffici numbers to support the expected n bers of maintenance teams to working at any one time and to al maintenance teams to clearly outli controlled areas. Instructions on use of these signs and other cont measures must be given in unit OIs.

e. In areas where easy access very high levels of RF radiation exist (i.e., greater than 5 times PEL), warning signs alone may provide adequate protection. Ot warning devices and controls, such flashing lights, audible signa fences, and interlocks may be requir Special administrative controls coordination with other organizati or units may also be required.

f. Do not post warning signs microwave ovens.

g. Do not post warning signs

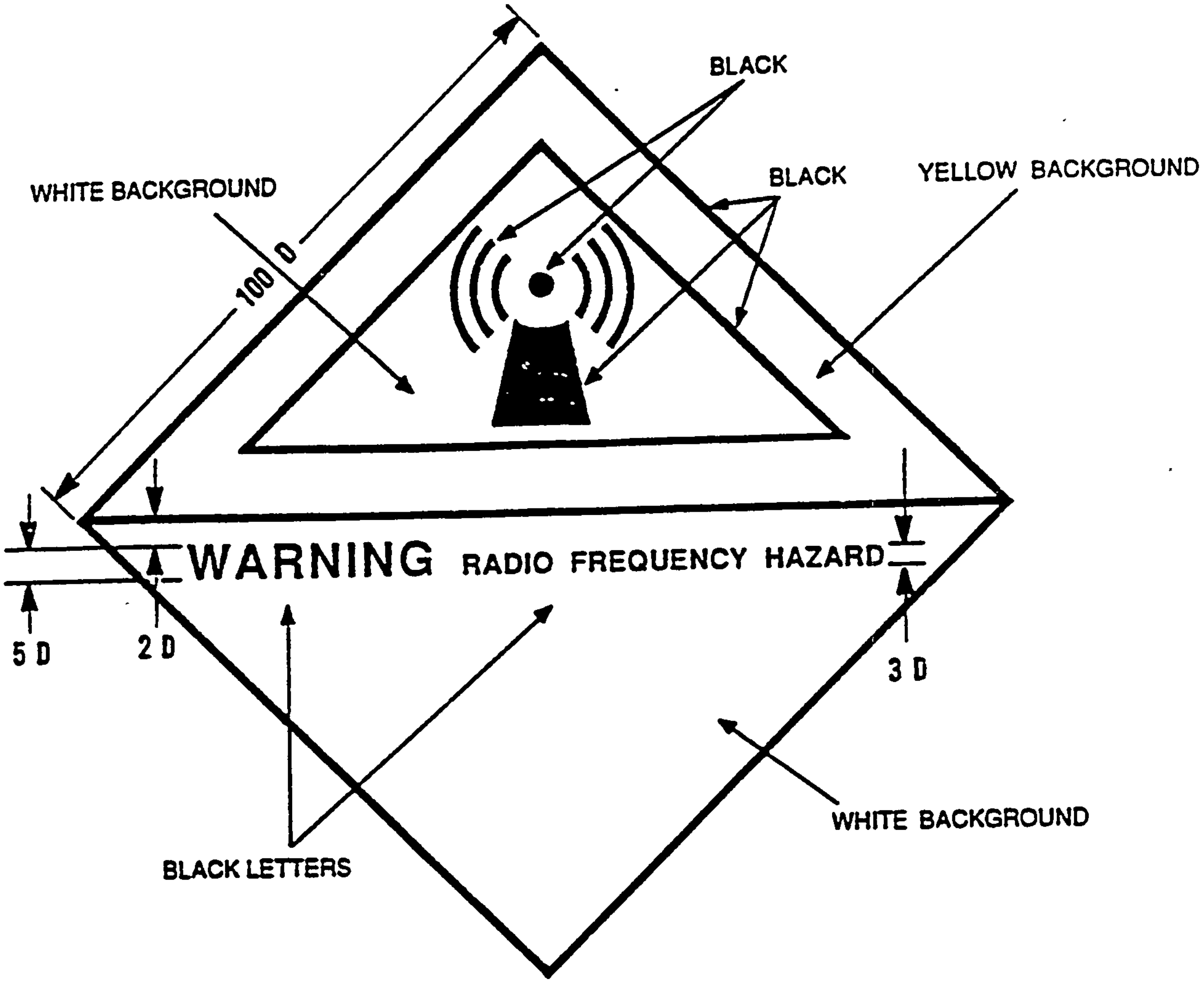


Figure 1. Radiofrequency Hazard Warning Sign.

GLOSSARY OF TERMS

NOTE: The following are common technical terms which comprise much of the vocabulary uniquely associated with the Radiofrequency Radiation Protection Program. They are defined in that context only.

A. Acronyms

AM	*Amplitude Modulation
BEE	Bioenvironmental Engineer
CW	*Continuous Wave
DBMS	Director, Base Medical Services
EED	*Electro-explosive Device
ELF	*Extremely Low Frequency
EHF	*Extremely High Frequency
EMI	*Electromagnetic Interference
EMP	*Electromagnetic Pulse
ECM	*Electronic Countermeasures
FM	*Frequency Modulation
FSK	*Frequency-Shift Keying
GCA	*Ground-Controlled Approach
HF	*High Frequency
ILS	*Instrument Landing System
LF	*Low Frequency
LORAN	*Long Range Navigation
[illegible]	*Medium Frequency
R	*Precision Approach Radar
PEL	*Permissible Exposure Limit
POL	*Petroleum, Oil, Lubricants
PRF	*Pulse Repetition Frequency
RAPCON	*Radar Approach Control
RF	*Radiofrequency
SAR	*Specific Absorption Rate
SHF	*Super High Frequency
SOP	Standard Operating Procedure
SSB	*Single Sideband
TACAN	*Tactical Air Navigation
TWT	*Traveling Wave Tube
UHF	*Ultra High Frequency
VHF	*Very High Frequency
VLF	*Very Low Frequency
VOR	*VHF Omnidirectional Range

B. Units

Amp	Ampere. Unit of electric current.
A/m	Amps/meter. Unit of magnetic field strength.
dB	Decibels. Logarithmic equivalent of a unitless ratio.
dBi	Decibels above isotropic. Used to describe the gain of an antenna as compared to an isotropic antenna.
GHz	Gigahertz. Unit of frequency equal to 10^9 cycles per second.
Hz	Hertz. Unit of frequency equal to one cycle per second.
kHz	Kilohertz. Unit of frequency equal to 10^3 cycles per second.
MHz	Megahertz. Unit of frequency equal to 10^6 cycles per second.
mW/cm^2	Milliwatts/square centimeter. Most common unit of power density.
Ohm	Ohm. Unit of electrical resistance.
Volt	Volt. Unit of electric potential or voltage.
V/m	Volts/meter. Unit of electric field strength.
Watt	Watt. Unit of power, equal to one joule per second.
W/kg	Watts/kilogram. Unit of biological energy deposition.
W/kg/ mW/cm^2	Watts/kilogram/milliwatt/square centimeter. Unit of specific absorption rate (SAR) normalized to incident power density.

*See definition in Section C of this Attachment

Definitions

Amplitude Modulation (AM) - A method of coding information on an RF wave in which the amplitude of the wave is varied in accordance with the intelligence being transmitted.

Antenna - A device which interfaces an electronic circuit (transmitter or receiver) with the outside world. In the case of a transmitter, it serves to convert RF energy generated by the circuitry into radiated electromagnetic energy.

Antenna Array - An arrangement of antennas which are physically and electronically spaced so that their individual contributions to the antenna pattern add in the preferred direction and cancel in other directions.

Antenna Gain - A measure of the effectiveness of an antenna in focusing RF energy in a given direction. It is generally expressed as the ratio of the power emitted by the antenna in the principal direction of radiation to the power which would be emitted in the same direction by an isotropic antenna, expressed in decibels (dB).

Antenna Pattern - The pattern which describes the gain or directivity of an antenna as a function of direction from the antenna, usually illustrated graphically as a polar plot of gain vs azimuth and/or elevation.

Attenuation - The reduction in intensity of RF energy as it passes through a device or physical medium, expressed as the ratio of output to input power, in decibels (dB).

Average Power, P. The time average rate of energy transfer:

$$P_{avg} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P\,dt$$

Where P is the power as a function of time.

Bandwidth - The difference between the frequency limits of an RF band containing the useful frequency components of the signal.

Beam Width - The angular width of a beam of RF energy defined by its halfpower points.

Biological Effect - Any phenomenon arising in a biological tissue or organ as a result of the absorption of RF energy, whether hazardous or not.

Carrier - The radio wave produced by a transmitter in the absence of any modulating signal.

Coaxial Cable - A transmission line made up of a center conducting wi surrounded by, and insulated f outer metal sleeve which serves t second conductor.

Continuous Wave (CW) - An RF transmi sion in which the carrier is transmi ted continuously, without any break FM is an example of CW. The du factor for a CW emitter is unity (1).

Decibel (dB) - The logarithmic un used to indicate relative intensiti of power or voltage, equal to 10 tim for power, and 20 times for voltag the common logarithm of the ratio.

Diathermy - The medical application RF energy to produce heat within so part of the human body for therapeut. purposes. Most diathermy equipme operates in the HF band.

Dipole - An antenna, approximate one-half wavelength long at maxim efficiency, split at its electric center for connection to a n mission line. A dipole has a maxim gain of approximately 2 dB at rig angles to the antenna.

Directivity - See Antenna Gain

Dummy Load - A dissipative device use at the end of a transmission line or wave guide to convert RF energy into heat, so that essentially no energy i radiated outward or reflected back to the source.

Duty Factor - (Duty Cycle, Duty Rati A unitless number, expressed as decimal fraction or percent, whi indicates the portion of time transmitter is actually emitting energy. For pulsed emitters, t product of pulse width and pul repetition frequency.

Electric Field - A fundamental comp nent of RF electromagnetic wave which exists when a voltage po i difference exists between two poin in space. See Field Strength.

Electro-Explosive Device - A pyrotec nic or explosive device designed detonate when an electric curre passes through it, commonly called a squib.

Electromagnetic Compatability (EMC) - The capability of electronic equipment to be operated in the intended electromagnetic enviroment at design levels of efficiency.

Electromagnetic Interference (EMI) - Interference with the proper functioning of an electronic device by electromagnetic means, internal or external.

Electromagnetic Pulse (EMP) - A pulse of very high magnitude and short duration, such as that which accompanies the detonation of a nuclear weapon.

Electromagnetic Spectrum - The total range of wavelengths of radiation extending from the longest radio waves to the shortest cosmic rays.

Electromagnetic Wave - A disturbance which propagates outward from an emitter, consisting of vibrating electric and magnetic fields which travel at the speed of light and are at right angles to each other and to the direction of travel.

Electronic Countermeasures (ECM) - An offensive or defensive tactic which uses an electronic device to interfere with the effective use of enemy radar, radio, etc.

Emitter - Any device which is designed to generate RF energy and couple this energy into the surrounding space.

Extremely Low Frequency - A radiofrequency below 300 Hz.

Extremely High Frequency - A radiofrequency above 30 GHz.

Far Field - (Fraunhofer region, plane wave region) The region far from an antenna, compared to the size of the antenna and the wavelength of the radiation. In this region the radiation has the properties of a plane wave. See Plane Wave.

Feed - The part of an antenna which couples RF energy to the antenna or reflector.

Field Strength - The magnitude of the electric field (in volts/meter) or magnetic field (in amps/meter).

Free Space - A region in the far field of an antenna which is devoid of any objects which could affect the radiation pattern.

Fraunhofer Region - See Far Field.

Frequency - The number of cycles completed by an electromagnetic wave in one second, given in cycles/second or hertz.

Frequency Band - A continuous range of frequencies, usually designated for one or more specific purposes.

Frequency Modulation (FM) - A method of coding information on an RF wave in which the frequency of the wave is varied in accordance with the intelligence.

Frequency-Shift Keying - A form of FM, used especially in telegraph and facsimile transmission, in which the modulating wave shifts the output frequency between predetermined values.

Fresnel Region - See Near Field.

Gain - See Antenna Gain.

Ground-Controlled Approach (GCA) - Control of the approach of an aircraft by a ground-based human controller. Aircraft position is determined by radar, and instructions are transmitted by radio. See Precision Approach Radar, Search Radar.

Height Finder - A radar system used to determine the elevation of airborne targets.

High Frequency (HF) - A frequency between 3 and 30 MHz, commonly used for moderate to long distance communication systems.

Horn - A type of microwave antenna made by flaring the end of a waveguide, for radiating RF energy directly into space or toward a reflector.

Hot Spot - An area of higher than average radiation caused by reflection and reinforcement of an RF beam.

Impedance - The total opposition that a circuit or propagation path presents to an RF current or wave. The ratio of the electric field strength to the magnetic field strength.

Instrument Landing System (ILS) - A system of radio navigation which provides lateral (glide path) and vertical (glide slope) guidance to aircraft approaching the runway for landing.

Ionizing Radiation - Particles or photons which have sufficient energy to produce direct ionization in their passage through a substance. (Examples: X-rays, gamma-rays, alpha particles)

Isotropic - Having identical properties in all directions.

Klystron - An electron tube in which an initial velocity modulation imparted to an electron beam results in a density modulation of the beam, used as a microwave oscillator or amplifier.

Lobe - One of the three dimensional portions of the directional pattern of a directional antenna. It is a region between two minima in the radiation pattern. The major or main lobe is that portion of the antenna field pattern containing the maximum radiation all other lobes, usually containing significantly less energy are side lobes.

Log-Periodic - An antenna which consists of several center-fed horizontal dipoles or vertical monopoles mounted parallel to each other in the same plane, characterized by broad bandwidth and moderate gain.

Long Range Navigation (LORAN) - An RF navigation aid which consists of master and slave ground stations.

Long Wave - an RF wave having a wavelength longer than the longest broadcast-band wavelength of 545 meters, corresponding to fre nc below about 550 kilohertz.

Low Frequency - A frequency between and 300 kHz.

Magnetic Field - A fundamental c ponent of electromagnetic wav produced by a moving electric fie See Field Strength.

Magnetron - A type of microwave t in which an electron beam is amplif under the combined force of a rad electric field and an axial magne field.

Medium Frequency - A frequency betw 300 and 3000 kHz.

Microwave - The term used to descri RF radiation at frequences above ab 1000 MHz.

Modulation - The process in whi amplitude, frequency, or phase oscillation is varied with time accordance with the wave form of intelligence signal.

Monopole - An antenna, usually in t form of a vertical pole or helic whip, which acts as one half of dipole, the other half being formed its electrical image in a ground plan

Navigation Aid - An RF system which used to assist in the navigation of aircraft.

Near Field - The electromagnetic fie which exists relatively near the radi tion source. In this area the electr and magnetic fields do not exhibit plane wave relationship, and the pow does not decrease with the square the distance from the source.

Nonionizing Radiation - Electromagnet radiation at wavelengths whose corr sponding photon energy is not enough to ionize an absorbing molecul All RF, infrared, visible, and ne ultraviolet radiation is nonionizing.

Overexposure - Any human exposure to energy which exceeds the establish PEL, as defined by this standard.

Peak Power - The maximum instantaneous power developed by an RF transmitter.

Permissible Exposure Limit (PEL) - That exposure level expressed in electric field, magnetic field, or plane wave power density to which an individual may be exposed and which, under the conditions of exposure, will not cause detectable bodily injury in light of present medical knowledge.

Petroleum, Oil, Lubricants (POL) - The common designation for flammable substances whose vapors could be ignited by RF energy.

Phased Array Radar - A radar having fixed array of many of antennae, each with an electronically variable phase shifter that permits steering of the beam over wide angles without antenna motion.

Plane Wave - An electromagnetic wave characterized by mutually orthogonal electric and magnetic fields which are related by the impedance of free space (377 ohms).

Polarization - The physical orientation of the electric field in an RF wave. Common polarizations are vertical, horizontal, circular, and elliptical.

Power density - The amount of power per unit area in an RF field, usually expressed in milliwatts per square centimeter.

Power Gain - The ratio of the power delivered to a specified load impedance by an amplifying device, to the power absorbed by the input to the device. Power gain is usually expressed in decibels. If more than one component is involved in the input or output, the particular component used must be specified.

Power Gain of an Antenna - Four π times the ratio of the radiation intensity in a given direction to the net power accepted by the antenna from the connected transmitter. When the direction is not stated, the power gain is usually taken to be the power gain in the direction of its maximum value. Power gain does not include reflection losses arising from mismatch of impedance. Greatest power gain is obtained during reception only when the incident polarization is the same as the polarization of the antenna on transmission.

Power Level - The ratio of the power at any point in a transmission system to some arbitrary amount of power chosen as a reference. This ratio is usually expressed as decibels referred to 1 milliwatt (dBm) or decibels referred to 1 watt (dBW).

Poynting vector - A vector, the flux of which through any surface represents the instantaneous electromagnetic power transmitted through the surface.

Precision Approach Radar (PAR) - The main component of a GCA system, a radar which scans limited angles of azimuth and elevation along the final approach to a runway.

Pulse Repetition Frequency (PRF, or Pulse Repetition Rate) - The number of times per second that pulses are transmitted by a radar or other pulsing transmitter. Reciprocal: Pulse Repetition Interval (PRI).

Pulse Width - The time width of an electromagnetic pulse, usually given in microseconds or milliseconds.

Radar - A system which beams RF energy into space and detects this energy as it is reflected from airborne objects, giving information about the distance, azimuth, elevation and/or velocity of these objects.

Radiofrequency - A frequency at which coherent electromagnetic radiated energy is useful for communication purposes, defined as 10 kHz to 300 GHz.

Radio Wave - An electromagnetic wave produced by reversal of current in a conductor at a frequency in the range from 10 kHz to 300 GHz.

Radar Approach Control (RAPCON) - The radar facility responsible for directing and controlling the aircraft in the general vicinity of an airport.

Reflector - A single rod, system of rods, metal screen, or metal sheet placed in the path of an RF wave in order to focus the energy in a given direction.

Rhombic - A very large, horizontal HF antenna consisting of four corner poles which support a diamond-shaped wire structure, fed at one apex by a transmission line and terminated with an impedance network at the opposite apex.

Search Radar - A radar system which constantly scans a region of space and displays aircraft as soon as they enter the region; used for early warning, ground-controlled approach, and air traffic control.

Short Wave - Propagation of radio waves at frequencies from about 1600 kHz to 30 MHz.

Single Sideband (SSB) - An AM communication system in which one of the two sidebands is suppressed, and the carrier may be transmitted or suppressed. If the carrier is suppressed, RF energy is transmitted only when the modulating signal is present.

Slot Antenna - A metal plate with a long narrow aperature cut into it, which is normally one half wavelength long. The aperature is energized by means of a cavity placed behind it, and a waveguide or a transmission line connected across it.

Specific Absorption Rate (SAR) - The time rate at which RF energy is absorbed per unit mass of material, usually measured in W/kg or normalized to incident power density in W/kg/mW/cm^2.

Super High Frequency - A frequency between 3 and 30 GHz.

Tactical Air Navigation (TACAN) - A radio navigation aid which provides accurate slant range and bearing info mation to aircraft. A VORTAC s combination TACAN and VOR.

Transmission Line - A system of co ductors, such as wires, waveguides, coaxial cables, which conducts energy between points in an RF system

Transmitter - A device which generat and amplifies an RF signal for tran mission into space as electromagnet waves.

Traveling Wave Tube (TWT) - An electr tube in which a stream of electror interacts with a guided electroma netic wave resulting in a transfer energy from the stream to the wav used as a microwave amplifier.

Ultra High Frequency (UHF) - A fr quency between 300 and 3000 MHz. T UHF band for military aircraft radi extends from 225 to 400 MHz.

Very High Frequency (VHF) - A fr [illegible] between 30 and 300 MHz. The VHF ba for aircraft radios extends from 108 136 MHz.

Very Low Frequency (VLF) - A frequen between 3 and 30 kHz.

VHF Omidirectional Range (VOR) - navigation aid which transmits cod bearing information to aircraft. VORTAC is a combination VOR and TACAN

Waveguide - A metallic duct which co fines and guides the propagation electromagnetic waves.

Wavelength - The distance between t points having the same phase in t consecutive cycles of a periodic wave

Yagi - A type of directional anten which has one dipole connected to t transmission line and a number equally spaced unconnected dipol mounted parallel to the first t same plane which serve as directo and reflectors.

EXAMPLE CALCULATIONS AND USEFUL EQUATIONS

A. EXAMPLE CALCULATIONS

1. Determination if PEL is exceeded for exposures of less than six minutes.

a. Given: Adult worker, exposed to an average power density of 50 mW/cm^2 at a frequency of 2.6 GHz for 180 seconds.

b. Solution:

(1) Since the frequency is greater than 1.5 GHz and the average power density exceeds the 10 mW/cm^2 PEL, check to see if the exposure averaged over six minutes still exceeds the PEL.

(2) Average exposure over 6 minutes (360 sec) is:

$$50 \text{ mW/cm}^2 \times \frac{180 \text{ sec}}{360 \text{ sec}} = 25 \text{ mW/cm}^2$$

(3) Since the average exposure exceeds the 10 mW/cm^2 PEL, an overexposure occurred.

2. Determination of maximum stay time:

a. Given: An adult worker exposed to an average power density of 200 mW/cm^2 at a frequency of 5 MHz.

b. Problem. To determine the maximum allowable exposure time.

c. Solution:

(1) Since no reference is made to installed electrically nonconducting mats or mandatory wear of electrical safety shoes the worker must be assumed to be in perfect ground plane contact.

(2) Since the frequency is between 3 and 30 MHz, the PEL is: 900/f^2 or 900/(5x5) or 36 mW/cm^2

(3) The maximum allowable exposure time in any 6-minute period is: (360 sec X 36 mW/cm^2)/(200 mW/cm^2) or 64.8 sec including entry and exit times.

3. Calculation of E-field:

a. Given: A pulsed RF emitter with a duty factor of 0.0002 produces an RF field having an average power density of 10 mW/cm^2.

b. Problem. To determine if the peak E-field PEL is exceeded; Page 10, Footnote 1.

c. Solution:

(1) The E-field PEL is 100kV/m or (1x10^{5}V/m)

(2) The peak power density (P_{pk}) is:

$$\frac{PAVG}{DF} = \frac{10 \text{ mW/cm}^2}{0.0002} = 5 \times 10^4 \text{ mW/cm}^2$$

(3) The peak E-field is $(3770P_{pk})^{0.5}$ or $(3770 \times 5 \times 10^4)^{0.5}$ or 1.37×10^4V/m which is less than the PEL.

4. Calculations on scanning radars:

a. Given: A scanning radar antenna is rotating at a constant speed thru 360 degrees, and radiating at 1 GHz with no significant back or side lobes. The average power density in the stationary beam at a distance of 7 meters was measured and found to be 40 mW/cm^2. The horizontal beam width at 7 meters is computed to be 1 meter.

b. Problem. To determine if a small child would be overexposed at 7 meters from this scanning radar.

c. Solution:

(1) Since the frequency is between 300 and 1.5 GHz, the PEL is f/300 or 1000/300 or 3.3 mW/cm^2 in a 6-minute period.

(2) The rotation is constant and therefore, the exposure times will be constant for any 6-minute period

selected. The total exposure time for 6 minutes will equal the exposure time per revolution times the number of revolutions in 6 minutes. Since all revolutions are the same, a fractional exposure time per revolution times 6 minutes will also give a total exposure time.

(3) Exposure time per revolution (t_r):

$$t_r = \frac{\text{beam width (bw)}}{\text{angular rotation velocity (w)} \times \text{distance to antenna } (d_a)}$$

$$t_r = \frac{bw}{w\ d_a}$$

(4) Total time for one revolution (t_t): $t_t = \frac{2\pi}{w}$

(5) Fractional exposure time (FET) for any revolution:

$$FET = \frac{t_r}{t_t}$$

$$FET = bw/2\pi \quad d_a$$

$$FET = \frac{1 \text{ meter}}{7 \text{ meter}} \times \frac{1}{2\pi} = 0.023$$

(6) Since the FEL is 3.3 mW/cm^2 for 6 minutes and the FET is 0.023, then the FEL is not exceeded if the power density in the main beam is less than:

$$\frac{3.3 \text{ mW/cm}^2}{.023} \quad \text{or } 143 \text{ mW/cm}^2$$

d. Alternate Solution:

(1) Since rotation is constant, each beam sweep can be considered a pulse and a rotational "duty factor" calculated:

(a) Pulse repetition frequency (PRF):

$$(PRF) = \frac{1 \text{ pulse}}{\text{revolution}} \times n \frac{\text{revolutions}}{\text{minute}}$$

(b) Pulse width (PW) = $\frac{bw}{w\ d}$

(c) but:

$$w = 2\pi \frac{\text{radians}}{\text{revolution}} \times n \frac{\text{revoluti}}{\text{minute}}$$

(d) Duty factor (DF) = PRF x PW

(e) Substituting and reducing:

$$DF = \frac{bw}{2\pi}\, d_a$$ (note that this is th equation for FET previously calculat

(2) The average power densit (P_a) to an individual is therefor the average stationary beam powe (P_b) reduced by the rotational dut factor i.e., $P_a = (P_b) \times DF = 4$. mW/cm^2 x 0.023 = 0.92 mW/cm^2

(3) The FEL was 3.3 mW/cm^2 hence no overexposure would occur.

e. Manipulation of terms in th equations for (t_r) and (t_t) previously described will demonstrat that the FET can also be described a defined in equation n of paragraph B. Once the FET is obtained, exposure may be calculated as shown above. Note that the definitions of FET ar independent of rotation or scannin speed and are applicable to an constant antenna rotations.

B. USEFUL EQUATIONS

1. Key to Symbols:

a. bw = Beam Width

b. d = Distance from antenna in meters

c. DF = Duty Factor (unitless)

d. E = Electric Field Strength in volts/meter

e. FET = Fractional Exposure Time

f. G_d = Gain in dB

g. G_n = Numerical Gain (unitless)

h. H = Magnetic Field Strength in amps/meter

i. P = Power (watts)

j. P_a = Average Power in watts

k. PD = Power density in mW/cm^2

l. P_p = Peak Power in watts

m. PpK = Peak Power/Density in mW/cm^2

n. PRF = Pulse Repetition Frequency in pulses/second

o. PW = Pulse Width in seconds

p. V = Voltage (volts)

2. Equations:

a. $DF = PW \times PRF$

[1]b. $P_a = P_p \times DF$

[1]c. $P_p = P_a/DF$

[2]d. $G_d = 10 \log P_2/P_1$

[2]e. $G_n = 10^a$ where $a = G_d/10$

[3]f. $G_d = 20 \log V_2/V_1$

[3]g. $G_n = 10^b$ where $b = G_d/20$

FOR FAR FIELD CONDITIONS

h. $PD = E^2/3770$

i. $PD = 37.7 \times H^2$

j. $E = (PD \times 3770)^{0.5}$

k. $H = (PD/37.7)^{0.5}$

l. PEL Distance

$$D_{PEL} = ((P_a \times G_n)/40\pi\ (PEL))^{0.5}$$

m. $E = (30 \times G_n \times P_p/d^2)^{0.5}$

[4]n. FET =

$$\frac{\text{beam width in scanning plane (deg)}}{\text{total scanned sector (deg)}}$$

$$= \frac{\text{beam width (meters) X 57 deg/rad}}{\text{total scanned sector (deg) X d}}$$

NOTES:

1. These equations may be used to compute power in watts or power density in mW/cm^2

2. Use these equations for power gain

3. Use these equations for voltage gain

4. These do not include back and side lobes, which must be calculated independently from the main beam. If the required data are known for such peripheral RF fields the equations may be applied to them.

INTRODUCTION TO RADIOFREQUENCY RADIATION AND ITS BIOLOGICAL EFFECTS

A. NATURE OF ELECTROMAGNETIC RADIATION

1. Electrical energy emitted into free space exists in the form of electromagnetic waves. These waves travel with the speed of light and consist of magnetic and electric fields at right angles to each other and also at right angles to the direction of travel. If these electric and magnetic fields could actually be seen, the wave would have the appearance indicated in figure A1. One-half of the energy contained in the wave exists in the form of electric energy, while the remaining half is in the form of magnetic energy.

2. The essential properties of a wave are the frequency, intensity, direction of travel, and polarization. The waves produced by an alternating current will vary with the current and, therefore, be alternating positive and negative as shown in Figure A1. The distance occupied by one complete cycle of such an alternating wave is equal to the speed of the wave divided by the number of cycles that are sent out each second and is called the wavelength. The relationship between wavelength λ in meters and frequency in hertz (Hz) is therefore:

$$\lambda = \frac{300,000,000}{f}$$

The quantity of 300,000,000 is the speed of electromagnetic propagation (speed of light) in meters per second.

A low-frequency wave has a long wavelength, while a high-frequency wave has a short wavelength.

3. The intensity of a wave is determined by the strength of its electric and magnetic field components.

The electric field strength (E) is usually given in volts per meter (V/m), and the magnetic field strength (H) is given in amperes per meter (A/m).

4. A plane parallel to the mutually and magnetic fields is called the wavefront. The wave always travels in direction at right angles to the wavefront, but whether it goes forward or backward depends upon the relative direction of the lines of magnetic and electric field. If the direction of either the magnetic or electric field is reversed, the direction of travel is reversed, but reversing both sets of fields has no effect.

5. The direction of the electric field lines is called the direction of polarization of the wave. If the electric field lines are horizontal, as shown in figure A1, the wave is horizontally polarized; if the electric field lines are vertical and the magnetic field lines are horizontal the wave is vertically polarized Elliptical polarization is characterized by the fact that the resultant magnetic (or electric) fields produced by an alternating wave never, at any instant, pass through zero; rather the resultant fields rotate in the plane of the wavefront at a rate corresponding to the frequency of the wave, while at the same time pulsatin in amplitude. The resultant field produced by elliptical polarization can, therefore, be represented by a rotating vector of varying length The field can never be zero because the vertical and horizontal components do not pass through zero at the same instant.

6. Figure A2 gives the electromagnetic frequency spectrum and show some of its specific applications an properties. The RF portion of th spectrum is contained within this broa spectrum of frequencies and is define as that segment between 10 kHz(10^4Hz and 300 GHz(3×10^{11}Hz). Conventional RF band designations may be found i T.O. 31-Z-10-4. Electronic Countermeasures (ECM) designations are liste in AFR 55-44.

B. PRODUCTION OF RADIOFREQUENCY RADIATION FIELDS

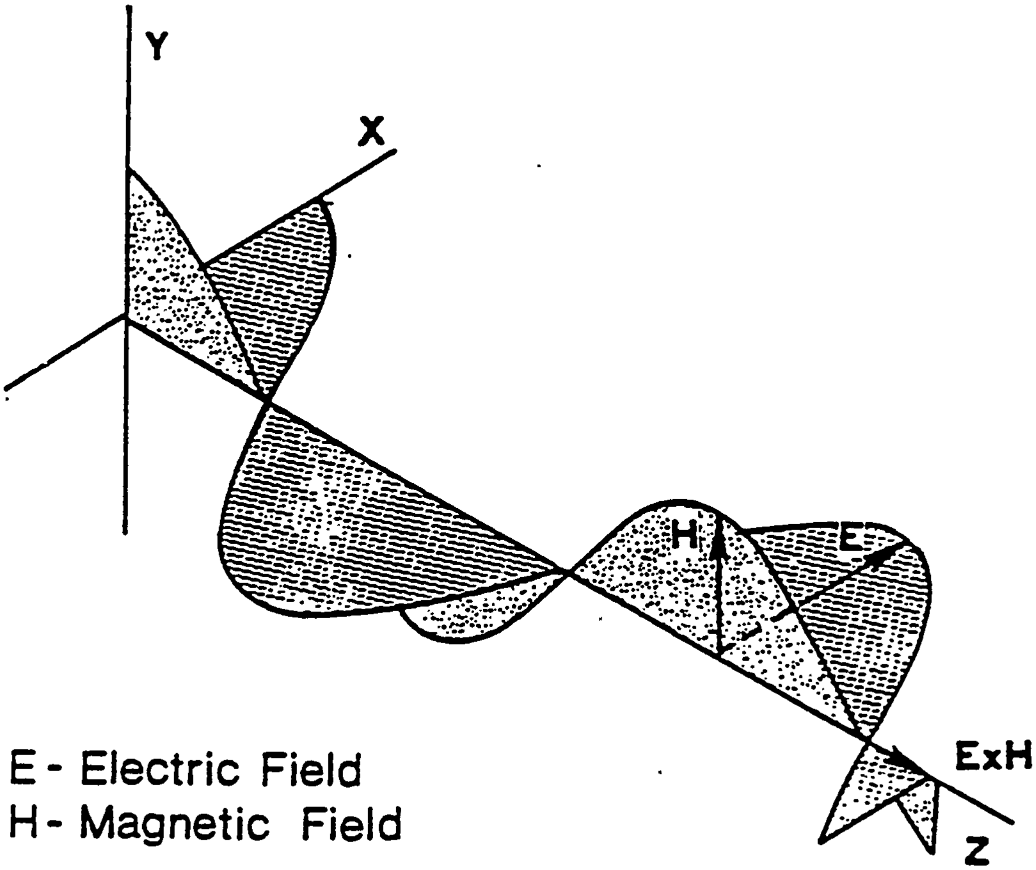


Figure A1. Properties of Electromagnetic Waves.

Figure A1. Properties of Electromagnetic Waves

1. Electromagnetic radiation is produced whenever a conductor carries an alternating current. Some common sources of electromagnetic radiation are: microwave ovens, diathermy, radar, television, radio communications, and microwave data link transmission. The laws governing such radiation are obtained using the four fundamental expressions of electromagnetism (Maxwell's equations) which are valid for all media. When these laws are used to express the fields associated with the conductor, there is an electric and magnetic component, termed the radiated field, which varies inversely with distance from the source.

2. The electric and magnetic fields in the immediate vicinity of an antenna (near field) are greater in magnitude and different in phase from the radiated fields (far fields). The electric and magnetic fields that must be added to the radiated fields, in order to give the fields actually present, are termed induction fields. These induction fields diminish in strength more rapidly than in inverse proportion to distance. At distances of a few wavelengths they become negligible in comparison with the radiated fields. However, at distances from the antenna that are small compared with a wavelength (or small compared with the antenna dimensions if the antenna is large), the induction electric and magnetic fields will be much stronger than the radiated fields of the antenna.

3. The three broad classes of antennas are aperture, directional wire, and omnidirectional. An aperture antenna is one from which essentially all of the radiation emanates from an aperture. Usually a feedhorn illuminates a reflecting surface which concentrates the RF energy into a small, highly directional beam. This results in the antenna having a power gain relative to an omni or nondirectional antenna. The beam widths produced by aperture antennas may be as small as 0.1 degree in both azimuth and elevation. Directional wire antennas such as the helix, the yagi, the log periodic, or the rhombic, have broad directiona characteristics and much lower we gains than aperture antennas. i- directional antennas such as th vertical whip, dipole, or inverted ve have low power gain.

4. RF radiation can be reflected in manner similar to light, and under th same condition that the physical dimension of the reflector must be larg compared to the wavelength reflected. Metallic reflecting surfaces in th shape of a parabolic, spherical, o cylindrical surface may be used t direct a beam of energy in a manne similar to an automobile headlamp. This type of beam transmission find most use at ultra high frequencie (0.3-3GHz) where the dimensions of th radiating elements are small. By usin two or more antennas properly space and phased in an array, directiona transmission can be realized by causin the radiated signals to add in th preferred direction and to cancel i others.

5. The directive gain of an antenn is defined as the ratio of the powe density that is radiated in the preferred direction to the radiated powe density averaged over all directions This can be expressed either as a powe density ratio (numerical gain) or i terms of decibels.

6. The decibel (abbreviated dB) is logarithmic unit used to express powe ratios. If the powers being compare are P_1 and P_2, then

$$dB = 10 \log_{10} P_2/P_1$$

The sign associated with the number o decibels indicates which power is th greater; thus a negative sign indicate that P_2 is less than P_1. Unde many conditions, relative power i proportionate to the square of th voltage V. Under these conditions

$$dB = 20 \log_{10} V_2/V_1$$

These relations must be used wit caution, however, as they hold onl when the impedence associated with V is equal to that associated with V_2.

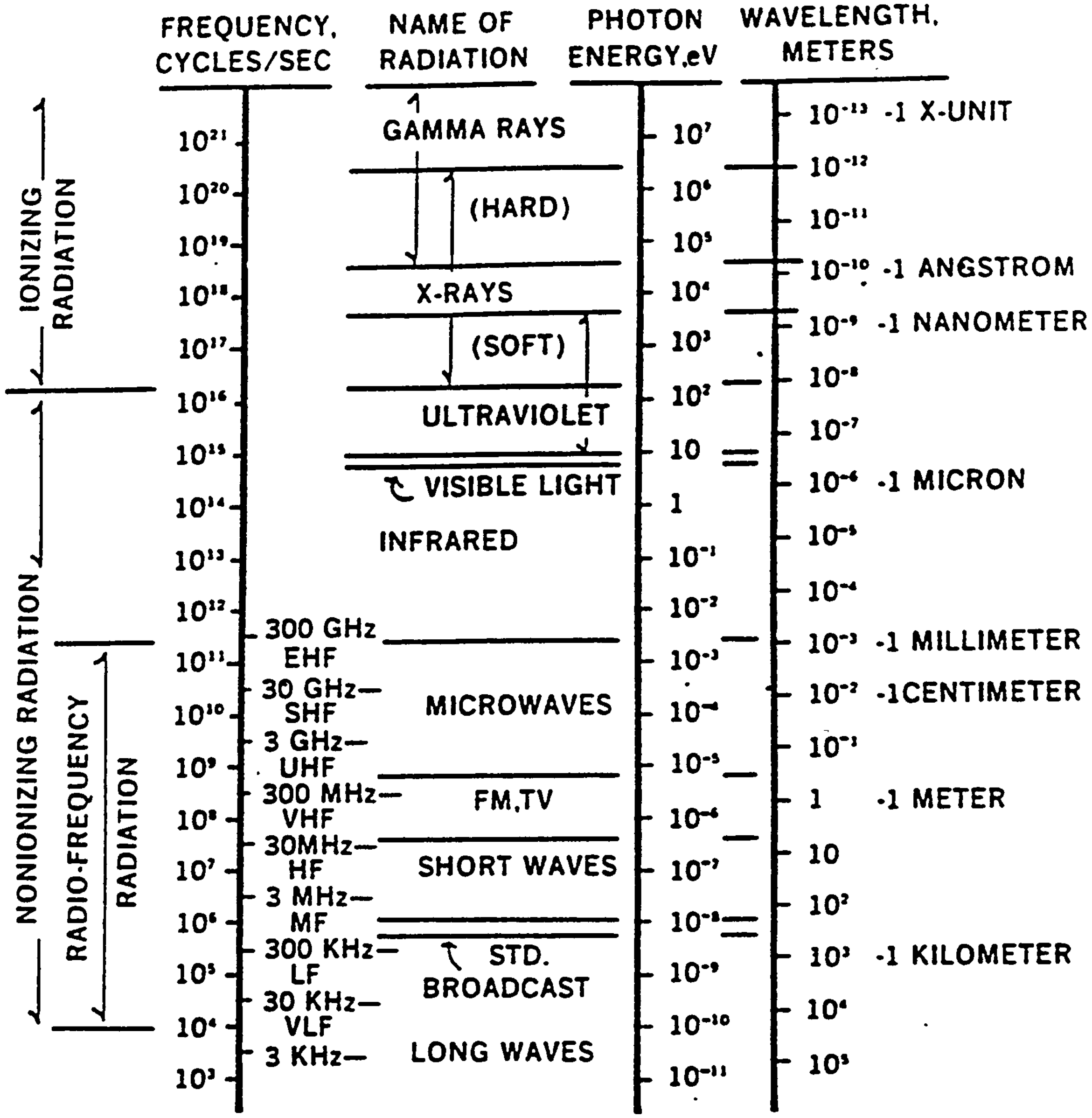


Figure A2. Electromagnetic Radiation Spectrum.

Figure A2. Electromagnetic Radiation Spectrum

7. The electromagnetic wave spreads out so that the intensity of the radiated energy (power density) in the far field region varies inversely as the square of the distance. The relationship between power density and distance is illustrated in figure A3, which shows part of the pattern of radiated energy from an isotropic antenna.

C. CHARACTERISTICS OF RADIOFREQUENCY APPLICATIONS

1. It is possible to convey information by modulating any property of a carrier wave. These properties are amplitude, frequency, and phase. Amplitude modulation (AM) is done by varying the output power of the transmitter in accordance with the modulating signal. Pulse modulation (used in telemetry and radar systems) is a special form of amplitude modulation. When the frequency of the carrier wave is varied in accordance with variations in a modulating signal, the result is frequency modulation (FM). Similarly varying the phase of the carrier current is called phase modulation (PM).

2. For AM with 100 percent modulation, the average power will equal a maximum of 1.5 times the unmodulated carried power. For pulse modulation, the average power is equal to the product of peak power and duty factor (DF), where DF = pulse width in units of time (PW) x pulse repetition frequency (PRF). For FM and PM the average power can be considered equal to the peak power.

D. ELECTROMAGNETIC PULSE

1. Nuclear explosions produce a short, intense electromagnetic pulse (EMP) which, depending on the altitude, can radiate over many hundreds of miles. This pulse is produced by a flow of Compton electrons generated in the atmosphere as the front of gamma rays from the burst interacts with the air molecules. The restrictions on atmospheric nuclear testing have made it necessary to construct EMP simulators for the empirical investigation of EMP interaction and effects on military hardware.

2. While available EMP data sugges that no acute or chronic bioeffect can be assigned to EMP exposure tentative limits are established i this standard as a precautionar measure.

E. BIOLOGICAL EFFECTS OF RADIOFREQUENC RADIATION

1. Introduction. Induction of hea in biologic tissue by RF radiation ha been known for more than 80 years This fact has been the basis of R diathermy as used in the practice o physical therapy. Energy from the R field is transferred to tissue by increasing the rotational energy o dipoles in the tissue. The principa dipole in biologic material, the wate molecule, has the property of hig viscosity (or long relaxation time) This makes it a very good absorber o RF energy. Changes result from th absorption of energy. Which m[illegible] o not produce temperature increases; however, the underlying mechanisms ar basically driven by thermodynami principles and the physiologica responses thereto. There has been substantial increase in researc regarding the biologic effects of RF radiation and a great deal has bee learned about the absorption an distribution of RF energy in biologi material and the resultin physiological consequences.

2. Absorption of RF Radiation.

a. The absorption of RF energy by biologic materials is strongly influenced by the frequency of the incident radiation and by the orientation of the object in the electromagnetic field. Using prolate spheroids, ellipsoids, and scaled models of man, studies have shown that whole-body absorption of RF energy is very strongly dependent [illegible]or the orientation of the long axis o[illegible]e body relative to the electric field. Furthermore, the greatest absorption in this orientation occurs when the body length is approximately 0.4 of the free-space wavelength. This optimal absorption occurs at frequencies of

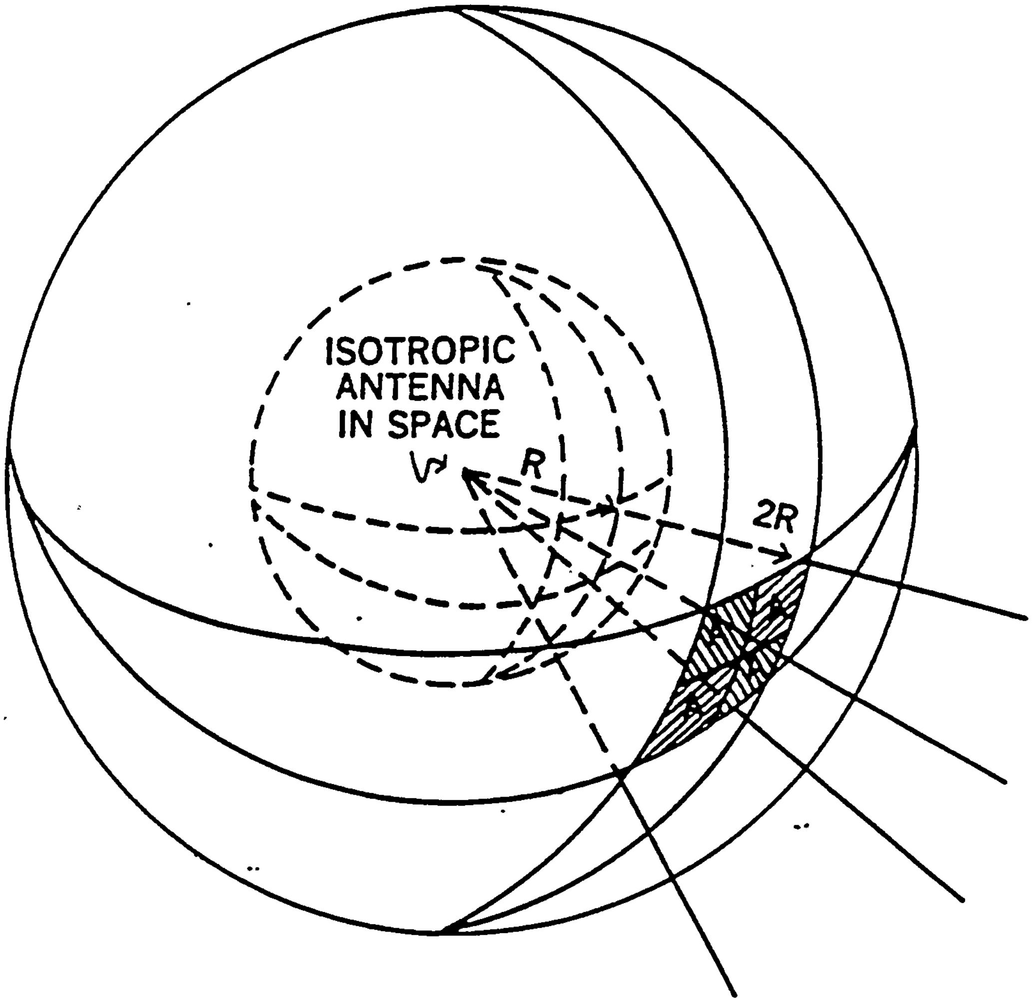


Figure A3. Power Density Versus Distance.

An ideal isotropic antenna distributes its radiated energy uniformly in all directions. Imagine a sphere of radius R (surface area = $4\pi R^2$) with the antenna at its center. The fraction of the total power which passes through the unit area A on the surface of the sphere is

$$P_A/P_T = A/4\pi R^2$$

and the power density at any point on this sphere is

$$PD_R = P_A/A = P_T/4\pi R^2.$$

The figure shows that at distance 2R from the source, the same fraction of the total power is projected on an area four times as great, so that the power density is decreased by a factor of four. Similarly, at distance 3R, the power density will have decreased by a factor of nine. The power density from a source, then, decreases in proportion to the square of the distance from the source.

about 70-80 MHz for adult humans. These frequencies are termed "resonant frequencies". When a person is in perfect ground contact, the resonant frequencies will shift to 35-40 MHz. A small separation from ground, e.g., wearing shoes, in most cases returns the resonant frequency to free-space conditions (70-80 MHz).

b. The concept of a specific absorption rate (SAR) was developed to facilitate comparison of exposure conditions from experiment to experiment and from experiment to man. The SAR is the mass normalized rate of RF energy absorbed under different exposure conditions and/or for different frequencies. The SAR concept has been particularly useful for the extrapolation of experimental data from animals to man. It is possible to equate the SAR at a particular frequency and power density required to produce a discrete bioeffect in an experimental animal to the frequency and power density required to produce that same SAR in man. SAR's are given in units of watts per kilogram (W/kg).

3. Biological Effects. The preponderance of studies reported to date have not defined any deleterious health effects from exposure to RF energy below a SAR of 4W/kg. Studies that have been reported which show effects below a SAR of 4W/kg either report effects which are not considered hazardous, or effects which have not been substantiated by replication in other laboratories. Extensive research continues in order to establish the validity and true nature of these effects. SAM-TR-87-03 provides a critique and summary of the relevant RF bioeffects literature to date, and is periodically updated to maintain currency with the extensive research underway in the world today.

4. Microwave Hearing Effect. The so-called "microwave hearing effect" has been known for more than 30 years and consists of an audible sound which seems to originate within or near the head. The sensation is described as a clicking, buzzing, or chirping sound depending upon the pulse repetitio rate and pulse width of the inciden RF radiation. The mechanism responsible for the sensation is similar t that produced by ordinary sound. Th pulses of RF energy appear to produc a thermoelastic wave or pressure wav described as a cochlear microphonic This wave is conducted by inner ea structures to receptors, and then b nerve impulses to the brain as i ordinary sound perception. For 15 microsecond pulses the threshold fo this response is approximately 700 mW/cm^2. Most operational systems will not produce power densities in accessible locations that reach this threshold. This effect, of itself, is not considered to be hazardous. However, any reports of this effect should be treated as a possible overexposure and carefully investigated.

5. Ophthalmologic Considerations: RF energy has been shown to produce cataracts in experimental animals when the exposure is sufficient to raise the temperature of the lens to around 41°Celsius. In rabbits, exposure for 1 hour to 2450 MHz radiation at 100 mW/cm^2 is sufficient to induce a cataract.

6. Indirect Biologic Effects. Electronic medical prosthetic devices such as artificial cardiac pacemakers can respond to pulsed RF radiation fields. Most modern devices are however, insensitive to the RF radiation levels encountered in areas where persons are allowed unrestricted access by this standard. Significant disruption of normal pacemaker funtion requires RF radiation signals having a primary frequency between 0.1 and 5 GHz, pulse widths of greater than ten microseconds, and electric field strengths greater than 200 V/m. It is, however, prudent for individuals dependent on such devices to recognize the possibility of interference and avoid controlled areas.

7. Metal Implants. Little is known concerning the interaction of RF radiation with metal implants such as cranial plates or orthopedic pins. However, it is thought that the PELs

APPENDIX I

EPA SITE PUBLICATIONS

APPENDIX I.1

Draft Bulletin: IITRI RFH SITE Demonstration

Technology Description: Radio frequency heating (RFH) is a process that uses electromagnetic energy generated by radio waves to heat soil in situ, thereby potentially enhancing the performance of standard soil vapor extraction (SVE) technologies. An RFH system developed by the ~~Illinois Institute of Technology~~ IIT Research Institute (IITRI) was evaluated under the Superfund Innovative Technology Evaluation (SITE) Program at Kelly Air Force Base (AFB) in San Antonio, Texas. This demonstration was performed in conjunction with a technology evaluation being performed by the U.S. Air Force (USAF).

Figure 1 is a schematic diagram of IITRI's RFH system. A 40-kW radio transmitter was used as the energy source for the system. Energy was supplied to the exciter electrodes via coaxial cables. Reflected energy was measured, and the electrical characteristics of the transmitted radio frequency (RF) energy were adjusted as necessary. The transmitted radio frequency and other operational parameters were selected based on soil dielectric properties.

The four exciter electrodes were installed in a row in the center of the treatment zone. Two rows of eight ground electrodes each were installed parallel to and on either side of the exciter electrode row. The electrode configuration was designed to direct the flow of RF energy through the soil and contain the energy within the treatment zone. Above-ground components connected to the ground electrodes completed the RF containment system.

The outer casing of each ground electrode was perforated on the side facing the treatment zone to permit the collection of vapors from the soil. Each ground electrode was connected to a manifold that led to the vapor treatment system. Two perforated vapor extraction pipes were also installed parallel to the ground surface to prevent buildup of vapors below the vapor barrier. A vapor barrier covered the surface of the soil in and around the treatment zone to prevent heat loss, contaminant migration, and air infiltration.

The vapor extraction system was operated throughout the heating and cooling portions of the demonstration. Vapors were channeled through a vapor collection system to a vapor treatment system. Vapors that condensed in the vapor collection and treatment systems were collected, then transferred to a Kelly AFB facility for further treatment. Uncondensed vapors were burned in a natural gas flare. The vapor treatment system was site- and contaminant-specific and was not evaluated as part of the RFH system.

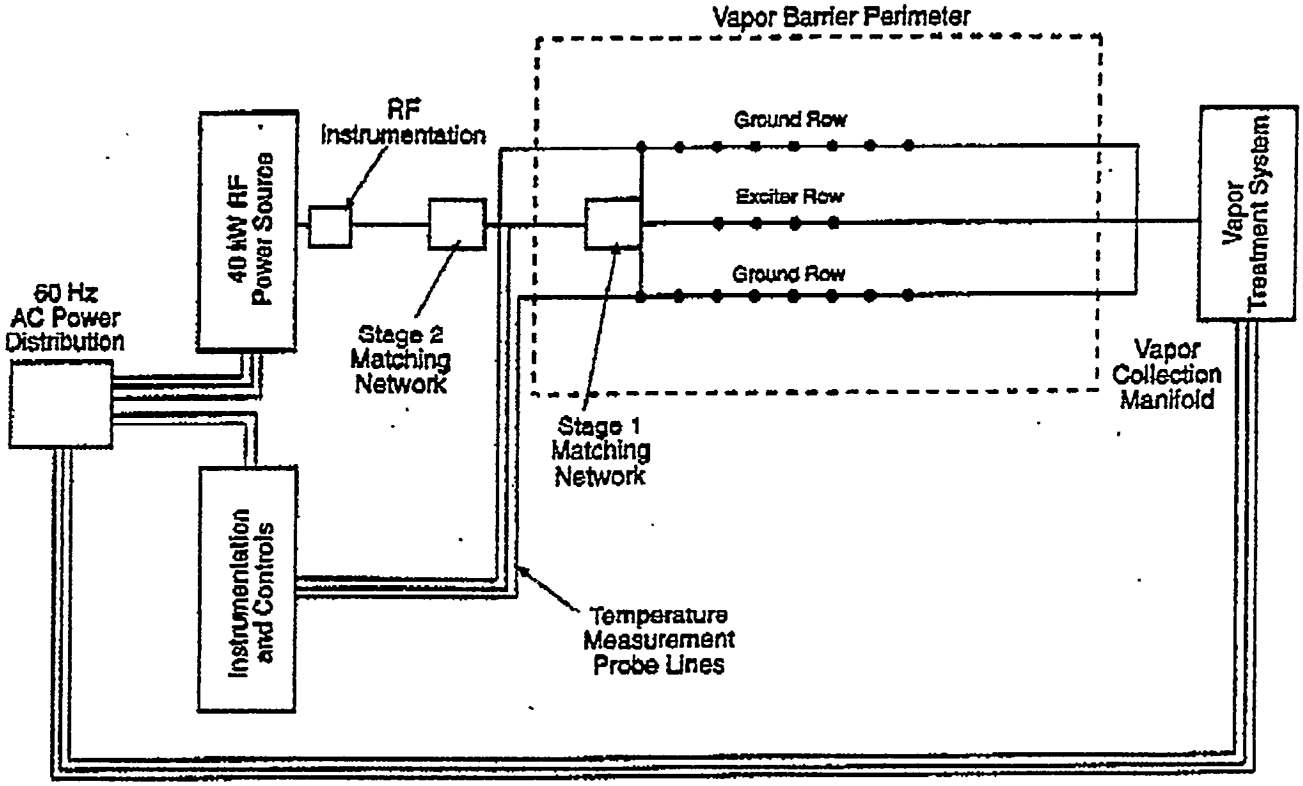


Figure 1. Schematic Diagram of IITRI's RFH System

Waste Applicability: RFH is a potential enhancement for in situ SVE systems. RFH is designed to speed the removal of volatile organics and to make it possible to remove semivolatile organics that would not normally be removed by standard SVE technologies. Inorganics, metals, and other nonvolatile contaminants would not normally be treated by SVE or RFH technologies.

Demonstration Results: During the demonstration, IITRI's RFH system was applied to a plot of soil 10 feet wide, 17.5 feet long, and 24 feet deep. The treatment zone was part of an intermediate storage area for wastes destined for off-base reclamation, and the soil was contaminated with mixed solvents, carbon cleaning compounds, and petroleum oils and lubricants.

Temperatures within and outside the treatment zone were monitored at various depths throughout the treatment period. As RF energy was applied to the soil, the soil temperature increased at all temperature monitoring points. The soil near the exciter electrodes absorbed much more energy than the soil near the ground electrodes, resulting in substantial temperature variations across the treatment zone. Maximum temperatures within the treatment zone ranged from more than 1,000°C near the exciter electrodes to less than 50°C near the bottom corners of the treatment zone. The treatment zone contained approximately ~~[illegible]~~ cubic feet of soil, of which approximately cubic feet achieved an average temperature of at least 4200 150°C for at least 2 weeks. 1270

Soil contaminant concentrations were evaluated as matched pairs of pre- and post-treatment data. Within the treatment zone, 35 matched pairs of data were collected; 2 matched pairs were collected outside the treatment zone. Both pre- and post-treatment contaminant concentrations varied considerably. For example, pretreatment total recoverable petroleum hydrocarbon (TRPH) concentrations ranged from 51,000 ppm to less than 30 ppm, and post-treatment TRPH concentrations ranged from 24,900 ppm to less than 25 ppm. Substantial localized variability also occurred within the treatment zone. For example, a pretreatment TRPH concentration of less than 32 ppm was measured only 4 feet away from a pretreatment TRPH concentration of 8,500 ppm. Other contaminants exhibited similar natural variability, making it difficult to exhibit statistically significant removals.

Contaminants that exhibited statistically significant changes (at the 80 percent confidence interval) are listed in Table 1. Because the concentrations of some contaminants increased and the concentrations of other contaminants decreased, Table 1 contains either mean percent increase or mean percent removal for each contaminant. Possible explanations for the increases in contaminant concentrations include migration from areas outside the treatment zone and chemical formation from other contaminants.

An Innovative Technology Evaluation Report and a Technology Evaluation Report describing the complete demonstration will be available by summer 1995.

Table 1. Results Summary

Contaminant	Mean Percent Removal	Mean Percent Increase
TRPH	53	
Chlorobenzene		120
Bis(2-ethylhexyl)phthalate	62	
Pyrene	44	
2-Hexanone		851
4-Methyl-2-pentanone		666
Acetone		555
Methyl ethyl ketone		446

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APPENDIX I.2

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Environmental Protection
Agency

Office of
Research and Development
Cincinnati, OH 45268

EPA/540/R-94/527a
March 1995

EPA

SITE Technology Capsule

IITRI Radio Frequency Heating Technology

Abstract

Radio frequency heating (RFH) technologies use electromagnetic energy in the radio frequency (RF) band to heat soil in situ, thereby potentially enhancing the performance of standard soil vapor extraction (SVE) technologies. Contaminants are removed from in situ soils and transferred to collection or treatment facilities.

The Illinois Institute of Technology Research Institute (IITRI) RFH process was evaluated under the U. S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program at a site containing various organic contaminants in a heterogeneous soil matrix. Due to changes in the original design and operational problems experienced during the demonstration, the treatment area was evaluated as two separate zones: the "revised" design treatment zone and the "heated" zone. The revised design treatment zone reflects both changes made to the design of the RFH system and operational problems associated with shallow groundwater at the test site. The heated zone consists of the area that achieved the target temperature of 150°C.

Concentration changes were calculated from paired pre- and post-demonstration soil samples; these concentration changes were evaluated for statistical significance. Conclusions have been drawn based only on data that were statistically significant at greater than or equal to the 90 percent confidence level.

Within the revised design treatment zone the estimated mean concentration decrease for Total Recoverable Petroleum Hydrocarbons (TRPH) was 60 percent. Estimated mean concentration decreases for two semivolatile organic compounds (SVOCs), pyrene and bis(2-ethylhexyl)phthalate were 87 and 48 percent, respectively. There were statistically significant increases in the concentrations of four volatile organic compounds (VOCs); the estimated mean concentration increases were 457 percent for 2-hexanone; 263 percent for 4-methyl-2-pentanone; 1,073 percent for acetone; and 683 percent for methyl ethyl ketone.

Outside of the revised design treatment zone, only TRPH showed a statistically significant change with an estimated 88 percent increase in the mean concentration.

Within the heated zone the estimated mean concentration decrease was 95 percent for TRPH.

Outside the heated zone, the estimated mean concentration decrease was 37 percent for bis(2-ethylhexyl) phthalate; estimated mean concentration increases were 423 percent for 2-hexanone; 249 percent for 4-methyl-2-pentanone; 1,347 percent for acetone; and 1,049 percent for methyl ethyl ketone.

Several possible reasons exist for changes in concentration observed. They include inward contaminant migration, low extraction rates, widely varying soil temperatures, low pretreatment contaminant concentrations in the soil, and the potential degradation of TRPH and SVOCs.

The estimated cost to treat 10,152 tons of contaminated soil based on a scale-up of the revised design treatment zone is $619 per ton; the estimated cost to treat 8,640 tons of contaminated soil based on IITRI's theoretical system design is $340 per ton.

The IITRI RFH technology was evaluated based on the nine criteria used for decision making in the Superfund feasibility study (FS) process. Results of the evaluation are summarized in Table 1. This evaluation was based on information from the SITE demonstration conducted at Kelly Air Force Base (AFB).

Introduction

In 1980 the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, committed to protecting human health and the environment from uncontrolled hazardous waste sites. CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986.

SITE
SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

Table 1. Evaluation Criteria for the IITRI RFH Technology[1]

Evaluation Criteria	*Performance*
Overall Protection of Human Health and the Environment	• *Site-specific treatability studies will be needed to verify the levels of contaminant removal achievable* • *Requires measures to protect workers during installation and treatment* • *Additional contaminants may form at high temperatures if not properly designed or operated*
Compliance with Federal ARARs[2]	• *Vapor collection and treatment are needed to ensure compliance with air quality standards* • *Construction and operation of an onsite vapor treatment unit may require compliance with location-specific ARARs* • *RF generator must be operated in accordance with National Institute of Occupational Safety and Health (NIOSH) and Federal Communication Commission (FCC) requirements*
Long-term Effectiveness and Performance	• *As with all SVE-based systems, the contamination source may not be adequately removed* • *Involves some residuals treatment (vapor stream)*
Reduction of Toxicity, Mobility, or Volume through Treatment	• *Potentially concentrates contaminants, reducing waste volume* • *Potentially reduces contaminant mobility, although downward mobility of contaminants during treatment has not been quantified* • *May form new contaminants, thereby potentially reducing or increasing toxicity, if not properly designed or operated*
Short-term Effectiveness	• *Presents minimal short-term risks to workers and community from air release during treatment* • *No excavation is required, although drilling will disturb the soil to some extent*
Implementability	• *RF generator must be operated in accordance with NIOSH and FCC requirements* • *Pilot-scale tests have been completed at two other sites to evaluate the technology; no full-scale applications to date* • *Because of operational problems experienced during the SITE demonstration, consistent soil heating was not observed*
Cost[3]	• *Cost evaluation based on revised design treatment zone is $619 per ton; cost evaluation based on IITRI's theoretical system design is $340 per ton*
State Acceptance	• *No excavation is required, which should improve state acceptance*
Community acceptance	• *No excavation is required, which should improve community acceptance* • *Potential health effects of RF fields may be an issue*

[1] *Based on the results of the SITE demonstration at Kelly AFB*

[2] *ARARs = Applicable or Relevant and Appropriate Requirements*

[3] *Actual cost of a remediation technology is site-specific and dependent on the target cleanup level, contaminant concentrations, soil characteristics, and volume of soil. Cost data presented in this table are based on the treatment of 10,152 tons of soil (scale-up based on the revised design treatment zone) and 8,640 tons of soil (based on IITRI's theoretical system design).*

These amendments emphasize the achievement of long-term effectiveness and permanence of remedies at Superfund sites. SARA mandates implementing permanent solutions and using alternative treatment technologies or resource recovery technologies, to the maximum extent possible, to clean up hazardous waste sites.

State and federal agencies, as well as private parties, are now exploring a growing number of innovative technologies for treating hazardous wastes. The sites on the National Priorities List total more than 1,200 and comprise a broad spectrum of physical, chemical, and environmental conditions requiring varying types of remediation. The EPA has focused on policy, technical, and informational issues related to exploring and applying new remediation technologies applicable to Superfund sites. One such initiative is EPA's SITE Program, which was established to accelerate development, demonstration, and use of innovative technologies for site cleanups. EPA SITE Technology Capsules summarize the latest information available on selected innovative treatment and site remediation technologies and related issues. These capsules are designed to help EPA remedial project managers, EPA on-scene coordinators, contractors, and other site cleanup managers understand the type of data and site characteristics needed to effectively evaluate a technology's applicability for cleaning up Superfund sites. Additional details regarding technology demonstrations are presented in the Innovative Technology Evaluation Reports.

This capsule provides information on the IITRI in situ RFH technology. This technology was developed to improve the removal of VOCs and SVOCs from the soil using standard SVE technologies. The IITRI RFH process was evaluated under the SITE Program from January through August 1993 at Kelly AFB in San Antonio, Texas. This demonstration was performed in conjunction with a technology evaluation performed by the U.S. Air Force (USAF). Information in this capsule emphasizes specific site characteristics and results of the SITE field demonstration at Kelly AFB. The capsule presents the following information:

- Technology Description
- Technology Applicability
- Technology Limitations
- Process Residuals
- Site Requirements
- Performance Data
- Technology Status
- Sources of Further Information
- References

Technology Description

RFH technologies use RF energy to heat soil in situ, thereby potentially enhancing the performance of standard SVE technologies. The RF energy causes dielectric heating of the soil, which is a faster and more efficient mechanism for heating solids than is convective heating. Some conductive heating also occurs in the soil.

In IITRI's proprietary system, an RF generator supplies energy to exciter electrodes, which are copper pipes installed in vertical boreholes. Copper balls welded onto the ends of the exciter pipes help distribute the energy, which tends to concentrate at these points. As the soil is heated due to the dissipation of the RF energy, contaminants and moisture in the soil are vaporized and pulled toward ground electrodes, which also serve as vapor extraction wells. The vaporized water may act as a steam sweep to further enhance the removal of organic contaminants. A standard SVE system provides a vacuum to the ground electrodes and transfers the vapors to collection or treatment facilities. Contaminants are treated using standard vapor treatment techniques. After soil treatment is complete, the soil is allowed to cool. The SVE system may be operated during part or all of this cooling period. The exact numbers of exciter and ground electrodes, electrode configurations, vapor collection or treatment techniques, and other design details are site-specific.

Figure 1 is a schematic diagram of the IITRI RFH system used for the SITE technology demonstration at Kelly AFB; Figure 2 is a cross-section of IITRI's RFH system. A 40-kW RF generator served as the energy source for the system. Energy was supplied to the exciter electrodes for approximately 9 weeks via coaxial cables. Reflected energy was measured, and the electrical characteristics of the transmitted RF energy were adjusted as necessary. Exciter electrodes were constructed of 2.5- and 4-inch (nominal diameter) copper pipe and were installed in 10-inch boreholes to a depth of 19.5 feet below the surface. The boreholes were backfilled around the electrodes using a material similar to the surrounding soil. Four exciter electrodes spaced 2.5 feet apart were installed in a row.

Two rows of eight ground electrodes each were installed parallel to and on either side of the exciter electrode row. The ground electrodes were fabricated from 2-inch-diameter aluminum pipe. The electrode configuration was designed to direct the flow of RF energy through the soil and contain the energy within the treatment zone. With the exception of the four corner electrodes that were not perforated, the ground electrodes were perforated on the side facing the treatment zone to permit the collection of vapors from the soil. They were perforated in a uniform pattern over the full length of the electrodes. Each perforated ground electrode was connected to a manifold, which led to the vapor treatment system. Two additional perforated vapor extraction pipes were installed parallel to the ground surface to prevent buildup of vapors below the vapor barrier.

As shown in Figure 1, the insulated vapor barrier extended several feet over the surface of the ground and exciter electrodes to prevent heat loss, contaminant emission, and air infiltration. A sheet of expanded aluminum covered the same area as the vapor barrier and was designed to contain RF energy. An arched aluminum shield that covered only the electrodes in the treatment zone was also designed to contain RF energy. To complete the RF containment system, the arched RF shield was electrically connected to the ground electrodes by aluminum wire mesh.

The system was designed to heat the soil evenly to a temperature of approximately 150°C. The soil heating began at the top of the treatment zone near the exciter electrodes, and the heated zone expanded outward and downward over time. The original area to be treated measured 10 feet wide by 17.5 feet long by 29 feet deep. Due to shallow groundwater and operational problems encountered during the demonstration, the treatment zone was revised to 10 feet wide by 14.1 feet long by 23.3 feet deep. The RFH system was evaluated using this "revised" design treatment zone. The RFH system was also evaluated using the "heated" zone, which is the area that achieved the target temperature of 150°C. This zone measures 5.7 feet wide by 10.8 feet long by 20.0 feet deep. Temperatures within and outside both treatment zones were monitored at various depths throughout treatment. Contaminant removals inside and outside each of these zones were evaluated separately; results of these evaluations are presented in the Performance Data Section.

The vapor extraction system was operated throughout the 9-week heating period and for approximately 2 months during the cooldown period. The vapor extraction system was operated at a suction pressure of at least 7 inches of water column while heat was being applied to the soil. Vapors were extracted from the soil at a rate of approximately 120 standard cubic feet per minute (scfm). Condensate that formed in the system was collected; uncondensed vapors were burned in a propane flare.

Technology Applicability

The heat provided by the RFH process increases the vapor pressure of contaminants in the soil, thereby potentially improving the effectiveness of SVE. RFH may make it possible to remove SVOCs that would not normally be removed by standard SVE technologies. RFH may also speed the removal of VOCs, which can be removed by standard SVE technologies. Contaminants that can potentially be removed using RFH include a wide variety of organics such as halogenated and

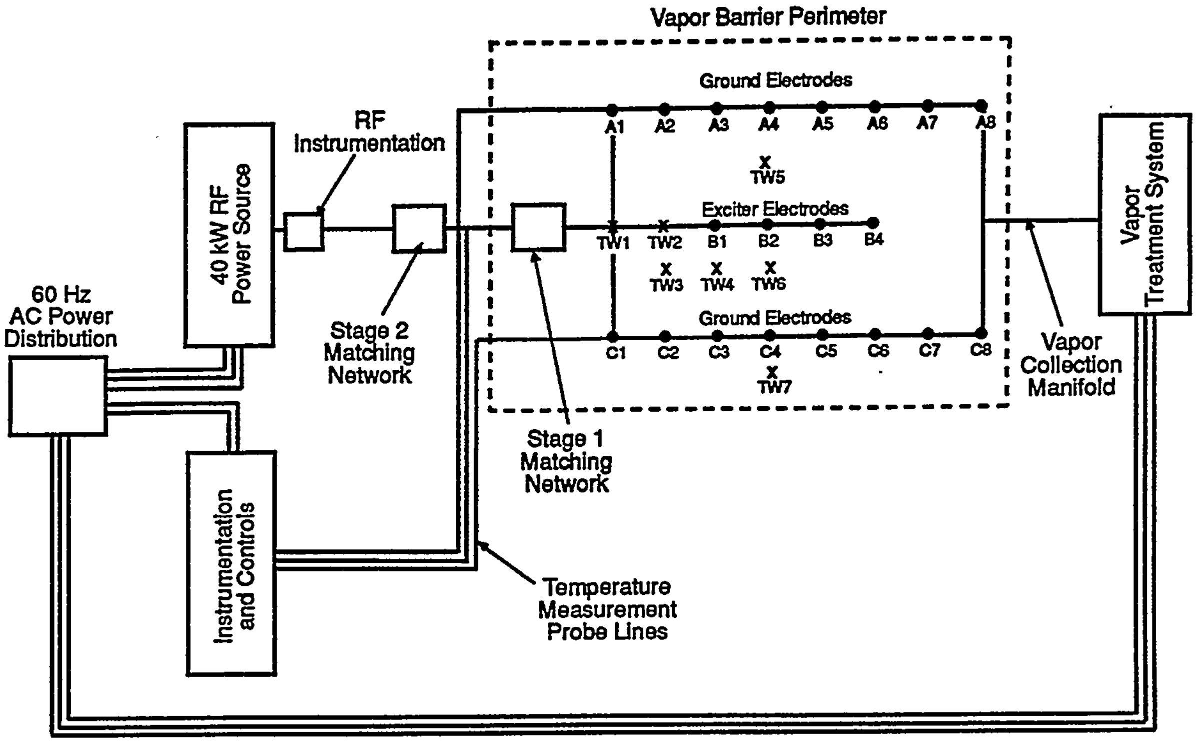

Figure 1. Schematic diagram of IITRI's RFH system.

nonhalogenated solvents and straight-chain and polycyclic aromatic hydrocarbons found in gasoline, jet fuel, and diesel fuel. Inorganics, metals, and other nonvolatile contaminants will not normally be treated by SVE or RFH technologies.

A previous study (not sponsored by the SITE program) conducted at Volk AFB indicated that IITRI's RFH system effectively removed VOCs and SVOCs from a small treatment zone containing homogenous, sandy soils. The soil in the Kelly AFB treatment zone was a heterogeneous mixture of sand, clay, and gravel. Due to the operational problems encountered during the Kelly AFB study, it cannot be determined how the heterogeneous soil matrix affected RFH system effectiveness. However, soils containing large amounts of silt, clay, and humic substances tend to adsorb organic contaminants more tightly. Soils containing a large fraction of clay may also have insufficient air permeability for adequate contaminant removal by SVE or RFH technologies. Site-specific, in situ treatability studies will need to be conducted to confirm the applicability of this technology.

Technology Limitations

IITRI claims its technology is not ready for commercialization. Considerable development and optimization of the process would be required before a full-scale system would be ready for field use. For example, IITRI must demonstrate the system's ability to treat an entire site and to use an RF generator that can supply more than 40 kW of RF energy. The IITRI RFH technology cannot be used as a stand-alone technology. Vaporized contaminants and steam must be collected for reuse or treatment. In some cases, residual contaminants may remain in the soil after treatment.

This technology currently appears to be limited to unsaturated soils, although groundwater pumping may be used to lower the water table and extend the treatment zone. RFH is further limited to soils contaminated with VOCs and SVOCs. Nonvolatile organics, metals, and inorganics will not normally be removed by RFH or SVE technologies.

Process Residuals

The IITRI RFH process generates one process waste stream that contains vaporized contaminants and steam diluted in extraction air. This waste stream can be treated by any of a number of standard vapor treatment technologies including vapor-phase carbon, condensation, or incineration. During the SITE demonstration at Kelly AFB, a propane flare was used to treat uncondensed contaminants in the vapor waste stream.

Steam and contaminants in the vapor stream that condensed in the vapor collection system were collected prior to the flare. These condensed residuals were handled along with other site wastes at Kelly AFB. When groundwater is pumped to lower the water table, the groundwater must also be handled as a liquid residual.

Some soil contaminants may remain after treatment. Significant quantities of several organics remained in the soil after treatment was completed at Kelly AFB, although remediation of

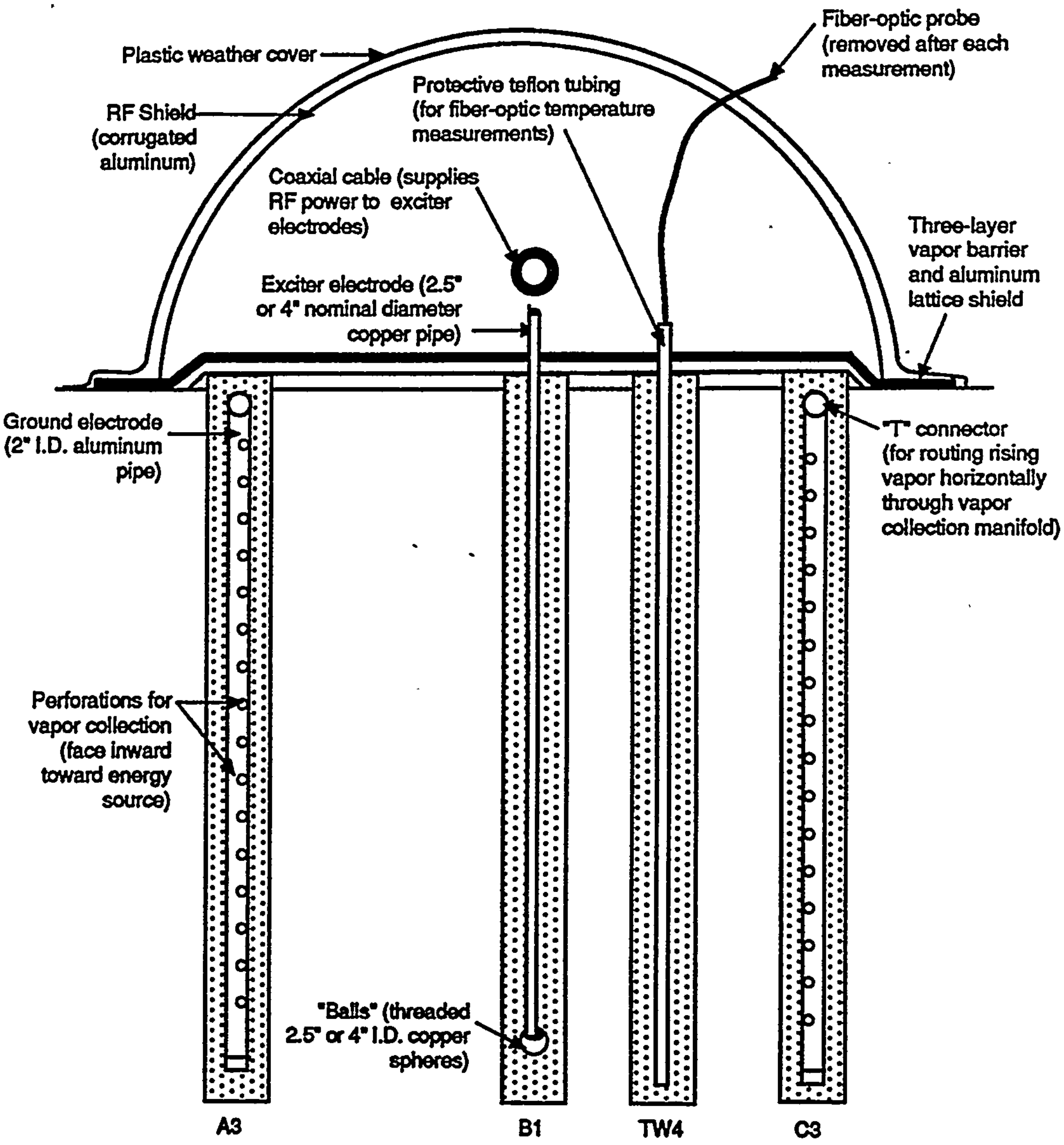

Figure 2. Cross-section of IITRI's RFH system.

the site was not an objective of the demonstration. Further treatment will be required to fully remediate these soils.

Site Requirements

Onsite assembly of the full-scale system will take several weeks, including drilling time. It is expected that medium to large sites will be divided into several sections that will be treated consecutively. The soil must be allowed to cool before final soil samples can be collected to confirm cleanup of each section. Soil cooldown will take up to several months if portions of the soil reach 1,000°C, as they did during the SITE demonstration. However, with proper design and operation, soil heating may be more uniform, resulting in lower soil temperatures and faster cooldown. After treatment is completed, system demobilization may take up to a week. Access roads are needed for equipment transport. Approximately 4,600 ft^2 of level ground are needed to accommodate the trailer-mounted RF generators, controllers, and other support equipment. A bermed area is needed for decontamination of the drill rig. Area is also needed for storage of condensed vapors, if applicable, and the selected vapor treatment system.

Remediation using the RFH process will require that certain utilities be available at the site. Water must be available for steam-cleaning and other equipment and personnel decontamination activities. Electrical power must also be available. The RF generator requires 480-volt, 3-phase power, and most of the minor system components require 240-volt, single-phase power. If carbon adsorption is used to treat vapors, compressed air may be required for system control, and steam or hot air will be needed if the carbon is regenerated onsite. Natural gas or propane will be required if a flare is used to control vapors.

The ground electrodes, expanded aluminum sheet, arched aluminum shield, and aluminum wire mesh minimize RF energy emissions. Monitoring should be conducted to ensure that the RF field outside of the treatment zone does not exceed NIOSH or FCC requirements. These regulations were reportedly met during the SITE demonstration and other previous field studies. The system is relatively quiet, and only during installation will dust and vapors be a potential problem. Therefore, the RFH technology can be applied near residential areas.

Performance Data

The system was designed to heat the soil evenly to a temperature of approximately 150°C. Soil temperatures were monitored by the vendor throughout the 61-day treatment period during which RF energy was applied to the soil. Before treatment began, the soil temperature throughout the area was approximately 20°C. During the SITE demonstration, the RF energy applied to the exciter electrodes progressed gradually from the surface to the deepest point of each exciter electrode. The soil temperature near the ground electrodes increased gradually as RF energy flowed from the exciter electrodes to the ground electrodes. Near the end of the demonstration all exciter electrode temperatures varied widely; maximum temperatures near the exciter electrodes exceeded 1,300°C. Temperatures near the ground electrodes did not exceed 112°C near the surface, and did not exceed 52°C below 24 feet. Based on temperature measurements, it appears that a system malfunction could have resulted in incomplete heating of the revised design treatment zone. IITRI believes this malfunction was a result of electrical problems due to shallow groundwater.

Groundwater levels may have been higher than originally expected by the vendor. Due to the presence of shallow groundwater, IITRI shortened the exciter electrodes to avoid potential system operational problems. Groundwater levels were monitored infrequently, so insufficient data are available to determine exact water levels during the demonstration. However, exciter electrodes removed after the demonstration had melted. Since copper melts at approximately 1,100°C, these electrodes provide evidence of a system malfunction that prevented full utilization of RF power for soil heating. Based on IITRI's soil temperature logs, it appears that the system malfunction occurred during the last weeks of the heating period.

Contaminant removal during the demonstration was evaluated by measuring contaminant concentrations in the soil before and after treatment. Soil samples were collected using split spoons with stainless steel sleeves before and after the soil was treated. The samples were collected as matched pairs; each post-treatment sample was collected as near as possible to its corresponding pretreatment sample. Within the revised design treatment zone, 28 matched pairs of soil samples were collected; 9 matched pairs of soil samples were collected outside this zone. Within the heated zone, 6 matched pairs of soil samples were collected; 31 matched pairs of soil samples were collected outside this zone. Only complete matched pairs were used in the evaluation of the data. A complete matched pair was defined as a matched pair in which both pre- and post-treatment samples were collected and analyzed, and in which the compound being evaluated was measured at a concentration greater than the detection limit in at least one of the two samples. The number of complete matched pairs was limited by the low pretreatment concentrations of many contaminants in the soil. This made it difficult to determine any change after treatment because pretreatment concentrations were often below analytical quantitation limits.

For each contaminant, the population distribution of the concentration data was evaluated. Most contaminants were log-normally distributed, and as a result, concentration data were log transformed. The ratio of post-treatment concentration to pretreatment concentration was calculated for each complete matched pair. The resulting set of ratios for each contaminant of interest was evaluated using a t-test to determine whether the contaminant concentration exhibited a statistically significant change between the pre- and post-treatment sampling events. The mean ratio of post-treatment concentration to pretreatment concentration was also calculated for each contaminant. The mean ratio was then converted to either the mean percent decrease or the mean percent increase, as appropriate. Conclusions have been drawn based only on changes that were statistically significant at the 90 percent confidence level or greater.

Because of the high concentrations of TRPH expected at the site, TRPH was designated as an indicator (i.e., critical) contaminant. Method 418.1 [1] was used to determine TRPH concentrations in the soil samples following extraction with Freon® according to Method 9071 [2].

Soil samples were extracted by Method 3540 [2] and analyzed for SVOCs using Method 8270 [2]. Five SVOCs were designated as indicator (i.e., critical) compounds because their concentrations were expected to be significant. These included 2-methylnaphthalene; naphthalene; 1,2-dichlorobenzene; 1,3-dichlorobenzene; and 1,4-dichlorobenzene. Because a preliminary statistical evaluation did not indicate any significant changes in the concentrations of these compounds, none of them were included in the final statistical evaluation and no conclusions can be drawn. Two other (i.e., non-critical) SVOCs were statistically evaluated because they exhibited concentration decreases.

Method 8240 [2] was used to determine VOC concentrations in the soil samples. Benzene, toluene, ethylbenzene, total xylenes, and chlorobenzene were designated as indicator (i.e., critical) VOCs because of their expected high concentrations. A preliminary statistical evaluation conducted for these five compounds indicated that only chlorobenzene exhibited a change in concentration, and was, therefore, the only indicator VOC included in the final evaluation. However, in the final statistical evaluation, chlorobenzene did not exhibit a statistically significant change at the 90 percent confidence level. Four other VOCs were statistically evaluated because they exhibited concentration increases.

Revised Design Treatment Zone Results

The following results were observed within the revised design treatment zone:

- There was a statistically significant decrease in TRPH concentration at the 95 percent confidence level; the estimated decrease in the mean concentration was 60 percent.
- No conclusions can be drawn regarding the five indicator SVOCs.
- There were statistically significant decreases in the concentrations of two other SVOCs, pyrene and bis(2-ethylhexyl)phthalate, at the 97.5 percent confidence level; estimated decreases in the mean concentrations were 87 and 48 percent, respectively.

The decreases in TRPH and SVOCs are likely due to the performance of the RFH system, which may have resulted in the volatilization of contaminants, allowing them to be collected by the SVE system. These decreases may also have been caused by the degradation of these compounds from the elevated temperatures of the RFH system. Decreases from outward migration are unlikely, since the configuration of the SVE system would limit this type of migration.

For the VOCs within the revised design treatment zone, the following results were observed:

- There was no statistically significant change in the concentration of chlorobenzene at the 90 percent confidence level. No conclusions can be drawn regarding the other four indicator VOCs.
- There were statistically significant increases in the concentrations of four other VOCs (all ketones) at the 99 percent confidence level; estimated increases in the mean concentrations were 457 percent for 2-hexanone, 263 percent for 4-methyl-2-pentanone, 1,073 percent for acetone, and 683 percent for methyl ethyl ketone.

The ketones may have been formed by the degradation of TRPH and SVOCs near the exciter electrodes, where soil temperatures were highest. A possible degradation pathway may be the pyrolytic conversion of TRPH to unsaturated hydrocarbons. In the presence of sufficient oxygen and a catalyst (e.g., silica in the soil), the RF energy may convert these hydrocarbons into ketones. The increase in ketones may also have been caused by inward migration. Possible sources of ketones are the groundwater, which was not sampled, and the soil beyond the sampled area, although these sources cannot be verified. However, there are insufficient data to confirm or disprove either of these hypotheses. Statistically significant changes in TRPH, SVOC, and VOC concentrations in the revised design treatment zone are listed in Table 2.

Outside of the revised design treatment zone, only TRPH showed a statistically significant change at the 95 percent confidence level, with an estimated 88 percent mean concentration increase. Based on the configuration of the SVE system, this increase may have been due to inward migration; however, it is not likely this increase was due to outward migration from the revised design treatment zone.

Heated Zone Results

The following results were observed within the heated zone:

- There was a statistically significant decrease in TRPH concentration at the 97.5 percent confidence level; the estimated decrease in the mean concentration was 95 percent.
- No conclusions can be drawn regarding the five indicator SVOCs.
- No conclusions can be drawn regarding the five indicator VOCs.

The TRPH decrease may be the result of the SVE system pulling the contaminants out of the heated zone into the vacuum wells. As in the revised design treatment zone, this decrease may also have been the result of the degradation of these compounds caused by the elevated temperatures of the RFH system.

There was also a statistically significant decrease in the concentration of bis(2-ethylhexyl)phthalate at the 90 percent confidence level outside the heated zone; the estimated decrease in the mean concentration was 37 percent. As inside the two zones, this decrease may be caused by the SVE system pulling the contaminant into the vacuum wells or by degradation due to the elevated temperatures of the RFH system.

There were statistically significant increases at the 99 percent confidence level in the concentrations of four other VOCs (all ketones) outside the heated zone. The estimated mean increases for these four ketones were 423 percent for 2-hexanone, 249 percent for 4-methyl-2-pentanone, 1,347 percent for acetone, and 1,049 percent for methyl ethyl ketone. As previously explained, these ketones may have been formed by the degradation of TRPH and SVOCs or inward migration.

Several possible reasons exist for changes in concentration observed. They include inward contaminant migration, low extraction rates, low soil temperatures achieved in some areas, and low pretreatment contaminant concentrations in the soil.

Two-dimensional modeling of gas flow rates was used to qualitatively evaluate inward migration and treatment zone extraction rates. The results of this modeling indicate inward gas flows. Due to inefficiencies in the design of the SVE system, gas flows between the outer edge of the impermeable cap and the extraction wells are five times greater than those between the two rows of extraction wells. As a result, contaminant migration into the treatment zone is possible, especially near the outer edges, and contaminant removal from the treatment zone may have been relatively slow as compared to inward contaminant migration.

Concentrations of TRPH and specific VOCs and SVOCs in the gas stream were monitored by a USAF subcontractor and were not part of the SITE demonstration. However, the appropriateness of the methods used and the quality of the data are unknown. The results appear to qualitatively indicate removals of TRPH and certain VOCs and SVOCs. Because of limitations of the sampling and analytical methods, the quantity of contaminants removed cannot be estimated.

Technology Status

Information is currently available from IITRI on two field studies (not sponsored by the SITE program) conducted at Volk AFB and Rocky Mountain Arsenal [3][4]. IITRI is performing a larger test at Sandia National Laboratory. Results of the Kelly AFB demonstration are documented in this capsule.

IITRI claims its technology is not ready for commercialization. Considerable development and optimization of the process would be required before a full-scale system would be ready for field use.

A 300-kW full-scale system has been proposed. The cost of a full-scale treatment system, based on the results obtained from the revised design treatment zone, is estimated to be $619 per ton for a site containing 10,152 tons of contaminated soil. The cost of a full-scale system treatment system, based on IITRI's theoretical system design, is $340 per ton for a site containing 8,640 tons of contaminated soil. Costs associated with analyses, site preparation, permitting, effluent treatment and disposal, and residuals and waste shipping are considered site-specific costs that will be assumed by the site owner or responsible party. As a result, these costs are not included in the per ton cost estimates.

Disclaimer

Although the technology conclusions presented in this report may not change, the data have not been reviewed by EPA Risk Reduction Engineering Laboratory Quality Assurance personnel at this time.

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3. Program Manager for Rocky Mountain Arsenal, Final Rocky Mountain Arsenal Task 012 In Situ Radio Frequency/Vapor Extraction Pilot Test Plan. Document Control Number 53300-01-12-AACB.
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APPENDIX I.3

Draft Bulletin: KAI RFH SITE Demonstration

Technology Description: Radio frequency heating (RFH) is a process that uses electromagnetic energy in the radio frequency (RF) band to heat soil in situ, thereby potentially enhancing the performance of standard soil vapor extraction (SVE) technologies. An RFH system developed by KAI Technologies, Inc. was evaluated under the Superfund Innovative Technology Evaluation (SITE) Program at Kelly Air Force Base (AFB) in San Antonio, Texas. This demonstration was performed in conjunction with a technology evaluation being performed by the U.S. Air Force (USAF).

Figure 1 is a schematic diagram of KAI's RFH system. A 25-kW radio transmitter serves as the energy source for the system. Flexible coaxial transmission lines supply energy to two antennae installed near the center of the treatment zone, progressively heating the soil in a radial direction from each antenna. Water and contaminants volatilize as the soil is heated, changing the electrical properties of the soil. As this change occurs, a diagnostic and control system automatically retunes the antennae impedance to maintain the most efficient heating level.

Prior to the demonstration, six extraction wells were installed on the edges of the treatment zone, and two extraction wells were installed near the center of the treatment zone. A vacuum was applied to one or more extraction wells. The vacuum level and the extraction wells to which the vacuum was applied were varied periodically throughout the demonstration. The vacuum system pulled water and contaminant vapors into the extraction wells, through a vapor collection system, and into a vapor treatment system. The vacuum was applied throughout the heating portion of the demonstration, for several days before heating was initiated, and for approximately 2 weeks during cooldown.

The treatment zone was covered by a vapor barrier, which was designed to eliminate direct contact between the surface of the treatment zone and the ambient air. The vapor barrier had three functions: to help maintain a vacuum for vapor collection, to prevent fugitive emissions from the heated surface, and to control infiltration of air into the treatment zone and thus into the vapor treatment system.

The vapor treatment system consisted of condensate collection and incineration. Vapors that condensed in the vapor collection and treatment systems were collected, and were then transferred to a Kelly AFB wastewater treatment facility. Uncondensed vapors were burned in a natural gas flare. This vapor treatment system was site- and contaminant-specific and was not evaluated as part of the RFH system.

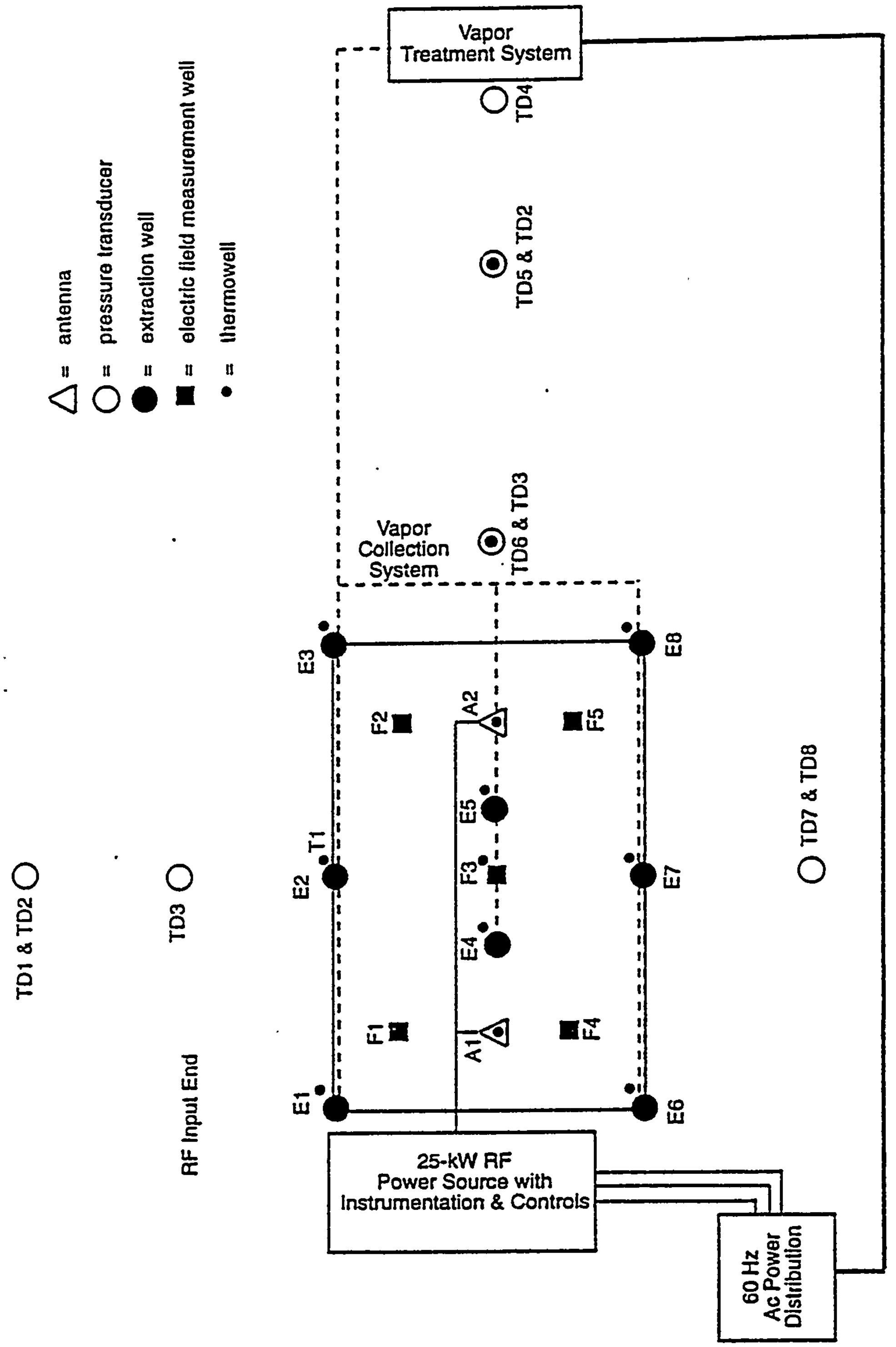

Figure 1. Schematic diagram of KAI RFH system.

Waste Applicability: RFH is a potential enhancement for in situ SVE systems. RFH is designed to speed the removal of volatile organics and to make it possible to remove semivolatile organics that would not normally be removed by standard SVE technologies. Inorganics, metals, and other nonvolatile contaminants will not normally be treated by SVE or RFH technologies.

Demonstration Results: The demonstration treatment zone was 10 feet wide, 15 feet long, and 20 feet deep. Samples were collected inside the treatment zone, below the treatment zone to a depth of 30 feet, and on two sides of the treatment zone.

During the demonstration, RF energy was applied to the first antenna for approximately 4 weeks, was then applied to the second for approximately 1.5 weeks, and back to the first for approximately 1 more week. Temperatures within and outside the treatment zone were monitored at various depths throughout treatment. At any given time, the soil near the antenna to which RF energy was being applied absorbed more energy than the soil located further away from that antenna. This resulted in temperature variations across the treatment zone. The maximum temperature on the outside perimeter of the treatment zone was 61°C; the maximum temperature near the center of the treatment zone was 224°C.

Soil contaminant concentrations were measured and evaluated as matched pairs of pre- and post-treatment data. The primary objective of the demonstration was to evaluate pre- and post-treatment total residual petroleum hydrocarbon (TRPH) concentrations. TRPH concentration was measured in 40 matched pairs collected inside the treatment zone and 24 matched pairs collected outside the treatment zone. The TRPH concentration inside the treatment zone exhibited a 32 percent decrease between pre- and post-treatment sampling. Preliminary results are listed in Table 1. The TRPH concentration outside the treatment zone appears to have increased, which may indicate the possibility of outward contaminant migration.

Concentrations of volatile and semivolatile organic compounds were often at the detection limit, which caused problems in determining a removal efficiency. Because of the expected low-level concentrations, these analyses were considered non-critical. In order to demonstrate these secondary objectives, only half of the matched sample pairs were analyzed for volatile and semivolatile organic compounds. The complete data package has not been tabulated, however, preliminary results for selected volatile and semivolatile organic compounds are summarized in Table 1.

A Technology Evaluation Report and an Innovative Technology Evaluation Report describing the complete demonstration will be available by summer 1995.

Table 1. Preliminary Demonstration Results

Contaminant	Mean Percent Removal (Inside Treatment Zone)
TRPH	32%
Volatile organic compounds	
Chlorobenzene	28%
Methyl ethyl ketone	51%
Methylene chloride	76%
Toluene	19%
Semivolatile organic compounds	
Bis(2-ethylhexyl)phthalate	17%
Pyrene	54%

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SITE Technology Capsule

KAI Radio Frequency Heating Technology

Introduction

In 1980 the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, committed to protecting human health and the environment from uncontrolled hazardous waste sites. CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986. These amendments emphasize the long-term effectiveness and permanence of remedies at Superfund sites. SARA mandates implementing permanent solutions and using alternative treatment technologies or resource recovery technologies, to the maximum extent possible, to clean up hazardous waste sites.

State and Federal agencies, as well as private parties, are now exploring a growing number of innovative technologies for treating hazardous wastes. The sites on the National Priorities List total more than 1,200 and comprise a broad spectrum of physical, chemical, and environmental conditions requiring varying types of remediation. The U.S. Environmental Protection Agency (EPA) has focused on policy, technical, and informational issues related to exploring and applying new remediation technologies applicable to Superfund sites. One such initiative is EPA's Superfund Innovative Technology Evaluation (SITE) Program, which was established to accelerate development, demonstration, and use of innovative technologies for site cleanups. EPA SITE Technology Capsules summarize the latest information available on selected innovative treatment and site remediation technologies and related issues. These capsules are designed to help EPA remedial project managers, EPA on-scene coordinators, contractors, and other site cleanup managers understand the type of data and site characteristics needed to effectively evaluate a technology's applicability for cleaning up Superfund sites. Additional details regarding technology demonstrations are presented in the Innovative Technology Evaluation Reports.

This capsule provides information on the in situ radio frequency heating (RFH) technology developed by KAI Technologies, Inc. This technology was developed to remove semivolatile organic compounds (SVOCs) and volatile organic compounds (VOCs) from the soil without excavation. The KAI RFH process was evaluated under the SITE Program from January through July 1994 at Kelly Air Force Base (AFB) in San Antonio, Texas. This demonstration was performed in conjunction with a technology evaluation performed by the U.S. Air Force (USAF). Information in this capsule emphasizes specific site characteristics and results of the SITE field demonstration at Kelly AFB. This capsule presents the following information:

- Abstract
- Technology description
- Technology applicability
- Technology limitations
- Process residuals
- Site requirements
- Performance data
- Technology status
- Sources of further information
- References

Abstract

RFH technologies use electromagnetic energy in the radio frequency (RF) band to heat soil in situ, thereby potentially enhancing the performance of standard soil vapor extraction (SVE) technologies. Contaminants are removed from in situ soils and transferred to collection or treatment facilities. Contaminant removal during the demonstration was evaluated by measuring contaminant concentrations in the soil before and after treatment.

The KAI RFH process was evaluated under the SITE Program at a site containing various organic contaminants in

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TECHNOLOGY EVALUATION

a heterogeneous soil matrix. The original treatment zone was 10 feet wide, 15 feet long, and 20 feet deep. Because RF heat was actually applied only to the upper half of the original treatment zone, this upper region is being designated the "revised treatment zone." A comparison of pre- and post-treatment soil samples within these two zones yielded the following results:

- Within the original treatment zone, the mean removal for total recoverable petroleum hydrocarbons (TRPH) was 30 percent, which was statistically significant at the 80 percent confidence interval. Concentrations in the pre-treatment samples varied from less than 169 to 105,000 parts per million (ppm); post-treatment samples varied from less than 33 to 53,200 ppm.
- Within the revised treatment zone, the mean removal for TRPH was 49 percent, which was statistically significant at the 95 percent confidence interval. Concentrations in the pre-treatment samples varied from less than 169 to 6,910 ppm; post-treatment concentrations varied from less than 33 to 4,510 ppm.
- Pre- and post-treatment concentrations of individual SVOCs were also measured. Benzo(b)fluoranthene, benzo(a)pyrene, and bis(2-ethylhexyl)phthalate exhibited statistically significant removals within the original treatment zone. Benzo(b)fluoranthene, benzo(a)pyrene, chrysene, pyrene, and fluoranthene exhibited statistically significant removals within the revised treatment zone.
- Pre- and post-treatment concentrations of individual VOCs were also measured, but these data did not indicate any statistically significant removals. This was partially a result of the low pretreatment concentrations of many VOCs.
- The migration of contaminants into and out the revised treatment zone was also evaluated. Downward migration out of the revised treatment zone may have occurred due to the design and operation of the SVE system.
- The cost to treat approximately 10,000 tons of contaminated soil using a proposed full-scale in situ RFH system (including costs associated with SVE) was estimated by scaling up costs for the original treatment zone. Cleanup costs are estimated to be $315 per ton if the system is utilized 90 percent of the time.

Contaminant removals were not as high as projected. Because of timing and funding limitations placed on the project by the USAF, only a portion of the revised treatment zone reached the target temperature of 100 to 130°C. It appears that the treatment zone did not achieve adequate temperature to achieve the goal of 90 percent removal of TRPH. The design and operation of the SVE system and problems with the available electrical power may have also adversely affected contaminant removals.

The KAI RFH technology was evaluated based on the nine criteria used for decision making in the Superfund feasibility study (FS) process. Results of the evaluation are summarized in Table 1.

Technology Description

RFH technologies use RF energy to heat soil in situ, thereby potentially enhancing the performance of standard SVE technologies. The RF energy causes radiative heating of the soil, which is a faster and more efficient mechanism for heating solids than is convective heating. Some conductive heating also occurs in the soil.

Figure 1 is a schematic diagram of the KAI RFH system used for the SITE Technology Demonstration at Kelly AFB. The Quality Assurance Project Plan (QAPP) developed under the SITE Program described KAI's original treatment zone, which was 10 feet wide, 15 feet long, and 20 feet deep. To adapt to budgetary and time constraints associated with the USAF funding, KAI modified their system to treat the revised treatment zone, which was 10 feet wide and 15 feet long but only extended from 4 feet below ground surface (bgs) to 14 feet bgs.

A 25-kW, 27.12-MHz RF generator served as the energy source for the system. Coaxial transmission lines supplied energy alternately to two antennae installed near the center of the revised treatment zone, progressively heating the soil in a radial direction from each antenna. Water and contaminants volatilized as the soil was heated.

RF energy was initially applied to antenna A2 for 28.9 days, was then applied to antenna A1 for 8.2 days, and back to antenna A2 for 12.9 days. At any given time, the soil near the antenna to which RF energy was being applied absorbed more energy than the soil located further away from that antenna.

Extraction wells were installed prior to treatment. The system used during the SITE Demonstration employed six extraction wells on the edges of the revised treatment zone and two extraction wells near the center of the revised treatment zone. These extraction wells are shown and labelled in Figure 1. Only two of the extraction wells (E2 and E7) had screened intervals that approximately matched the depth of the revised treatment zone. These two wells were screened from 0 to 10 feet bgs; the other six extraction wells were screened from 10 to 20 feet bgs.

An SVE system provided a vacuum to one or more extraction wells. The vacuum level and the extraction wells to which the vacuum was applied were varied periodically. Vacuum was not applied to wells E6, E7, or E8 at any time, and they were capped for most of the demonstration. The SVE system initially operated at a suction pressure of 30 inches of water column for 22 days. The vacuum was gradually reduced throughout the rest of the demonstration to a low of 7 inches of water column while heat was being applied. The flow rate through the vapor treatment system was approximately 120 standard cubic feet per minute (scfm). The SVE system was operated for 8 days before heating was initiated, throughout the heating portion of the demonstration (50 days), and for 14 days as the soil cooled down after treatment.

The vapors collected during the demonstration were treated using standard techniques. Condensate that formed in the vapor collection and treatment systems was collected, and then transferred to a Kelly AFB wastewater treatment facility. Uncondensed vapors were burned in a propane flare. This vapor treatment system was site- and contaminant-specific and was not evaluated as part of the RFH system. Samples of the vapors being extracted from the soil were, however, collected and analyzed periodically to characterize the vapor stream.

At the end of the treatment period, the soil was allowed to cool. Soil contamination was measured both before and after treatment. Concentrations of TRPH and specific SVOCs and VOCs were measured in matched pairs of pre- and post-treatment soil samples. Within the original treatment zone, 40 matched pairs of soil samples were collected; 22 of these matched pairs were within the revised treatment zone. Outside the original treatment zone, 24 matched pairs of soil samples were collected. As specified in the QAPP, all matched pairs of samples were analyzed for TRPH, and half of the matched pairs were analyzed for specific SVOCs and VOCs.

The implementation of the KAI RFH system varies depending on site size and characteristics. Vapor collection or

Table 1. Evaluation Criteria for the KAI RFH Technology

Evaluation Criteria	*Performance*
Overall Protection of Human Health and the Environment	• *The contaminant removals achieved may not provide adequate protection.* • *Requires measures to protect workers during installation and treatment.* • *During the limited time period of the SITE demonstration, soil samples exhibited average TRPH removals of 30 percent in the original treatment zone and 49 percent in the revised treatment zone.*
Compliance with Federal ARAR[1]	• *Vapor collection and treatment are needed to ensure compliance with air quality standards.* • *Construction and operation of onsite vapor treatment unit may require compliance with location-specific ARARs.* • *RF generator must be operated in accordance with Occupational Safety and Health Administration (OSHA) and Federal Communication Commission (FCC) requirements.*
Long-term Effectiveness	• *The contaminant removals achieved during the limited demonstration period may not and Performance adequately remove the contamination source.* • *Involves some residuals treatment (vapor stream).*
Reduction of Toxicity, Mobility, or Volume through Treatment	• *Potentially reduces waste volume by volatilizing contaminants, which are then collected (in a more concentrated form) by an SVE system.* • *Potentially reduces long-term contaminant mobility by volatilizing contaminants, which are then removed from the soil and collected by an SVE system.*
Short-term Effectiveness	• *Presents minimal short-term risks to workers and community from air release during treatment.* • *No excavation is required, although drilling will disturb the soil to some extent.*
Implementability	• *RF generator must be operated in accordance with OSHA and FCC requirements.* • *Other pilot-scale tests have been completed; no full-scale applications to date.*
Cost[2]	• *$315 per ton.*
State Acceptance	• *No excavation is required, which should improve state acceptance.*
Community Acceptance	• *No excavation is required, which should improve community acceptance.* • *May require some community education to assure residents that the operation of the RFH system is compliant with OSHA safety requirements.*

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[1] *ARARs = Applicable or Relevant and Appropriate Requirements*

[2] *Actual cost of a remediation technology is highly site-specific and dependant on the original target cleanup level, contaminant concentrations, soil characteristics, and volume of soil. Cost data presented in this table are based on the treatment of approximately 10,000 tons of soil, and include costs associated with SVE.*

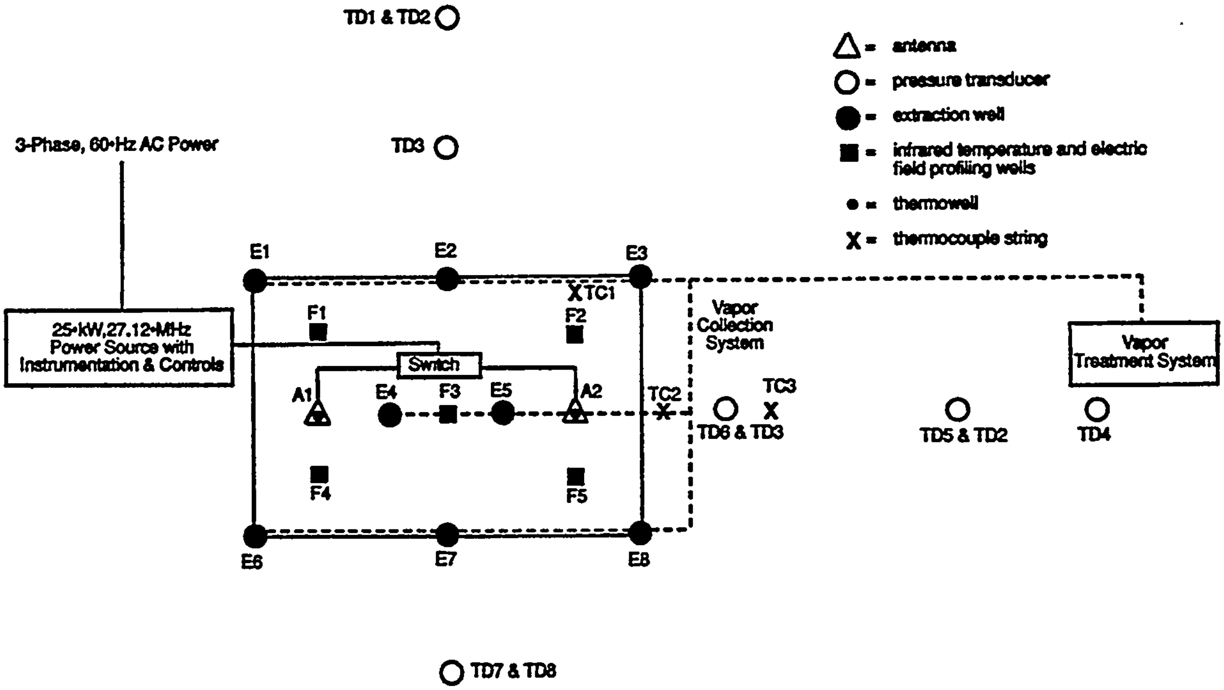

Figure 1. *Schematic diagram of KAI RFH system.*

treatment techniques, numbers and configurations of extraction wells and antennae, and other design details are site-specific.

Technology Applicability

The heat provided by the RFH process increases the vapor pressure of contaminants in the soil, thereby potentially improving the effectiveness of SVE. RFH may make it possible to remove SVOCs that would not normally be removed by standard SVE technologies. RFH may also speed the recovery of VOCs, which can be removed by standard SVE technologies. Contaminants that can potentially be removed using RFH include a wide variety of organics such as halogenated and nonhalogenated solvents and straight-chain and polycyclic aromatic hydrocarbons found in gasoline, jet fuel, and diesel fuel.

Technology Limitations

The KAI RFH technology cannot be used as a stand-alone technology. Vaporized contaminants and steam must be collected for reuse or treatment. In some cases, residual contaminants may remain in the soil after treatment.

This technology currently may be limited to unsaturated soils. Groundwater pumping may be used to lower the water table and increase the depth to which the soil can be treated. Soils composed primarily of sand and other coarse materials may be best suited to this technology. Nonvolatile organics, metals, and inorganics will not normally be removed by RFH or SVE technologies.

Process Residuals

The KAI RFH process generates one process waste stream that contains vaporized contaminants and steam mixed with extraction air. This waste stream can be treated by any of a number of standard vapor treatment technologies including vapor-phase carbon, condensation, or incineration. During the demonstration, steam and some contaminants in the vapor stream were condensed and collected. These condensed residuals were handled along with other site wastes at Kelly AFB. A propane flare was used to treat uncondensed contaminants in the vapor waste stream. When groundwater is pumped to lower the water table, the groundwater must also be handled as a liquid residual.

Some soil contaminants may remain after treatment. At a given site, the removals achieved and site-specific cleanup requirements will determine whether the soil will require additional treatment.

Site Requirements

Onsite assembly of the full-scale system will take several weeks, including drilling time. It is expected that medium to large sites will be divided into several sections that will be treated consecutively. The soil must be allowed to cool before final soil samples can be collected to confirm cleanup of each section. After treatment is completed, system demobilization may take up to one week. Access roads are needed for equipment transport. Approximately 4,600 square feet of flat ground are needed to accommodate the trailer-mounted RF transmitters, controllers, and other support equipment. A bermed area is needed for decontamination of the drill rig. Areas are also needed for storage of condensed vapors, if applicable, and the selected vapor treatment system.

Remediation using the RF heating process will require that certain utilities be available at the site. Water must be available for steam cleaning and other equipment and personnel decontamination activities. Electrical power must also be available. If carbon adsorption is used to treat vapors, compressed air may be required for system control, and steam or hot air will be needed if the carbon is regenerated onsite. Natural gas or propane will be required if a flare is used to control vapors.

The operation of a RFH system is specifically addressed by the FCC under regulations governing industrial, scientific, and medical equipment. Health and safety issues are regulated under OSHA. All requirements were reportedly met by the developer during the SITE Demonstration. The system is relatively quiet, and only during installation will dust and vapors be a potential problem. Therefore, the RFH technology can be applied near residential areas.

Performance Data

The demonstration system was designed to heat the soil in the revised treatment zone to a temperature of 100 to 130°C. Soil temperatures within and outside the revised treatment zone were monitored at various depths throughout the demonstration using thermocouples, infrared temperature sensors and fiber-optic temperature probes. All temperature measuring devices were mounted in lined boreholes, which made direct readings of the soil temperature impossible. The developer claims that actual soil temperatures were higher than the measurements indicate; however, this difference cannot be quantified. The maximum measured temperature on the perimeter of the revised treatment zone was 61°C. The maximum measured temperature near the center of the revised treatment zone was 234°C, but this peak was not representative of the majority of the temperature measurements at this location. During most of the heating period, temperatures between 100 and 150°C were measured near the antenna to which energy was being applied. Although not observed during the demonstration, the developer claims that temperatures will become more uniform after all moisture is removed from around the antennae.

Soil samples were collected before and after the soil was treated using KAI's RFH technology. The soil samples were collected as matched pairs; each post-treatment sample was collected as near as possible to its corresponding pretreatment sample. Only complete matched pairs were used in the evaluation of the data. For each contaminant, the mean percent removal was calculated, and a t-test was conducted to determine whether the mean removal was statistically significant at the 80 percent confidence interval or higher.

EPA Method 418.1 [1] was used to determine TRPH concentrations in the soil samples following extraction with freon according to EPA Method 9071 [2]. TRPH data are listed in Tables 2 and 3. For each complete matched pair of TRPH data, sample location and depth (of the pretreatment sample), pretreatment concentration, post-treatment concentration, and percent removal are shown. The mean removals in the original and revised treatment zones are 30 percent and 49 percent, respectively. These removals were accepted at the 80 and 95 percent significance levels, respectively.

SVOCs and VOCs were designated as noncritical measurements for this demonstration because samples collected prior to the demonstration indicated that the soil at the site generally contained low concentrations of SVOCs and VOCs. Because SVOCs and VOCs were noncritical measurements,

Table 2. *TRPH Concentrations Within the Revised Treatment Zone*[1]

Sample Location and Depth	Pretreatment Concentration (ppm)	Post-treatment Concentration (ppm)	Percent Removal[2]
E1, 10-12'	3,350	1,160	65.4%
E6, 8-10'	1,860	930	50.0%
F1, 4-6'	6,910	828	88.0%
F1, 10-12'	1,240	1,580	(27%)
E4, 7-9'	1,310	1,090	16.8%
E4, 9-11'	729	593	18.7%
F4, 12-14'	1,790	643	64.1%
E2, 10-12'	168.5[3]	582	(>245%)
F3, 4-6'	4,920	702	85.7%
F3, 10-12'	336	4,510	(1,240%)
E7, 12-14'	1,400	825	41.1%
E5, 4-6'	2,710	673	75.2%
E5, 6-8'	1,530	587	61.6%
E5, 10-12'	668	330	50.6%
E5, 12-14'	739	1,450	(96.2%)
F5, 12-14'	1,220	1,530	(25.4%)
A2, 4-6'	1,530	154	89.9%
A2, 10-12'	1,290	33.3[3]	>97.4%
A2, 12-14'	622	106	83.0%
E8, 6-8'	655	861	(31.5%)

[1] These data were used to determine the mean percent removal of TRPH within the revised treatment zone. These data were also used, in conjunction with the data presented in Table 3, to determine the mean percent removal of TRPH within the original treatment zone. The mean percent removals were calculated using the geometric mean, since the data are log-normally distributed.

[2] Parentheses around a value in this column indicate a percent increase, rather than a percent removal.

[3] TRPH was not detected in this sample above the practical quantitation limit; therefore, the practical quantitation limit is provided.

Table 3. *TRPH Concentrations Within the Original Treatment Zone But Outside the Revised Treatment Zone*[1]

Sample Location and Depth	Pretreatment Concentration (ppm)	Post-treatment Concentration (ppm)	Percent Removal[2]
E1, 0-2'	352	4,830	(1,270%)
E1, 16-18'	22,000	19,200	12.7%
A1, 0-2'	458	184	59.8%
A1, 16-18'	79,700	20,800	73.9%
A1, 18-20'	39,300	28,300	28.0%
E6, 16-18'	3,160	253	92.0%
F1, 18-20'	5,440	23,100	(325%)
F4, 0-2'	1,220	448	63.3%
F4, 16-18'	1,090	12,500	(1,050%)
E2, 0-2'	1,730	3,620	(109%)
E7, 2-4'	492	161	67.3%
F2, 14-16'	3,250	555	82.9%
E5, 18-20'	105,000	35,800	65.9%
F5, 16-18'	22,100	20,900	5.43%
F5, 18-20'	35,000	53,200	(52.0%)
E3, 14-16'	1,210	1,770	(46.3%)
E3, 16-18'	7,410	2,820	61.9%
A2, 0-2'	2,330	8,850	(280%)
A2, 2-4'	203	2,570	(1,170%)
A2, 16-18'	23,800	6,500	72.7%

[1] These data were used, in conjunction with the data presented in Table 2, to determine the mean percent removal of TRPH within the original treatment zone. The mean percent removal was calculated using the geometric mean, since the data are log-normally distributed.

[2] Parentheses around a value in this column indicate a percent increase, rather than a percent removal.

their concentrations were measured in only half of the soil samples. SVOC samples were extracted by EPA Method 3540 [2] prior to analysis by EPA Method 8270 [2]. VOC concentrations were determined using EPA Method 8240 [2].

Concentrations of individual SVOCs and VOCs in the soil samples were evaluated statistically using the same procedures described above for TRPH. Concentrations of several SVOCs exhibited statistically significant changes (at an 80 percent significance level) within the original and revised treatment zones. Statistically significant changes in SVOC concentrations within the original and revised treatment zones are presented in Table 4. None of the individual VOCs exhibited statistically significant changes (at an 80 percent significance level) within the original or revised treatment zone.

Several hypotheses may help explain the low contaminant removals measured during the demonstration. Because only a portion of the revised treatment zone reached the target temperature of 100 to 130°C, it seems most likely that the system did not achieve an adequate temperature. The low temperatures were at least partially due to problems with the electrical power available at the site. The design and operation of the SVE system, which is described in the Technology Description portion of this capsule, may have caused the contaminants to migrate downward out of the revised zone.

Technology Status

Information is currently available from two pilot-scale KAI RFH demonstrations: the Kelly AFB SITE demonstration documented in this capsule, and a demonstration conducted at Savannah River. KAI has conducted other tests for private clients, but the results of these tests are not available to the public. KAI has tentative plans for additional pilot-scale demonstrations. KAI also has long-term plans for larger-scale demonstrations investigating applicators that can travel the length of a horizontal or vertical borehole.

The cost of full-scale RFH treatment using a 200-kW generator is estimated to be $315 per ton for a site containing approximately 10,000 tons of contaminated soil. This cost estimate is based on a scale-up of the original treatment zone. The estimate includes costs associated with SVE, since SVE is an integral part of treatment using an RFH system. Major components of the cost estimate are equipment costs; startup and fixed costs; operating costs during treatment; supplies costs; consumables costs; facility modification, repair, and replacement costs; and site demobilization costs. The estimate does not include costs associated with analyses, site preparation, permitting, effluent treatment and disposal, or residuals and waste shipping, which are considered site-specific costs that will be assumed by the site owner or responsible party.

Table 4. Summary of SVOC Removals

Contaminant	*Mean Percent Removal in Original Treatment Zone*	*Mean Percent Removal in Revised Treatment Zone*
Benzo(b)fluoranthene	*44*[1]	*40*[2]
Benzo(a)pyrene	*44*[3]	*43*[2]
Bis(2-ethylhexyl)phthalate	*55*[4]	***[5]
Chrysene	***[5]	*40*[2]
Pyrene	***[5]	*60*[4]
Fluoranthene	***[5]	*53*[2]

[1] *Accepted at the 97.5 percent significance level.*

[2] *Accepted at the 80 percent significance level.*

[3] *Accepted at the 95 percent significance level.*

[4] *Accepted at the 90 percent significance level.*

[5] *No statistically significant change at the 80 percent significance level.*

Disclaimer

While the conclusions from this technology demonstration may not change, these data have not been reviewed by EPA Risk Reduction Engineering Quality Assurance personnel at this time.

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References

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