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SOLAR TOTAL ENERGY SYSTEM

LARGE SCALE EXPERIMENT
SHENANDOAH, GEORGIA

MASTER

FINAL TECHNICAL PROGRESS REPORT

VOLUME II

SECTION 3 - FACILITY CONCEPT DESIGN

CONTRACT NO. EG-77-C-04-3987

ERDA
ALBUQUERQUE OPERATIONS OFFICE
ALBUQUERQUE, NEW MEXICO

C-19650
17 OCTOBER 1977

STEARNS-ROGER
McDONNELL DOUGLAS

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INTRODUCTION

This report describes Stearns-Roger Engineering Company conceptual design of ERDA's Large Scale Experiment No. 2 (LSE No. 2). The various LSE's are part of ERDA's Solar Total Energy Program (STES) and a separate activity of the National Solar Thermal Power Systems Program.

The object of this LSE is to design, construct, test, evaluate and operate a STES for the purpose of obtaining experience with large scale hardware systems and to establish engineering capability for subsequent demonstration projects. This particular LSE is to be located at Shenandoah, Georgia and will provide power to the Bleyle knitwear factory.

Under this contract Stearns-Roger developed a conceptual design, which was site specific, containing the following major elements:

System Requirements Analysis
Site Description
System Conceptual Design
Conceptual Test and Operating Plans
Development Plans
Procurement and Management Plans for Subsequent Phases
Cost Estimates

This Solar Total Energy system is sized to supply 1.720 MW thermal power and 383.6 KW electrical power. The STES is sized for the extended knitwear plant of 3902 M^2 (42,000 SQ-FT) which will eventually employ 300 people. Included is an artist concept of the physical layout of the Solar Total Energy - Large Scale Experiment.

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SECTION 3

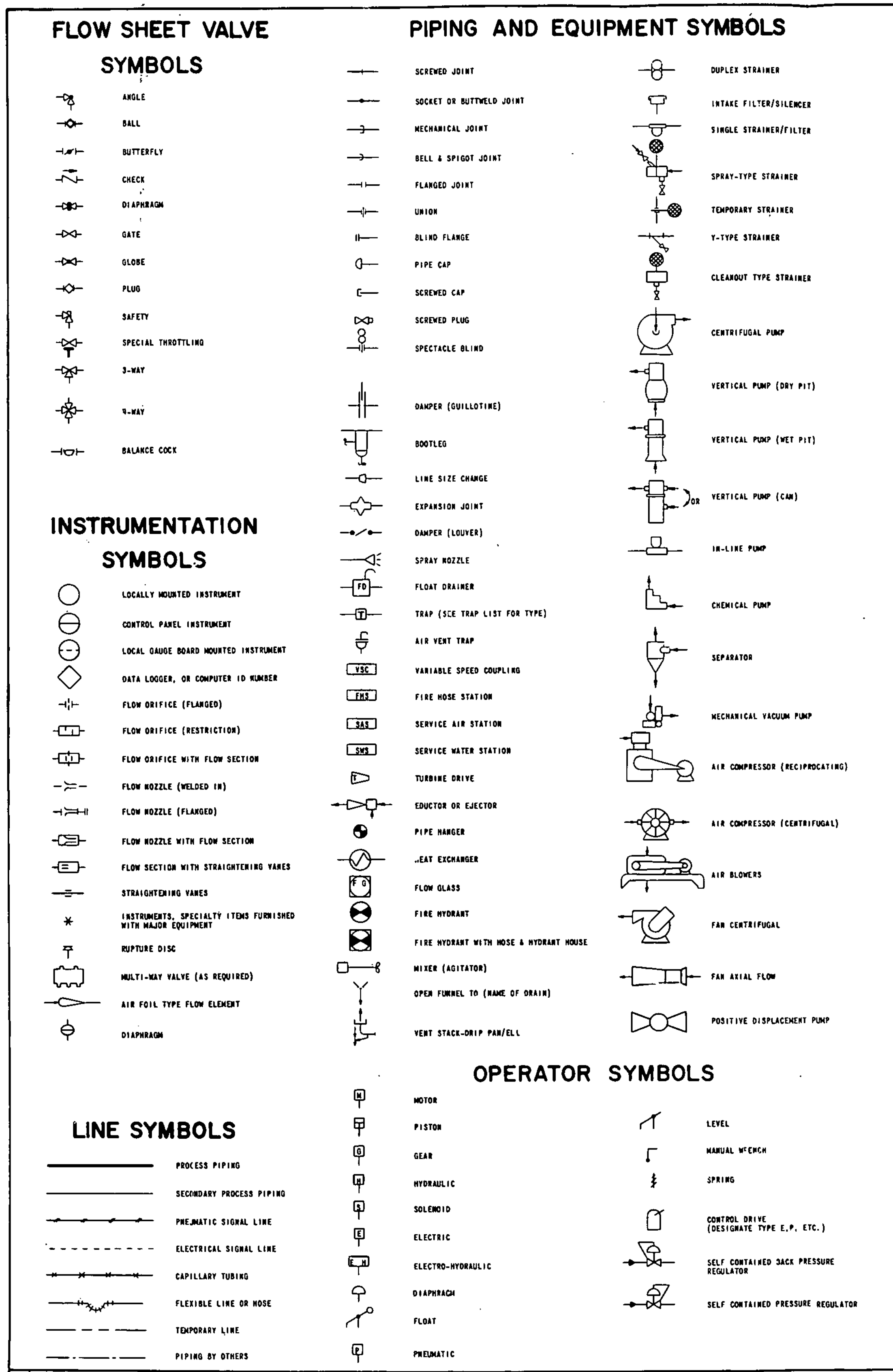
SECTION 3

CONCEPTUAL DESIGN

This section of the report provides the details of studies conducted for Phase II of the Solar Total Energy System (STES) for the conceptual design requirements of the facility. Included in this section are the detailed descriptions and analyses of the following subtasks:

Facility Concept Design
System Concept Design
Performance Analysis
Operation Plan
Component and Subsystem Development
Procurement Plan
Cost Estimating and Scheduling
Technical and Management Plans

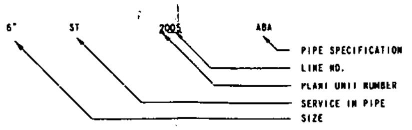
Detailed conceptual flow sheets and facility layouts are presented on the following engineering drawings: Figure 3–1 (Sheet P1–1), Figure 3–2 (Sheet P3–1), Figure 3–3 (Sheet P3–2), Figure 3–4 (Sheet P3–3), Figure 3–5 (Sheet G1–1), and Figure 3–6 (Sheet G1–2).



INSTRUMENT AND EQUIPMENT ABBREVIATIONS

A	ALARM POINT
AI	ANALYZER INDICATOR
AN	ANNUNCIATOR
AR	ANALYZER RECORDER
AS	AIR SUPPLY (INSTRUMENT AIR)
AT	ANALYZER TRANSMITTER
ADV	AUTOMATIC DRAIN VALVE
AOV	AIR OPERATED VALVE
CCV	CONDUCTIVITY CONTROL VALVE
CD	SIGNAL CONVERTER OR PNEUMATIC RELAY
CE	CONDUCTIVITY ELEMENT
CI	CONDUCTIVITY INDICATOR
CHC	CONDUCTIVITY HAND CONTROLLER
CR	CONDUCTIVITY RECORDER
CT	CONDUCTIVITY TRANSMITTER
DC	DENSITY CONTROLLER
DPI	DIFFERENTIAL PRESSURE INDICATOR
DPS	DIFFERENTIAL PRESSURE SWITCH
DPT	DIFFERENTIAL PRESSURE TRANSMITTER
DR	DENSITY RECORDER
DT	DENSITY TRANSMITTER
E	ELECTRIC
EH	ELECTRO-HYDRAULIC
EJ	EXPANSION JOINT
E/P	ELECTRIC TO PNEUMATIC CONVERTER
ER	ELECTRIC RELAY
FD	FLOAT DRAINER
FC	FLOW CONTROLLER
FCD	FLOW CONTROL DRIVE
FCV	FLOW CONTROL VALVE
FE	FLOW ELEMENT
FG	FLOW GLASS
FH	FLEXIBLE HOSE
FHC	FLOW HAND-AUTO CONTROLLER
FHS	FIRE HOSE STATION
FI	FLOW INDICATOR
FM	FLOW METER
FO	FLOW ORIFICE (RESTRICTION)
FQ	FLOW INTEGRATOR
FR	FLOW RECORDER
FRC	FLOW RECORDER CONTROLLER
FS	FLOW SWITCH
FT	FLOW TRANSMITTER
FX	FLOW TEST POINT (NO ELEMENT)
G	GEAR
H	HYDRAULIC
HCV	HAND CONTROL VALVE
IL	INDICATING LIGHT
IN	INDICATOR
LC	LEVEL CONTROLLER
LCD	LEVEL CONTROL DRIVE
LCV	LEVEL CONTROL VALVE
LG	LEVEL GLASS
LHC	LEVEL HAND CONTROLLER
LI	LEVEL INDICATOR
LMS	LIMIT SWITCH
LR	LEVEL RECORDER
LRC	LEVEL RECORDER CONTROLLER
LS	LEVEL SWITCH
LT	LEVEL TRANSMITTER
M	MOTOR
MI	MOTOR (POSITION) INDICATOR
MOD	MODULE (MULTIPLE LIGHTED PB)
MOV	MOTOR OPERATED VALVE
MT	MOTION (POSITION) TRANSMITTER
P	PNEUMATIC
PB	PUSHBUTTON
PBIL	PUSHBUTTON WITH INDICATING LIGHT
PC	PRESSURE CONTROLLER
PCD	PRESSURE CONTROL DRIVE
PCV	PRESSURE CONTROL VALVE
P/E	PNEUMATIC TO ELECTRIC CONVERTER
PF	PERMANENT STRAINER
PHC	PRESSURE HAND CONTROLLER
pHC	pH CONTROLLER
pHE	pH ELEMENT
pHI	pH INDICATOR
pHR	pH RECORDER
pHT	pH TRANSMITTER
PI	PRESSURE INDICATOR
PR	PRESSURE RECORDER
PRC	PRESSURE RECORDER CONTROLLER
PS	PRESSURE SWITCH
PSV	PRESSURE SAFETY VALVE
PT	PRESSURE TRANSMITTER
PX	PRESSURE TEST POINT
RE	RESISTOR
RHEO	RHEOSTAT
RD	RUPTURE DISC.
S	SOLENOID
SAS	SERVICE AIR STATION
SC	SAMPLE COOLER
SF	SPRAY TYPE STRAINER
SI	SPEED INDICATOR
SN	SAMPLE NOZZLE
ST	SPEED TRANSMITTER
SV	SOLENOID VALVE
SW	SWITCH (ELECTRICAL)
SWS	SERVICE WATER STATION
SX	SAMPLE TEST POINT
T	TRAP
TC	TEMPERATURE CONTROLLER
TCD	TEMPERATURE CONTROL DRIVE
TCV	TEMPERATURE CONTROL VALVE
TD	TURBINE DRIVE
TDV	TEST DEVICE
TE	TEMPERATURE ELEMENT
TF	TEMPORARY STRAINER
THC	TEMPERATURE HAND CONTROLLER
TI	TEMPERATURE INDICATOR
TR	TEMPERATURE RECORDER
TRC	TEMPERATURE RECORDER CONTROLLER
TS	TEMPERATURE SWITCH
TSW	TEST SWITCH
TT	TEMPERATURE TRANSMITTER
TW	TEMPERATURE WELL
TV	TELEVISION
TX	TEST WELL
UVS	FLAME SCANNER
V	VALVE
VSC	VARIABLE SPEED COUPLING
VSD	VARIABLE SPEED DRIVE
ZI	POSITION INDICATOR
ZSS	ZERO SPEED SWITCH
ZT	POSITION TRANSMITTER

PIPE LINE NUMBERING SYSTEM

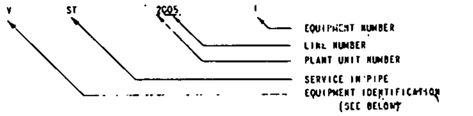


SERVICE ABBREVIATIONS

AC	ACID CLEANING
AD	DRAINS TO ASH WATER SYSTEM
AS	AUXILIARY STEAM
AW	ASH WATER
BD	BOILER BLOWDOWN
BF	BOILER FEEDWATER
BO	BLOWOUT
BW	BEARING COOLING WATER
CA	CONVEYING AIR
CD	CO_2
CF	CONDENSATE CYCLE FLUSH
CH	CHEMICAL
CM	CONDENSATE MAKE-UP
CO	CONDENSATE
CW	CIRCULATING WATER
DL	DRAINS TO DAYLIGHT
DO	DIESEL OIL
DM	DOMESTIC WATER
DR	DRAINS TO CYCLE
DW	DEMINERALIZED WATER
ED	EQUIPMENT DRAIN
EW	EQUIPMENT COOLING WATER
EX	EXTRACTION STEAM
FA	FLY ASH
FD	FLOOR DRAIN
FG	FUEL GAS
FO	FUEL OIL
FP	FIRE PROTECTION WATER
FW	FEED WATER
HD	HEATER DRAINS
HC	HEATING CONDENSATE
HS	HEATING STEAM
HW	HOT WATER - DOMESTIC
HY	HYDROGEN
IO	IGNITOR OIL
LO	LUBE OIL
MM	MISCELLANEOUS MATERIAL
MS	MAIN STEAM
N	NITROGEN
NA	INSTRUMENT AIR
NB	DRAINS TO NEUTRALIZING BASIN
PW	POTABLE WATER
RB	DRAINS TO HOLDING BASIN
RD	ROOF DRAINS
RH	REHEAT (HOT & COLD)
RW	RAW WATER
SA	SERVICE AIR
SB	SOOT BLOWER AIR
SS	SANITARY SEWER
ST	STEAM (INCL. TRAPS)
SW	SERVICE WATER
SP	SPECIAL
TA	TRANSFER AIR
TW	TREATED WATER
VT	VENTS (INCL. RELIEF VALVES)
WA	WET ASH
WD	DRAINS TO WASTE DISPOSAL SUMP
YD	YARD DRAINS
CHWS	CHILLED WATER SUPPLY
CHWR	CHILLED WATER RETURN
TOLV	TOLUENE VAPOR
TOLL	TOLUENE LIQUID
HWS	HOT WATER SUPPLY
HWR	HOT WATER RETURN
TF	THERMAL FLUID (THERMINOL-66)

GENERAL NOTES

EQUIPMENT NUMBERING SYSTEM



EJ	EXPANSION JOINT	H	PIPE HANGER
FH	FLEXIBLE HOSE	FD	FLOAT DRAINER
MOV	MOTOR OPERATED VALVE	PSV	PRESSURE SAFETY VALVE
PF	PERMANENT STRAINER	SV	SOLENOID VALVE
SF	SPRAY TYPE STRAINER	FO	FLOW ORIFICE
TF	TEMPORARY STRAINER		
T	TRAP		
V	VALVE		
AOV	AIR OPERATED VALVE (NOT MODULATING)		

Equipment numbering system above is for in-line piping components only. For equipment numbering system for pumps, tanks, etc., see P3 series drawings and project equipment nomenclature list.

ABBREVIATIONS

FLOW DIAGRAM INDEX

NO.	REVISIONS	DATE	BY	CH'D	APP'D	REFERENCE DRAWINGS	PRINT RECORD
							REVISION NO
							ISSUED
							CUSTOMER
							S R FIELD

Stearns-Roger

DRAWN	HFO	9-8-71	COORD CK.	
STRUCT. CK.			APPROVED	
MECH. CK.			APPROVED	
ELECT. CK.			APPROVED	

ALBUQUERQUE OPERATIONS OFFICE
ALBUQUERQUE, NEW MEXICO

RECOMMENDED FOR APPROVAL
APPROVED
APPROVED

TITLE
STE/LSE PHASE II MECHANICAL
PIPING, INSTRUMENT AND EQUIPMENT
SYMBOLS AND NOMENCLATURE

SCALE NONE
ORDER NO. C-15650
1 OF 1

PRELIMINARY
FOR APPROVAL
APP. FOR CONST.
DWG. NO. L-22878
SHEET NO. PI-1
REV. △

FIGURE 3–1. PIPING, INSTRUMENT, AND EQUIPMENT SYMBOLS AND NOMENCLATURE

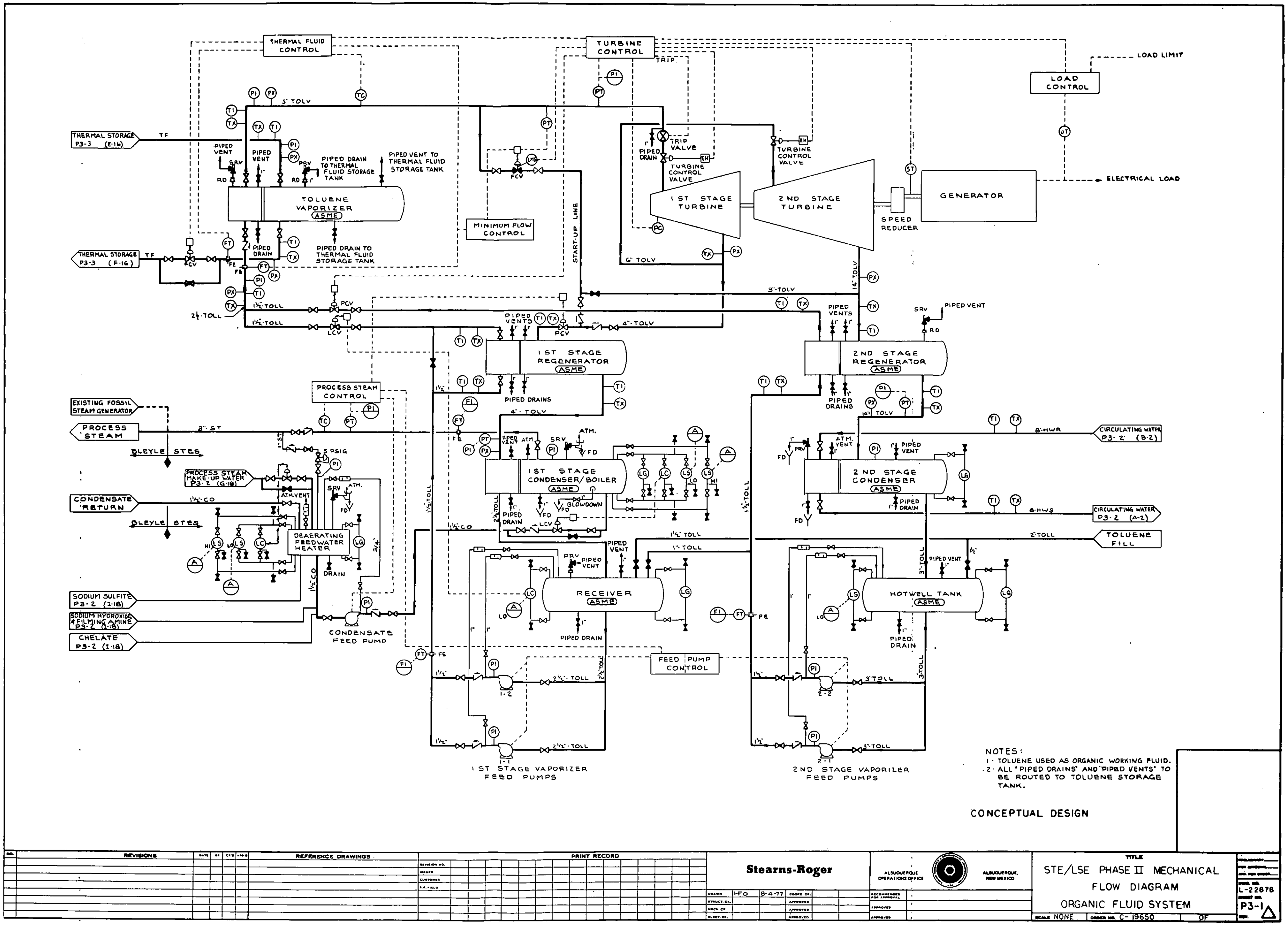


FIGURE 3–2. ORGANIC FLUID SYSTEM FLOW DIAGRAM

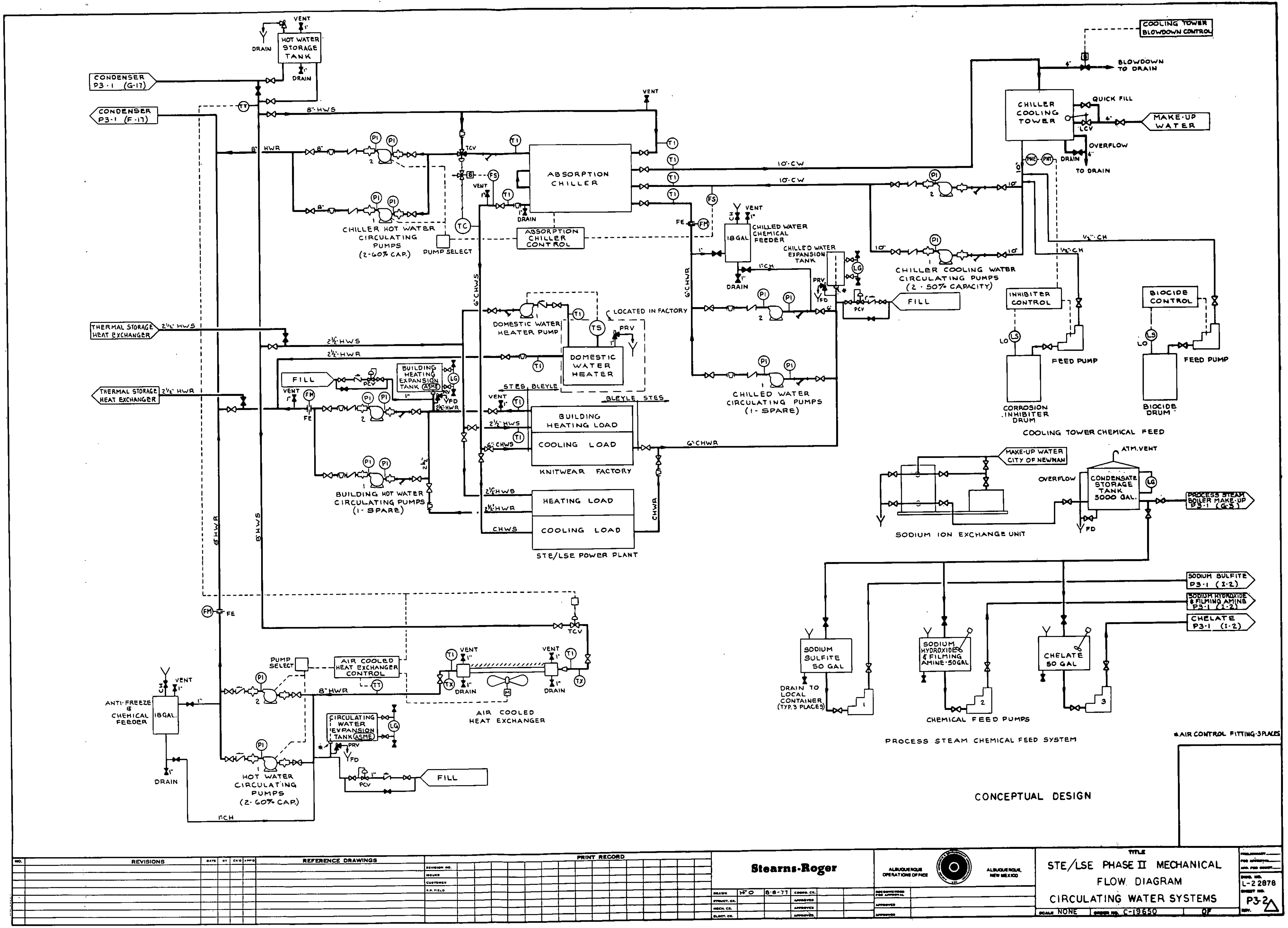
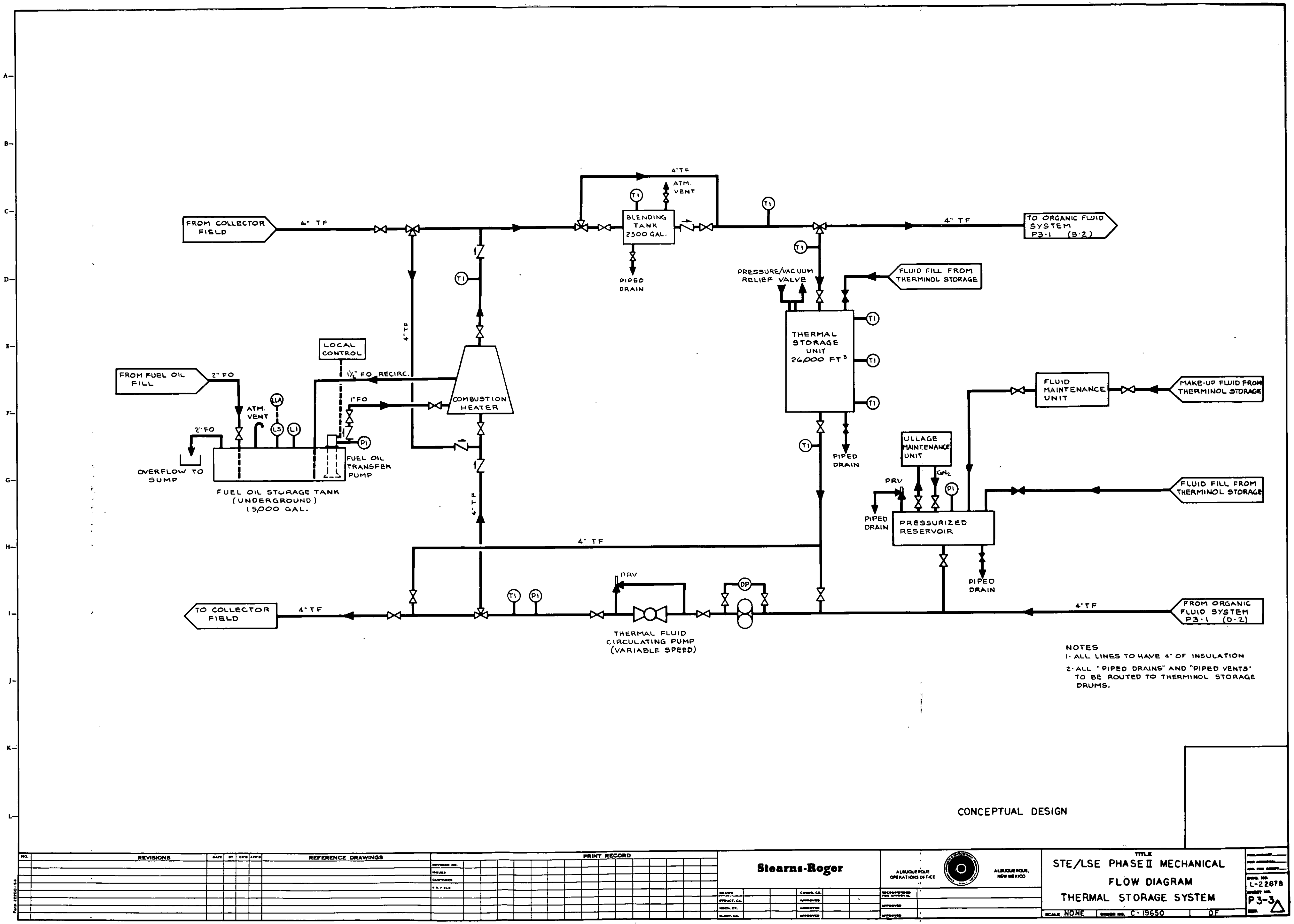


FIGURE 3–3. CIRCULATING WATER SYSTEMS FLOW DIAGRAM



NOTES
1. ALL LINES TO HAVE 4" OF INSULATION
2. ALL "PIPED DRAINS" AND "PIPED VENTS" TO BE ROUTED TO THERMINOL STORAGE DRUMS.

FIGURE 3–4. THERMAL STORAGE SYSTEM FLOW DIAGRAM

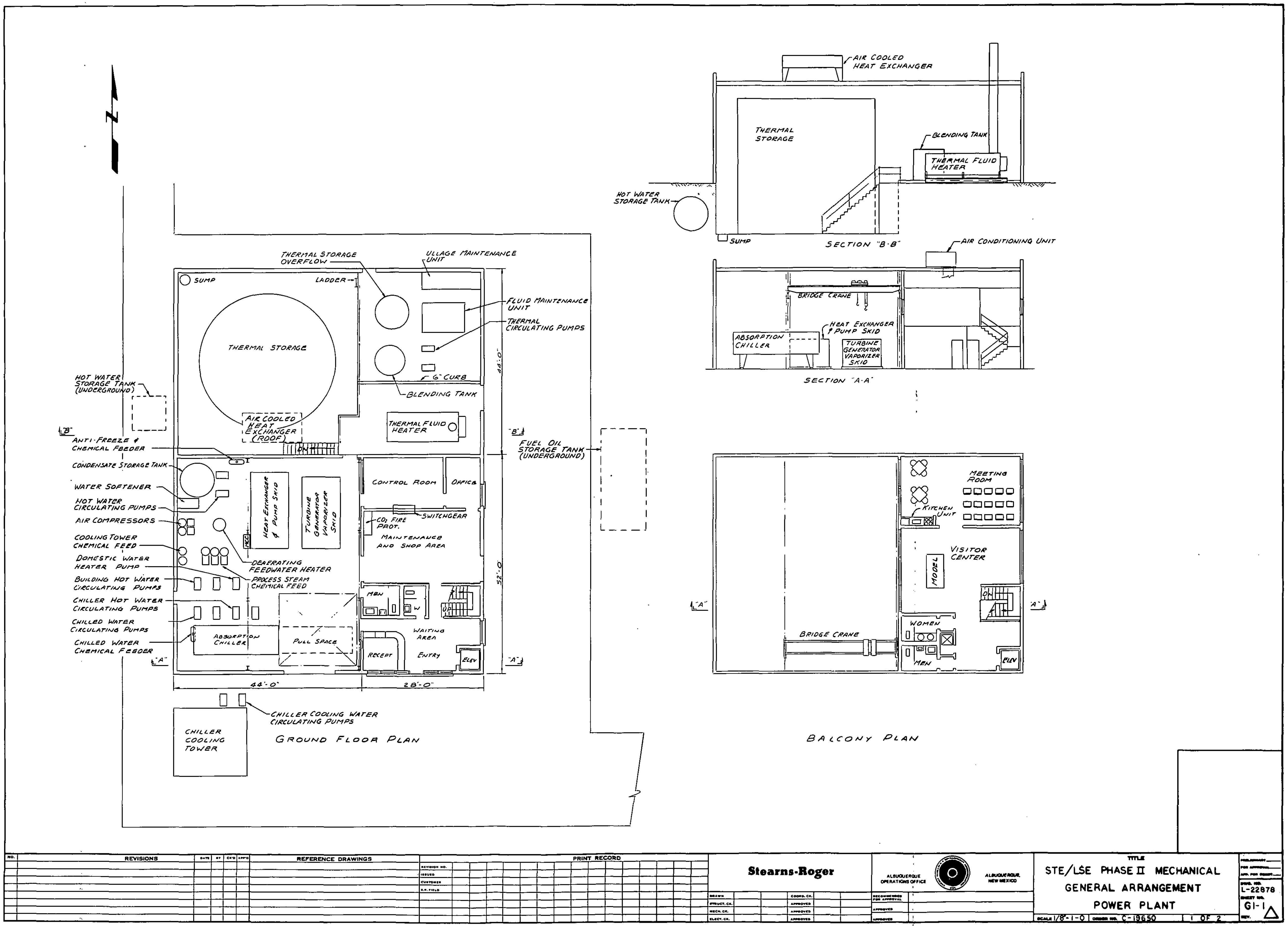


FIGURE 3–5. POWER PLANT GENERAL ARRANGEMENT

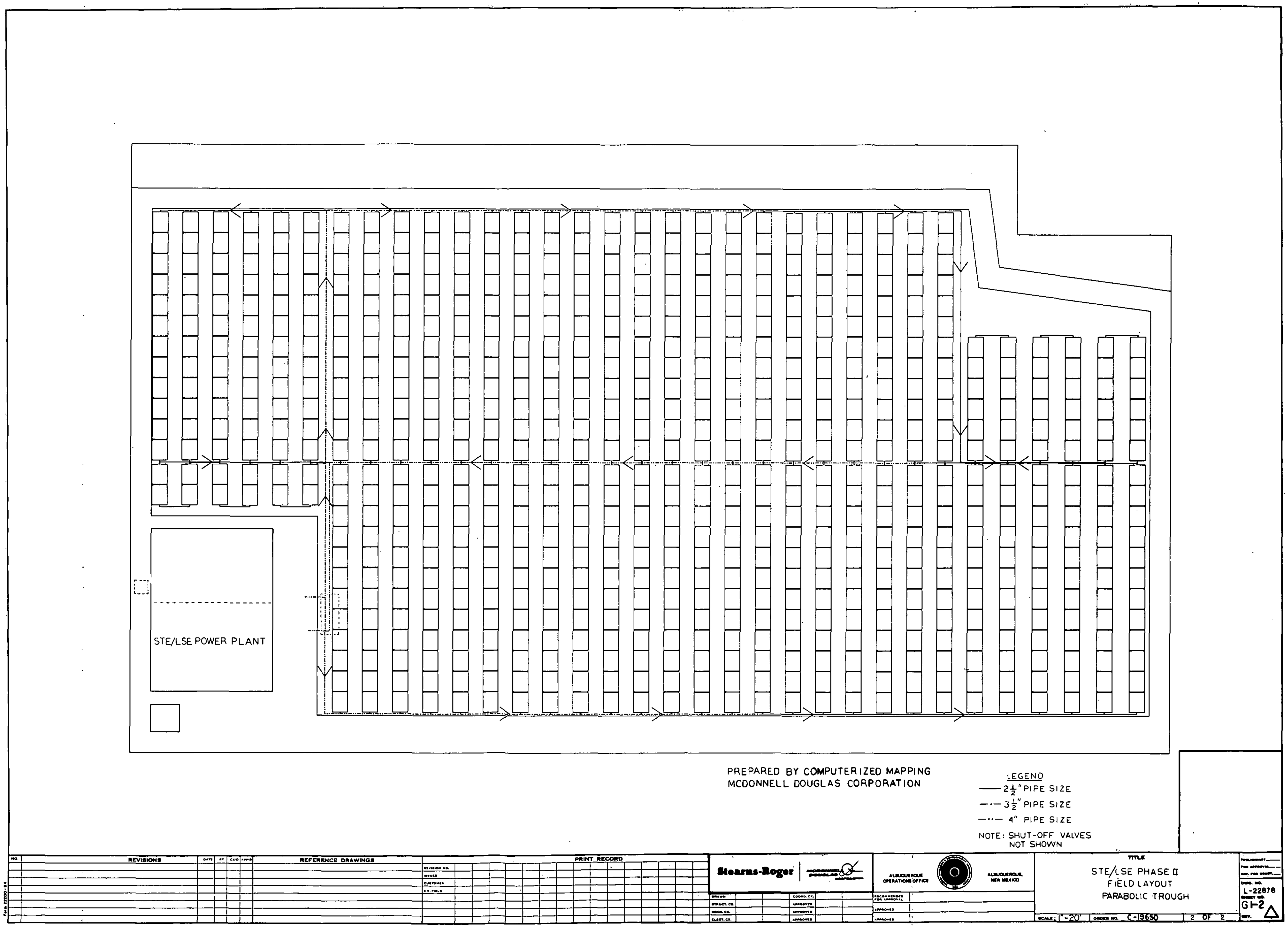


FIGURE 3–6. PARABOLIC TROUGH COLLECTOR FIELD LAYOUT

SUBSECTION 3.1

3.1 FACILITY CONCEPT DESIGN

3.1.1 SITE PREPARATION

The accompanying plot plan (Figure 3.1–1) shows the 4.96-acre plot located northeast of the knitwear factory site in the Shenandoah Development. The streets are installed paved roads and the factory is currently under construction.

The land slopes and drains to the north; second-growth pine occupies the northern third of the site, the remainder being roughly grassed. An additional survey will be required as the land has been moved and disturbed by the developer.

3.1.2 PLOT PLAN

The grading and plot plan shown in Figure 3.1–2 depicts the civil development of the site. The site is to be graded as nearly level as possible consistent with proper drainage and economical earth moving costs. This will result in an approximate two percent slope to the north. Steep slopes were avoided where possible and placed outside the actual property where feasible.

Contractually, access is provided to the site by Shenandoah Development in the southeast corner. Paved roads will be provided within the site for access around the collector field and to the power plant building.

The power plant building was located in the southwest corner of the site after a series of shading (see Appendix), steamline loss, and electrical studies indicated this to be the most advantageous location.

The site will be fenced with cyclone fencing and have electrically operated gates.

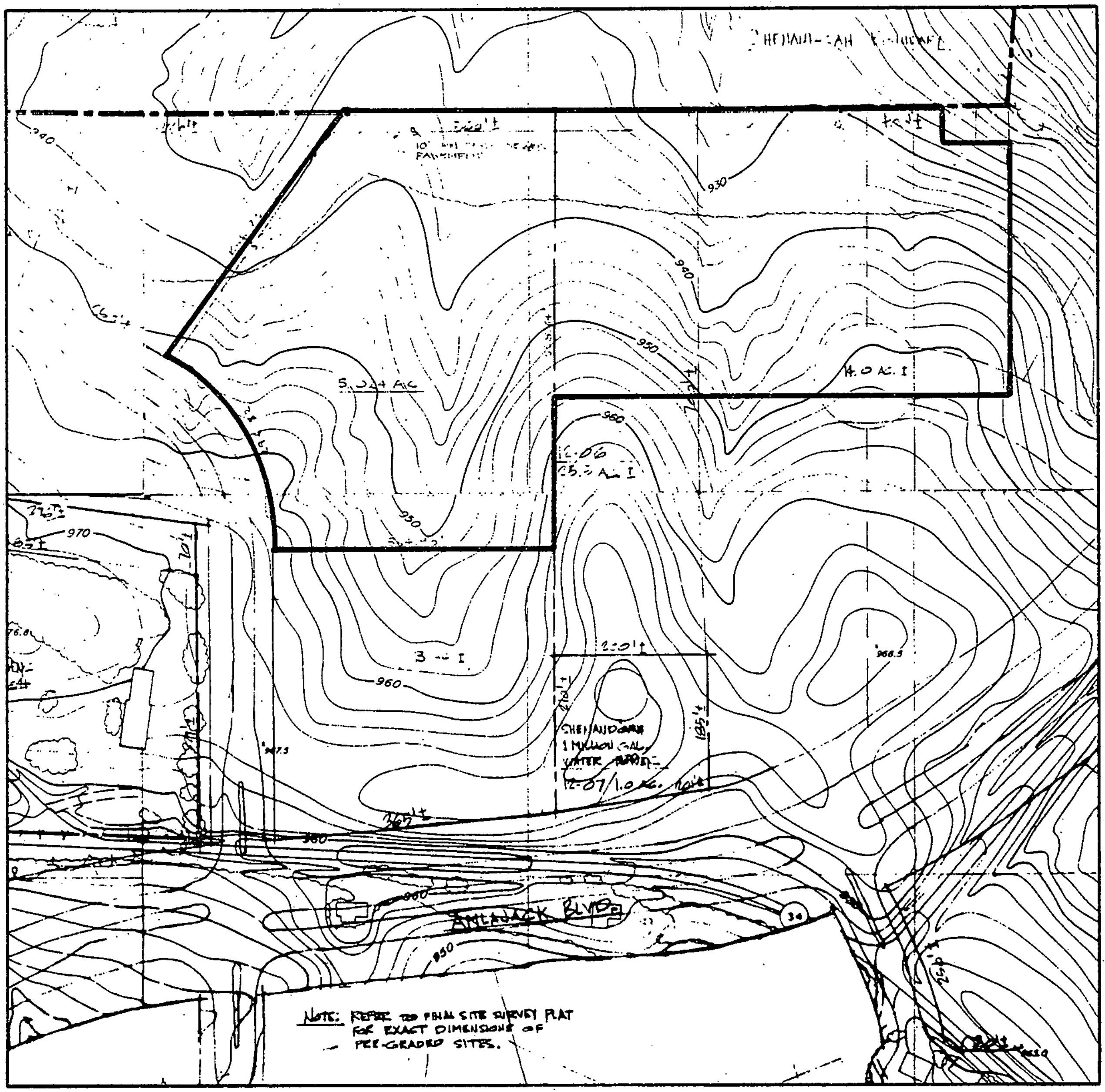
3.1.3 BUILDING AND STRUCTURAL DEVELOPMENT

Subsurface investigations in the area indicate no exceptional foundation problems, and, in fact, indicate that the soil can sustain heavy industrial loads if required. Normal light industrial foundation work is anticipated. The buildings and structures will comply with aesthetic requirements of the Shenandoah Development as well as all applicable codes and standards.

3.1.4 GENERAL ARRANGEMENT

The general arrangement shown in Figures 3.1–3 and 3.1–4 represent the power plant layout for the Baseline Design. Special attention was given to logical arrangement of equipment to facilitate ease of installation, maintenance, and operation. Applicable safety codes and ordinances were given consideration.

The visitor center is arranged to provide an onsite view of the entire operation from the second level of the power plant.



NOTE: REFER TO FINAL SITE SURVEY PLAT FOR EXACT DIMENSIONS OF PRE-GRADED SITES.

FIGURE 3.1–1. PRELIMINARY PLOT PLAN

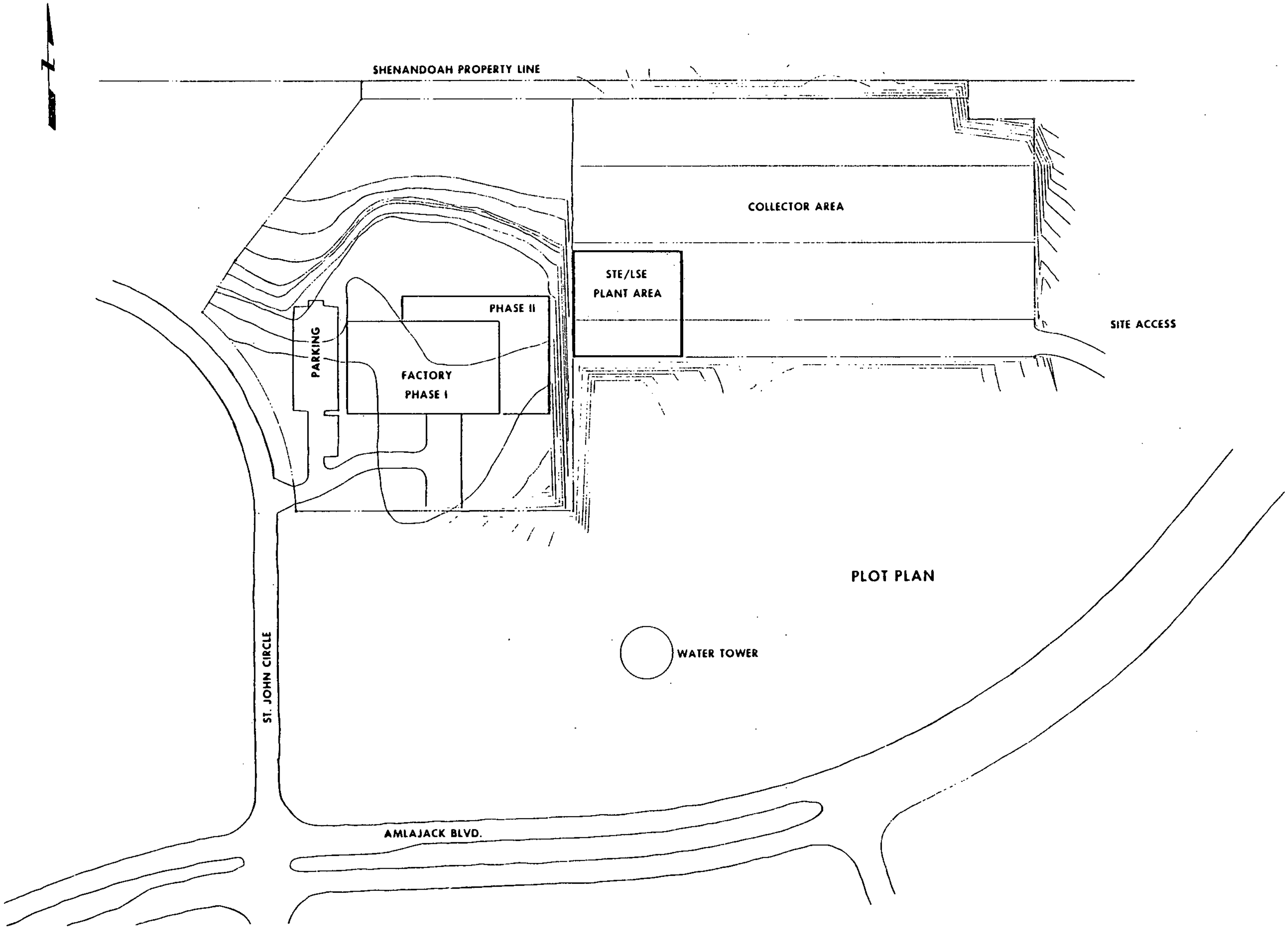
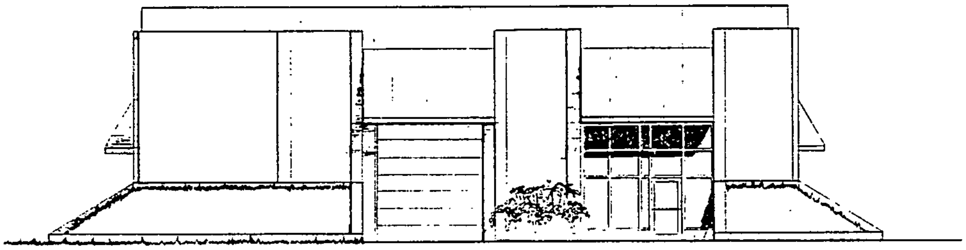
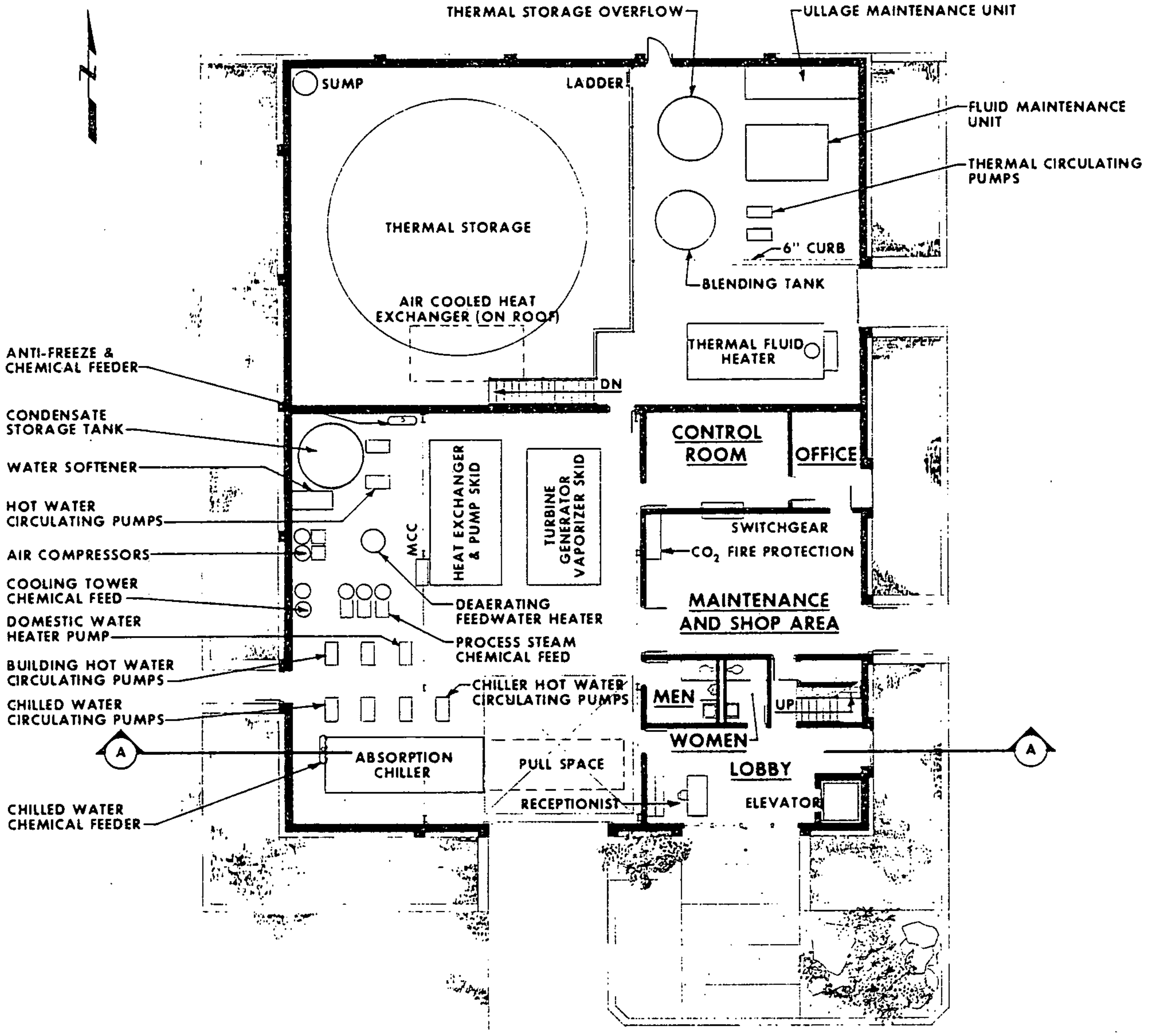


FIGURE 3.1–2. SITE GRADING AND PLOT PLAN



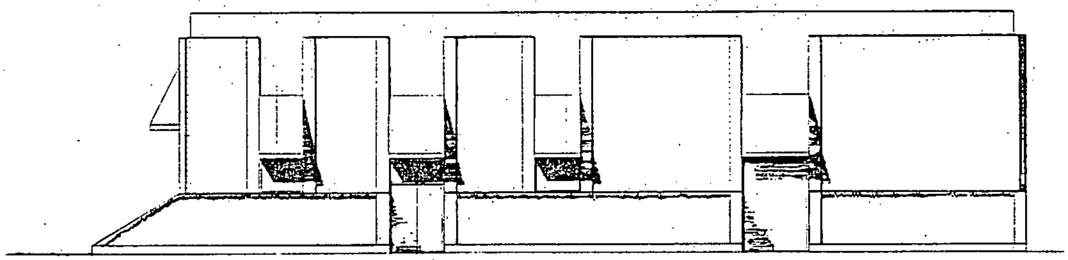
SOUTH ELEVATION



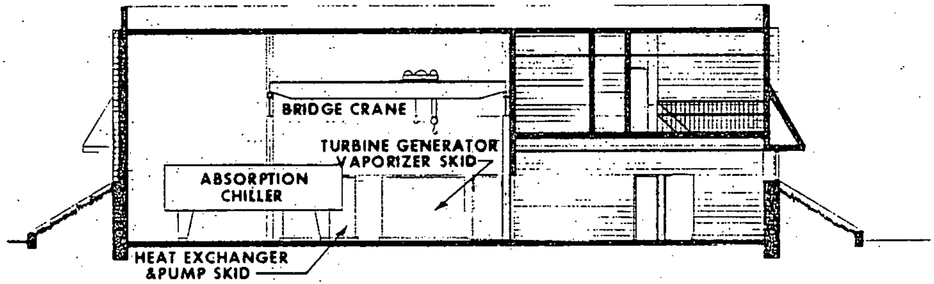
GROUND FLOOR PLAN

GENERAL ARRANGEMENT

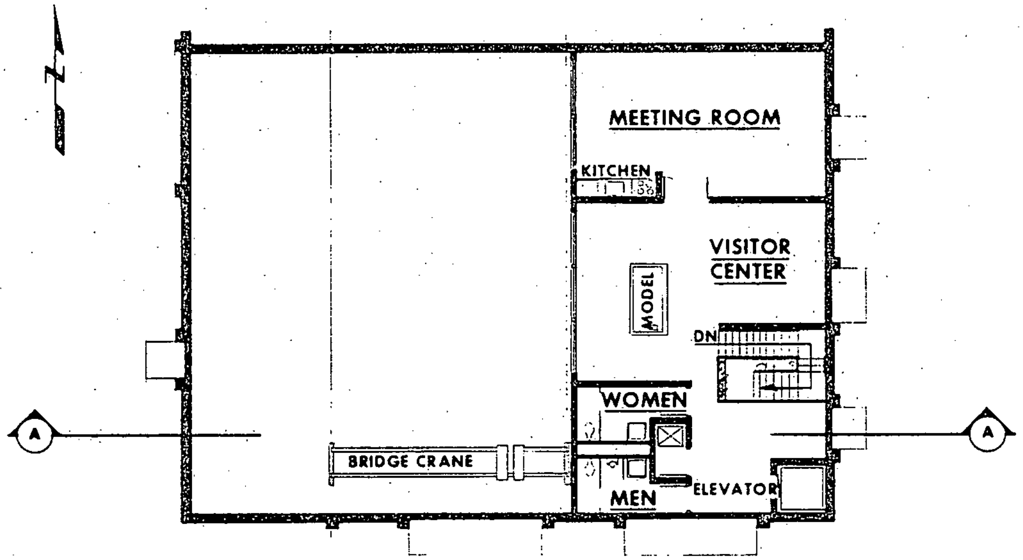
FIGURE 3.1–3. GENERAL ARRANGEMENT - GROUND FLOOR



EAST ELEVATION



BUILDING SECTION "A"



MEZZANINE FLOOR PLAN

GENERAL ARRANGEMENT

FIGURE 3.1–4. GENERAL ARRANGEMENT - MEZZANINE

3.1.5 HEATING, VENTILATING AND AIR CONDITIONING

3.1.5.1 GENERAL

The building to be provided with the HVAC system is a 3902-square-meter (42,000-square-foot) Knitwear Manufacturing Plant. The plant will operate five days a week from 7 AM to 12:15 AM.

3.1.5.2 SYSTEM DESCRIPTION

The plant will be heated and cooled by a battery of packaged rooftop air conditioning units equipped with direct expansion cooling with natural gas heating. These units will be equipped, in addition, with chilled water coils and hot water coils for operation with the Solar Total Energy System. Chilled water will be supplied from a low-temperature input absorption chiller and hot water from the turbine condenser. The hot water from the turbine condenser will be the source of heat for the absorption chiller. A cooling tower will be furnished to supply cooling water to the absorption chiller. Auxiliary equipment like pumps, expansion tanks, and interconnecting piping will be furnished to circulate water. Hot water from the turbine condenser when not used by the HVAC system will be cooled by an air-cooled heat exchanger. The piping arrangement will be such that when hot water from the turbine condenser is not available, water for space heating will be drawn from a Thermal Storage Heat Exchanger.

Hot water will also be used to furnish domestic hot water. This system is shown schematically on Figure 3–3 (Sheet P3–2).

3.1.5.3 DESIGN CRITERIA

Design Temperature	**Winter**	**Summer**
Outside	- 7.8°C (18°F)DB	33.3°C (92°F)DB, 25.6°C (78°F)WB
Inside	12.8°C (55°F)DB	25.6°C (78°F)DB 55% RH

NOTE:

During the operation of the plant, due to high internal heat load, the plant will require cooling all year. The building will require heating in winter only during the off periods of night, weekends, and holidays. During such periods the building will be heated to 12.8°C (55°F)DB as shown above.

Heating Media: Turbine Condenser Water

Temperature of Water 90.6°C (195°F)
Design Temperature Drop 11.1°C (20°F)
Design Water Flow 0.1136 M^3/MIN (30 GPM)

Cooling Media: Chilled Water from Absorption Machine

Design Chilled Water Flow 1.78 M^3/MIN (470 GPM)
Temperature of Water 6.7°C (44°F)
Design Temperature Rise 6.7°C (12°F)

Absorption Chiller: Heating Water Temperature 90.6°C (195°F)
Design Temperature Drop 4.4°C (8°F)
Design Water Flow 3.68 M^3/MIN (972 GPM)

Cooling Water Temperature 29.4°C (85°F)
Design Temperature Rise 4.4°C (8°F)
Design Cooling Water Flow 5.68 M^3/MIN (1500 GPM)

Nominal Capacity $1.4771 \times 10^6 W_t$ (420 tons)
Actual Capacity $0.774 \times 10^6 W_t$ (220 tons)
Expected Coefficient of Performance 0.74

3.1.5.4 ROOFTOP PACKAGED AIR CONDITIONERS

The rooftop packaged air conditioner fans will be started by a timer on a preset schedule. When the Solar Total Energy System (STES) is on the line, the primary cooling and heating will be provided by chilled and hot water coils. The direct expansion cooling and the natural gas heating systems within the packaged units will be used only as supplementary sources. During winter months when the outside air temperature is low, the units will use the outside air to supply cooling to the plant. Refrigeration will not be used.

3.1.5.5 ABSORPTION CHILLER

When the STES is on the line, the chilled water for the rooftop units cooling coils will be furnished by the absorption chiller. The chiller will use cooling water from the turbine condenser as the source of heat. The chiller will be started by supplying power to the chilled water pump. As the chilled water pump is started, the cooling water pump is energized through auxiliary contacts. When the chilled water and cooling water flows are established, the flow switch contacts are closed and the absorption chiller is started through an "on-off" switch. The capacity of the chiller is controlled by varying the flow of hot water through the chiller. The flow switch in the chilled water supply line will energize a solenoid air valve when the chilled water flow is established. When the solenoid air valve is opened, control pressure supplied by the chilled water temperature controller (TC) will pass to a pneumatic temperature control valve (TCV) in the hot water circuit. The output from TC will change with the system demand and will modulate the TCV to maintain constant supply water temperature. An outside air thermostat will stop the chilled water pumps and turn the chiller off if the outside temperature drops below 10°C (50°F).

3.1.5.6 CIRCULATING PUMPS

The building hot and chilled water pumps and the chiller hot and cooling water pumps will be base-mounted centrifugal type. On a demand for cooling from the plant, the chiller hot water and the building chilled water circulating pumps will be started manually. The chiller cooling water circulating pump will be furnished with an H-O-A switch and will be meter-locked to start when the chilled hot water circulating pump is energized.

On a demand for heating, the chilled water and chiller hot water circulating pumps will be de-energized and the building hot water pump will be started manually.

The hot water circulating pump for domestic water heater will be an inline circulator furnished with an H-O-A switch. With the switch indexed for automatic operation, a temperature switch in the water heater will cycle the inline circulator to maintain a minimum water temperature in the water heater tank.

COOLING WATER

The cooling tower fans will be interlocked with the condenser water circulating pump to start when the pump motor is energized. An electric heater will be provided in the sump of the cooling tower for freeze protection. A temperature controller with its sensor in the sump water will activate the electric heater, de-energize the fan, and close the discharge dampers if the temperature in the sump drops below 4.4°C (40°F).

3.1.6 AUXILIARY SYSTEMS

3.1.6.1 WATER TREATMENT AND CHEMICAL FEED SYSTEMS

The systems requiring water treatment are the condensate make-up for process steam, the hot water system to the chiller, the chilled water system, and the cooling tower circulating water system.

This subsection describes the preliminary design for the water treatment and chemical feed for these systems based on the water analysis provided by the City of Newnan and shown in Table 3.1–1. The systems are shown diagrammatically on Figures 3–2 and 3–3 (Sheets P3–1 and P3–2).

3.1.6.1.1 Process Steam Boiler Condensate Treatment

The treatment of the process steam boiler makeup is based on criteria for boilers up to 2068 kPa (300 PSI). The recommended boiler water limits for this pressure are:

Silica	150 PPM
Total Alkalinity	700 PPM
Specific Conductance	7000 micromhos/CM

	RAW WATER (PPM)	FINISHED WATER (PPM)
Iron (Fe)	0.1	.00
Manganese	.07	.00
Total Hardness as ($CaCo_3$)	22	48
Fluoride (F)	0.2	0.9
Silica (SiO_2)	11	12
Calcium (Ca)	4.4	17
Magnesium (Mg)	1.2	1.2
Sodium (Na)	4.3	5.5
Potassium (K)		
Carbonate (CO_3)	.00	15
Bicarbonate (HCO_3)	21	12
Sulfate (SO_4)	2.5	14
Chloride (CL)	3.5	6.8
Nitrates (NO_3)	.9	.2
Color	6	1
Turbidity	15	0
pH	6.9	9.0
Alkalinity	20	29
CO_2	3	0

TABLE 3.1–1. WATER ANALYSIS - NEWNAN WATER WORKS, JULY 28, 1977

Complete demineralization of the boiler feed water is not recommended and sodium-ion-exchange softening will be used. Operating limits can be controlled by minimal blowdown. The smallest "industrial quality" units of this type are normally rated at about 0.03785 M^3/MIN (10 GPM). A 18.93 M^3 (5000-gallon) softened water storage tank is included in the system. The softener unit, brine tank, and controls would be skid mounted, requiring a floor space of approximately 0.762 M x 1.52 M (2-FT-5-IN x 5-FT) with 1.83 M (6 FT) allowance for clearance over piping. Such a unit would require regeneration approximately every 5 to 7 days (depending on throughput) and would require 2.49 KG (5.5 pounds) of salt per regeneration.

The use of phosphate and hydrazene as treatment chemicals is not recommended. Depending upon the boiler construction, there might be phosphate scale formation, and hydrazene is not a good oxygen scavenger at the indicated temperatures and pressures.

A deaerator will be included in the system immediately before the condensate pump. The softened make-up water will be saturated with oxygen and there may not be sufficient time for the sodium sulfite, which is added in the deaerator, to fully react to reduce this oxygen before the condensate enters the boiler.

Chelate, caustic soda and a filming amine will be added to the condensate in the suction line of the condensate feed pump.

The chelate addition is a scale control chemical which prevents precipitation of scale-forming compounds on metal surfaces.

The caustic soda (sodium hydroxide) increases the alkalinity, raises the pH, and helps prevent the formation of carbon dioxide.

The filming amine helps to prevent corrosion in the piping by protecting against oxygen and carbon dioxide attack. The filming amine forms a protective film on the metal surfaces of the system.

The feeding of chelate, caustic soda, and a filming amine may seem to be overkill. There are proprietary chemical compounds available for situations as this; the use of such a chemical would require only one tank and pump system. However, only one manufacturer supplies this chemical and for this conceptual design it is recommended not to restrict the design to this one supplier.

Caustic soda and the filming amine can be mixed together in one tank. The sodium sulfite tank should *not* have a mixer. The use of 0.189 M^3 (50-gallon) tanks and feed pumps rated at slightly over 0.011356 M^3/HR (3 GPH) are recommended so that each tank would be emptied during the 16 hour operating cycle. Each tank and pump system will be approximately 0.914 M x 1.52 M x 1.52 M (3 FT x 5 FT x 5 FT) in size (including mixer).

3.1.6.1.2 Cooling Tower Circulating Water System

"Finished water" from the city of Newnan should be used as the makeup to the cooling tower. The pH of the circulating water should be maintained at 7 or slightly higher. This will mean operating the tower at 2 to 3 cycles of concentration.

It was assumed that this system will not be constructed of corrosion resistant material. The circulating water will become aggressive during concentration through the cooling tower and, therefore, a corrosion inhibiting chemical will be required. A biocide should be fed at infrequent intervals in order to control biological growth in the system. Several "package" treatment systems are available; for example, the system described in the Nalco Bulletin C-13 illustrates a typical system. The chemicals are pumped directly from the supplier's drums. This system is shown on Figure 3–3 (Sheet P3–2).

3.1.6.1.3 Hot Water and Chilled Water Circulating System

Since the volume of these systems is relatively small, it is suggested that they be filled with sodium-ion-exchange softened water.

Here again it was assumed that these systems will not be constructed of corrosion resistant materials throughout. Therefore, the addition of a corrosion inhibitor is recommended. As these are closed systems, an additional chemical charge of approximately 2000 PPM can be added through a by-pass feeder, and additional inhibiter would be added infrequently on an "as needed" basis.

Feeders 0.068 M^3 (18 gallons) in size are included although smaller units might prove to be adequate. These bypass chemical feeders are shown on Figure 3–3 (Sheet P3–2).

3.1.6.2 INSTRUMENT AND SERVICE AIR SYSTEMS

The instrumentnd service air systems will consist of a service air compressor, an instrument air compressor, air receivers, necessary dryers and filters, and associated piping and fittings.

3.1.6.2.1 Instrument Air System

A 1.7 actual M^3/MIN (60 ACFM), 689.5 kPa (100 PSIG) discharge-pressure, reciprocating, oil-free compressor was estimated to be adequate for this service. The compressor assembly will include an aftercooler, air receiver, filter, and dryer to provide clean, dry air to the STES control valves and instruments.

An instrument air header will be routed through the power plant with air stations located at a number of convenient places. Instrument air tubing will be routed to these air stations and to the various air-operated valves and control instruments.

During the definitive system design phase, the capacity of the air compressor will be re-evaluated and the routing of the air header, together with the location of the air station, will be defined.

3.1.6.2.2 Service Air System

A 3.54 actual M^3/MIN (125 ACFM), 689.5 kPa (100 PSIG), reciprocating air compressor was selected for this service. The compressor assembly will include a receiver, aftercooler, and filter.

The purpose of this system is to provide service air for air-operated tools and maintenance operations involving cleaning and drying.

It is anticipated that during the definitive design phase the number and locations of service air quick-disconnect stations will be established based on criteria as established by the operators of the facility. At that time, compressor capacity will also be re-evaluated.

3.1.6.3 FIRE PROTECTION SYSTEM

This subsection presents the fire protection system proposed for the STE/LSE facility. The system will be designed to meet all local codes and will comply with NFPA requirements and those of the insurance underwriters for the facility.

Fire protection in the areas of the power conversion system and the thermal storage tank inside the power house will consist of water deluge and/or carbon dioxide systems, both automatically and manually actuated.

The visitors center will be protected by sprinkler systems.

Hand held extinguishers will be placed at strategic locations inside the building and particularly in areas where combustible materials will be stored.

External fire hydrants will be located outside the building and near the solar collector field to contain any fires caused by leaking thermal fluid in the field.

3.1.7 EQUIPMENT LIST AND MOTOR LIST

A list of required equipment for the STE/LSE in accordance with this conceptual design is included as Table 3.1–2. The motor list for the facility is included as Table 3.1–3.

3.1.8 AUXILIARY POWER REQUIREMENTS

This subsection presents the auxiliary power requirements necessary to operate the baseline solar collector field system and the baseline power conversion system. Also included are the power requirements necessary to supply chilled water and hot water for summer cooling and winter heating. Support system power requirements for the chemical treatment equipment and compressed air systems are also included.

Table 3.1–4 presents the estimated auxiliary power requirements for the July season. The table is set up for each piece of equipment requiring power, the

EQUIPMENT LIST

PROJECT SOLAR TOTAL ENERGY SYSTEM LARGE SCALE EXPERIMENT
CUSTOMER ERDA, ALBUQUERQUE, NEW MEXICO
JOB NO. C-19650
REV./DATE 0 / 8/23/77
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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
THERMAL STORAGE & COLLECTION SYSTEM				
1) Blending Tank	1	1	2500 GALS. 75 FT DIA X 75 FT Long	
2) Thermal Fluid Circulating Pumps	2	1,2	200 GPM, Horizontal, centrifugal, 20 HP	
3) Fossil Fuel Oil Heater	1	1	10×10^6 BTU/HR Rating, NO.2 Fuel Oil Fired	ASME Code
4) Thermal Storage Tank	1	1	26,000 FT^3 32 FT DIA X 32 FT High	ASME Code API Code
5) Thermal Storage Overflow Tank	1	1	1200 GALS. 12.7 FT DIA X 12.7 FT High	
6) Ullage Maintenance Unit	1	1		
7) Thermal Fluid Makeup Storage Tank	1	1	Fluid makeup MFGS Supply Drums	
8) Solar Collectors			9 x 12 FT North-South PARABOLIC Troughs	

TABLE 3.1–2. EQUIPMENT LIST (Sheet 1 of 10)

EQUIPMENT LIST

PROJECT SOLAR TOTAL ENERGY SYSTEM LARGE SCALE EXPERIMENT
CUSTOMER ERDA, ALBUQUERQUE, NEW MEXICO
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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
POWER CONVERSION SYSTEM				
(DRWG SHT P3-1				
1) Toluene Vapor Turbine	1	Stage 1,2	Two-stage impulse condensing turbine,	
			Pin=650 PSIA Tin = 625^{O}F, PEXH,=8.7 PSIA (Summer)	
			Between STG EXTR For process STM GEN	
2) Speed Reducer	1	1	Speed reduction to 3600 RPM, Efficiency = 95%	
3) Generator	1	1	550 KVA, 480V, 3600 RPM, Efficiency = 94%, 0.80	
			PF	
4) Toluene Vaporizer	1	1	Shell and tube heat exchanger Shell fluid	
			Therminol-66, Tube Fluid Toluene	ASME Code
5) First Stage Regenerator	1	1	Shell and Tube, Vapor Shell Side, Liquid Tube	
			Side	ASME Code
6) First Stage Condenser/	1	1	2200 LB/HR Process Steam Boiler at 113.6 PSIA SAT.	
Boiler			Shell Side Water, Tube. Side Condensing Toluene	ASME Code

TABLE 3.1–2. EQUIPMENT LIST (Sheet 2 of 10)

EQUIPMENT LIST

PROJECT SOLAR TOTAL ENERGY SYSTEM LARGE SCALE EXPERIMENT
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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
POWER CONVERSION SYSTEM (cont'd)				
7) Receiver	1	1	370 Gallons	ASME Code
8) First Stage Vaporizer	2	1-1, 1-2	Multi Stage Horizontal, Centrifugal 50 GPM/PUMP	
Feed Pumps			TDH=2017 FT	Each 100% Size
9) Condensate Feed Pump	1	1	Horizontal, Centrifugal 5 GPM, TDH=300 FT	1 HP Motor Full Size
10) Deaerating Feed Water	1	1	Vertical, 50 GAL., For deaeration of process	ASME Code
Heater			Steam Makeup	
11) Second Stage Regenerator	1	2	Shell and Tube, Shell Side Vapor, Tube Side	ASME Code
			Liquid	
12) Second Stage Condenser	1	2	Shell and Tube, 2592 SF, CIRC Water from Chiller	ASME Code
			Tube Side	
13) Hot Well Tank	1	2	415 Gallons	ASME Code
14) Second Stage Vaporizer	2	2-1, 2-2	Multi-stage, Horizontal Centrifugal 55 GPM/pump,	
			TDH=1970 FT 50 HP Motor	Each 100% Size

TABLE 3.1–2. EQUIPMENT LIST (Sheet 3 of 10)

EQUIPMENT LIST

PROJECT SOLAR TOTAL ENERGY SYSTEM LARGE SCALE EXPERIMENT
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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
CIRCULATING WATER SYSTEM				
(DRWG. Sheet P3-Z)				
1) Absorption Chiller	1	1	220 Tons Design Capacity, 195°F Inlet Water TEMP.	
			184°F Outlet Water TEMP, Lithium Bromide Absorption Unit	
2) Chiller Hot Water	2	1,2	Centrifugal, Horizontal 550 GPM/Pump TDH=56 FT	Each 60% Size
Circulating Pumps			15 HP Motor	
3) Chiller Cooling Tower	1	1	2 Cell, Cross Flow Mech. Draft, 15 HP/Cell	
4) Chiller Cooling Water	2	1,2	Centrifugal, Horizontal 800 GPM/pump TDH = 75 FT	Each 50% Size
Circulating Pumps			30 HP Motor	
5) Chilled Water Circulating	2	1,2	Centrifugal, Horizontal 440 GPM/pump TDH = 75 FT,	Each 100% Size
Pump			15 HP	
6) Chilled Water Expansion	1	1	30 Gallons	
Tank				

TABLE 3.1–2. EQUIPMENT LIST (Sheet 4 of 10)

EQUIPMENT LIST

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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
CIRCULATING WATER SYSTEM (cont'd)				
7) Chilled Water Chemical Feeder	1	1	By Pass Feeder, 18 Gallon Capacity	
8) Building Heating Circulating Pumps	2	1,2	Centrifugal, Horizontal 60 GPM/pump TDH = 80 FT 3 HP Motor	Each 100% Size
9) Building Heating Expansion Tank	1	1	100 Gallons	
10) Domestid Water Heater Pump	1	1	Centrifugal, Horizontal 5 GPM, TDH = 67 FT 0.25 HP Motor	Full size
11) Domestic Water Heater	1	1	40 Gallons	
12) Hot Water Circulating Pumps	2	1,2	Centrifugal, Horizontal 180 GPM/pump, TDH = 56 FT 5 HP Motors	Each 60% Size
13) Circulating Water Expansion Tank	1	1	100 Gallons	

TABLE 3.1–2. EQUIPMENT LIST (Sheet 5 of 10)

EQUIPMENT LIST

PROJECT: SOLAR TOTAL ENERGY SYSTEM LARGE SCALE EXPERIMENT
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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
CIRCULATING WATER SYSTEM (cont'd)				
14) Air Cooled Heat Exchanger	1	1	Air-Cooled, Mechanical Draft, 3.7 x 10^6 BTU/HR	
15) Anti-Freeze and Chemical Feeder	1	1	Bypass Feeder, 18 Gallon Capacity	
16) Hot Water Storage Tank	1	1		ASME Code

TABLE 3.1–2. EQUIPMENT LIST (Sheet 6 of 10)

EQUIPMENT LIST

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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
MISCELLANEOUS				
1) CO_2 Fire Protection System For Toluene System	1			
2) Hydrocarbon Leak Detector	1		100 PPM Toluene Vapor in Air	
3) Instrument Air Compressor	1	1	60 ACEM, 100 PSIG Reciprocating, oil Free Motot HP = 10	
4) Service Air Compressor	1	1	125 ACFM, 100 PSIG, Reciprocating, Motor HP = 25	
5) Equipment Room Crane	1		5 Tons Bridge Crane, 26 FT Span	
6) Condensate Storage Tank	1	1	5000 GALS. 8 FT DIA x 14 FT High	
7) Fuel Oil Storage Tank	1	1	15000 GALS. under ground 10 FT-6 IN. DIA x 23 FT-7 IN. Long	
8) Fuel Oil Transfer Pump	1	1	2 GPM, TDH = 40 FT, 1/4 HP, Vertical Centrifugal	

TABLE 3.1–2. EQUIPMENT LIST (Sheet 7 of 10)

EQUIPMENT LIST

PROJECT SOLAR TOTAL ENERGY SYSTEM LARGE SCALE EXPERIMENT
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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
MISCELLANEOUS (cont'd)				
9) Sodium Ion Exchange Unit	1	1	10 GPM Capacity	
10) Cooling Tower Corrosion Inhibiter Feed Unit	1	1	1/8 HP Pump, Pumped from Suppliers Drums	
11) Cooling Tower Biocide Feed Unit	1	1	1/2 HP Pump, Pumped from Suppliers Drums	
12) Chelate Feed Unit	1	1	1/4 HP Feed Pump, 1.0 GPH, Mixer, 50 Gallon Tank	
13) Sodium Hydroxide and Filming Amine Feed Unit	1	1	1/4 HP Feed Pump, 1.0 GPH, Mixer, 50 Gallon Tank	
14) Sodium Sulfite Feed Unit	1	1	1/4 HP Feed Pump 1-GPH, 50 Gallon Tank	

TABLE 3.1–2. EQUIPMENT LIST (Sheet 8 of 10)

EQUIPMENT LIST

PROJECT SOLAR TOTAL ENERGY SYSTEM LARGE SCALE EXPERIMENT
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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
ELECTRICAL EQUIPMENT				
1) Circuit Breaker	1		Metal Enclosed, 600 AMP Frame, For Startup Stand by source	
2) Switch Gear	1		Metal Enclosed, with one 1600 AMP, Power circuit Breaker for generator and one 600 AMP power Circuit breaker for auxiliaries	
3) Motor Control Center	1		With Automatic Transfer Switch, size 1, 2 and 3 Starters as required	
4) 750 KVA Transformer	1		480 V Delta - 277/480 V WYE, Outdoor	
5) 480 V Bus	1			
6) Meter	1		For Billing and Accounting Provided by GA. Power Co.	
7) Station Battery	1		200 AMP-HR, 125 V	

TABLE 3.1–2: EQUIPMENT LIST (Sheet 9 of 10)

EQUIPMENT LIST

PROJECT SOLAR TOTAL ENERGY SYSTEM LARGE SCALE EXPERIMENT
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EQUIPMENT	QUANTITY	I.D. NUMBER	DESCRIPTION	REMARKS
ELECTRICAL EQUIPMENT (cont'd)				
8) Battery Charger	1		125 V, 25 AMPS DC, 460 V AC	
9) Inverter	1		50 KVA, 125 V DC/480 V AC, 3 0, 4 Wire	
10) Control Panel	1		With AM meters, wattmeters, varmeters, voltmeters synchroscope, switchs, Indicating Lamps, Relays, ETC.	

TABLE 3.1–2. EQUIPMENT LIST (Sheet 10 of 10)

REV. NO.	A ACTUAL E ESTIMATED	NAME PLATE DESCRIPTION	H.P.	RPM (SYN)	VOLTAGE PHASE & FREQUENCY	ENCLOSURE	INSULATION	TEMP. RISE ABOVE 40°C	FULL LOAD AMPERES	LOCKED ROTOR AMPERES	SPACE HTR WATTS	REMARKS	P.O. NO. OR CONTRACT NO.
0	E	Thermal Fluid Cir-	20	1800	460/3/60	TEFC	B					Variable Speed Drive	
		culating Pumps 1,2										1 pump Operating	
0	E	Fossil Fuel Heater	2	1800	460/3/60	ODP	B					1 Pump Operating	
		Burner Oil Pump 1											
0	E	Fossil Fuel Heater	5	1800	460/3/60	ODP	B					1 Blower Operating	
		Blower 1											

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TABLE 3.1–3. MOTOR LIST (Sheet 1 of 6)

REV. NO.	A · ACTUAL E ESTIMATED	NAME PLATE DESCRIPTION	H.P.	RPM (SYN)	VOLTAGE PHASE & FREQUENCY	ENCLOSURE	INSULATION	TEMP. RISE ABOVE 40°C	FULL LOAD AMPERES	LOCKED ROTOR AMPERES	SPACE HTR WATTS	REMARKS	P.O. NO. OR CONTRACT NO.
0	E	First-Stage Vaporizer Feed Pumps 1-1, 1-2	50	3600	460/3/60	TEFC	B	85				1 Pump Operating	
0	E	Second Stage Vaporizer Feed Pumps 1-1, 1-2	50	3600	460/3/60	TEFC	B	85				1 Pump Operating	
0	E	Condensate Feed Pump 1	1	1800	230/3/60	ODP	B	80				1 Pump Operating	
0	E	Hot Water Circulating Pumps 1,2	5	1800	460/3/60	ODP	B	80				2 Pumps Operating	
0	E	Chiller Hot Water Circulating Pumps 1,2	15	1800	460/3/60	ODP	B	80				2 Pumps Operating	

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TABLE 3.1–3. MOTOR LIST (Sheet 2 of 6)

REV. NO.	A ACTUAL E ESTIMATED	NAME PLATE DESCRIPTION	H.P.	RPM (SYN)	VOLTAGE PHASE & FREQUENCY	ENCLOSURE	INSULATION	TEMP. RISE ABOVE 40°C	FULL LOAD AMPERES	LOCKED ROTOR AMPERES	SPACE HTR WATTS	REMARKS	P.O. NO. OR CONTRACT NO.
0	E	Chilled Water Circulating Pumps 1,2	15	1800	460/3/60	ODP	B	80				1 Pump Operating	
0	E	Chiller Cooling Water Circulating Pumps 1,2	30	1800	460/3/60	TEFC	B	80				2 Pumps Operating	
0	E	Building Heating Circulating Pumps 1,2	3	1800	460/3/60	ODP	B	80				1 Pump Operating	
0	E	Domestic Water Heater Pump 1	1/4	1800	115/1/60	ODP	B	80				1 Pump Operating	
0	E	Air Cooled Heat Exchanger Fans	10	1800	460/3/60	TEFC	B	80				2 Fans Operating	

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TABLE 3.1–3. MOTOR LIST (Sheet 3 of 6)

REV. NO.	A ACTUAL E ESTIMATED	NAME PLATE DESCRIPTION	H.P.	RPM (SYN)	VOLTAGE PHASE & FREQUENCY	ENCLOSURE	INSULATION	TEMP. RISE ABOVE 40°C	FULL LOAD AMPERES	LOCKED ROTOR AMPERES	SPACE HTR WATTS	REMARKS	P.O. NO. OR CONTRACT NO.
0	E	Chiller Cooling Tower Fans 1,2	15	1800	460/3/60	TEFC	B	80				2 Fans Operating	
0	E	Chiller Purge and Circulating Pumps	4	1800	460/3/60	ODP	B	80				2 Pumps Operating	
0	E	Instrument Air Compressor 1	10	1800	460/3/60	ODP	B	80				1 Compressor Operating	
0	E	Service Air Compressor 1	25	1800	460/3/60	ODP	B	80				1 Compressor Operating	
0	E	Fuel Oil Transfer Pump	1/3	1800	460/3/60	TENV	B	85				1 Pump Operating	
0	E	Bridge Crane Motor				ODP	B	80				1 Motor (Hoist)	

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TABLE 3.1–3. MOTOR LIST (Sheet 4 of 6)

REV. NO.	A ACTUAL E ESTIMATED	NAME PLATE DESCRIPTION	H.P.	RPM (SYN)	VOLTAGE PHASE & FREQUENCY	ENCLOSURE	INSULATION	TEMP. RISE ABOVE 40°C	FULL LOAD AMPERES	LOCKED ROTOR AMPERES	SPACE HTR WATTS	REMARKS	P.O. NO. OR CONTRACT NO.
0	E	Collector Drive Motors	1/12	1800	115/1/60	TENV	B	85				122 Motors Operating	
0	E	Cooling Tower Corrosion Inhibiter Feed Pump	1/8		230/3/60		B						
0	E	Cooling Tower Biocide Feed Pump	1/2		230/3/60		B						
0	E	Chelate Feed Pump	1/4		230/3/60		B						
0	E	Chelate Tank Mixer	1/8										
0	E	Sodium Hydroxide and Filming Amine Feed Pump	1/4		230/3/60		B						

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TABLE 3.1–3. MOTOR LIST (Sheet 5 of 6)

REV. NO.	A · ACTUAL E · ESTIMATED	NAME PLATE DESCRIPTION	H.P.	RPM (SYN)	VOLTAGE PHASE & FREQUENCY	ENCLOSURE	INSULATION	TEMP. RISE ABOVE 40°C	FULL LOAD AMPERES	LOCKED ROTOR AMPERES	SPACE HTR WATTS	REMARKS	P.O. NO. OR CONTRACT NO.
0	E	Sodium Hydroxide/	1/8										
		Filming Amine Tank											
		Mixer											
0	E	Sodium Sulfite	1/4		230/3/60		B						
		Feed Pump											

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TABLE 3.1–3. MOTOR LIST (Sheet 6 of 6)

ELECTRIC POWER USER	POWER REQUIREMENT KW	USE FACTOR	OPERATING POWER, KW
1 - Thermal Fluid Circulating Pump	14.9	1.0	14.9
2 - Fossil Fuel Heater Burner Oil Pump	1.5	0.5	0.8
3 - Fossil Fuel Heater Blower	3.7	0.5	1.9
4 - 1st Stage Vaporizer Feed Pump	37.3	1.0	37.3
5 - 2nd Stage Vaporizer Feed Pump	37.3	1.0	37.3
6 - Condensate Feed Pump	0.75	1.0	0.75
7 - Hot Water Circulating Pumps	7.5	0.0	0
8 - Chiller Hot Water Circulating Pumps	22.4	1.0	22.4
9 - Chilled Water Circulating Pump	11.2	1.0	11.2
10 - Chiller Cooling Water Circulating Pumps	44.7	1.0	44.7
11 - Building Heating Circulating Pump	2.2	0.0	0
12 - Domestic Water Heater Pump	0.2	0.5	0.1
13 - Air Cooled Heat Exchanger Fans	14.9	0.0	0
14 - Chiller Cooling Tower Fans	22.4	1.0	22.4
15 - Chiller Purge and Circulating Pumps	6.0	1.0	6.0
16 - Instrument Air Compressor	7.5	0.5	3.75
17 - Service Air Compressor	18.6	0.2	3.7
18 - Fuel Oil Transfer Pump	0.2	0.5	0.1
19 - Bridge Crane Motor		0	0
20 - Collector Drive Motors	7.6	0.5	3.8

TABLE 3.1–4. ESTIMATED AUXILIARY POWER REQUIREMENTS - JULY SEASON (Sheet 1 of 2)

ELECTRIC POWER USER	POWER REQUIREMENT KW	USE FACTOR	OPERATING POWER, KW
21 - Cooling Tower Corrosion Inhibiter Feed Pump	0.1	0.5	0.05
22 - Cooling Tower Biocide Feed Pump	0.4	0.5	0.2
23 - Chelate Feed Pump	0.2	0.5	0.1
24 - Chelate Tank Mixer	0.1	0	0
25 - Sodium Hydroxide and Filming Amine Feed Pump	0.2	0.5	0.1
26 - Sodium Hydroxide and Filming Amine Tank Mixer	0.1	0	0
27 - Sodium Sulfite Feed Pump	0.2	0.5	0.1
TOTAL AUXILIARY POWER(JULY SEASON)			
INCLUDES ORC POWER REQUIREMENTS			211.7
NOT INCLUDING ORC POWER REQUIREMENTS			137.1

TABLE 3.1–4. ESTIMATED AUXILIARY POWER REQUIREMENTS - JULY SEASON (Sheet 2 of 2)

power required for the equipment, and an estimated "use factor." The power requirement is multiplied by the "use factor" to obtain the operating power requirement. The total auxiliary power requirement is shown with and without the organic-Rankine-cycle vaporizer feed pump power.

Table 3.1–5 shows a similar chart of axuiliary power requirements based on an estimated January season.

Comparing the total auxiliary power requirements for the July and January seasons, not including the ORC vaporizer feed pump power which is assumed constant for both seasons, it is obvious that the big power user is the absorption chiller and its associated equipment.

ELECTRIC POWER USER	POWER REQUIREMENT KW	USE FACTOR	OPERATING POWER, KW
1 - Thermal Fluid Circulating Pump	14.9	1.0	14.9
2 - Fossil Fuel Heater Burner Oil Pump	1.5	0.5	0.8
3 - Fossil Fuel Heater Blower	3.7	0.5	1.9
4 - 1st Stage Vaporizer Feed Pump	37.3	1.0	37.3
5 - 2nd Stage Vaporizer Feed Pump	37.3	1.0	37.3
6 - Condensate Feed Pump	0.75	1.0	0.75
7 - Hot Water Circulating Pumps	7.5	0.5	3.75
8 - Chiller Hot Water Circulating Pumps	22.4	0	0
9 - Chilled Water Circulating Pump	11.2	0	0
10 - Chiller Cooling Water Circulating Pumps	44.7	0	0
11 - Building Heating Circulating Pump	2.2	1.0	2.2
12 - Domestic Water Heater Pump	0.2	0.5	0.1
13 - Air Cooled Heat Exchanger Fans	14.9	0.5	7.45
14 - Chiller Cooling Tower Fans	22.4	0	0
15 - Chiller Purge and Circulating Pumps	6.0	0	0
16 - Instrument Air Compressor	7.5	0.5	3.75
17 - Service Air Compressor	18.6	0.2	3.70
18 - Fuel Oil Transfer Pump	0.2	0.5	0.1
19 - Bridge Crane Motor		0	0
20 - Collector Drive Motors	7.6	0.5	3.8

TABLE 3.1–5. ESTIMATED AUXILIARY POWER REQUIREMENTS - JANUARY SEASON
(Sheet 1 of 2)

ELECTRIC POWER USER	POWER REQUIREMENT KW	USE FACTOR	OPERATING POWER, KW
21 - Cooling Tower Corrosion Inhibitor Feed Pump	0.1	0	0
22 - Cooling Tower Biocide Feed Pump	0.4	0.5	0.2
23 - Chelate Feed Pump	0.2	0.5	0.1
24 - Chelate Tank Mixer	0.1	0	0
25 - Sodium Hydroxide and Filming Amine Feed Pump	0.2	0.5	0.1
26 - Sodium Hydroxide and Filming Amine Tank Mixer	0.1	0	0
27 - Sodium Sulfite Feed Pump	0.2	0.5	0.1
TOTAL AUX. POWER (JANUARY SEASON)			
INCLUDES ORC POWER REQUIREMENT			118.2
NOT INCLUDING ORC POWER REQUIREMENT			43.6

TABLE 3.1–5. ESTIMATED AUXILIARY POWER REQUIREMENTS - JANUARY SEASON
(Sheet 2 of 2)

SUBSECTION 3.2

3.2 SYSTEM CONCEPT DESIGN

This subsection describes the rationale and methodology used for the selection of the solar collector subsystem, power conversion subsystem, thermal storage/fluid loop subsystem, and the system integration studies made to maximize the Solar Total Energy System (STES) performance and energy displacement.

3.2.1 INSOLATION METHODOLOGY

The 1975 Atlanta, Georgia, Test Reference Year (TRY) was selected as the best source of readily available hourly insolation and meteorological data for the Solar Total Energy/Large Scale Experiment (STE/LSE) Phase II conceptual design studies. The insolation data include hourly direct normal and total hemispherical data derived from an Aerospace Corporation total cloud cover correlation. This data has been converted to the standard Aerospace insolation data tape format.

In a previous study*, it was found that a typical week per season method for insolation selection provided a reasonably accurate indication of the annual insolation characteristics of a given location. Sandia selected one week for each of the four seasons from the 1975 Atlanta TRY year to be used for performance analyses. The four weeks selected for performance analyses of the conceptual designs are: January 8-14, April 1-7, July 11-17, and October 13-19. Table 3.2–1 presents the average daily total horizontal and direct normal insolation for the selected weeks.

Since collector operating fluid temperature requirements for solar total energy systems necessitate the use of focusing or concentrating types of collectors, only the direct normal insolation need be considered. The estimating and selection procedures employed to obtain the direct normal insolation resulted in some limitations of the solar model year which have a direct bearing on collector performance:

(1) The estimating procedure limits peak direct insolation to 0.85 KW/M^2 (270 BTU/HR/SQ-FT). Observed direct insolation will reach values of about 1 KW/M^2 (317 BTU/HR/SQ-FT) on very clear conditions. Obviously, the limitation penalizes the collector performance.

(2) The daily average direct insolation for the January typical week is significantly lower than either the average daily insolation for all of January in the Aerospace data tape or the values estimated for January from the Sandia maps.** This will further penalize the north-south one-axis horizontal orientation in January.

**Industrial Application of Solar Total Energy*, ERDA Contract EY-C-76-03-1132.

***Distribution of Direct and Total Solar Radiation Available for the USA*, Sandia Laboratories Report SAND 76-0411.

SEASON	TOTAL HORIZONTAL KW-HR/M^2-DAY	DIRECT NORMAL KW-HR/M^2-DAY
JANUARY 8-14	2.70	2.67
APRIL 1-7	6.14	6.28
JULY 11-17	6.45	5.33
OCTOBER 13-19	4.25	4.53
ANNUAL AVERAGE	4.89	4.70
NOTE: ATLANTA TEST REFERENCE YEAR (1975) USED FOR CONCEPTUAL DESIGN AEROSPACE INSOLATION CORRELATION		

TABLE 3.2–1. AVERAGE DAILY TOTAL HORIZONTAL AND DIRECT NORMAL INSOLATION FOR SELECTED WEEKS

As data becomes available from the Shenandoah, Georgia, site or more accurate correlations are determined, the collector performance analyses of Subsection 3.2.2 should be updated.

A comparison of the direct insolation incident on various collector apertures for the four typical weeks is given in Table 3.2–2. The four collectors referred to in the table are:

(1) Two-dimensionally tracked aperture whose normal always points toward the sun.

(2) One-dimensionally tracked aperture which rotates about a horizontal east-west axis.

(3) One-dimensionally tracked aperture which rotates about a horizontal north-south axis.

(4) One-dimensionally tracked aperture which rotates about a line that is parallel to the earth's axis. This collector is also referred to as north-south polar and differs from collector NO. 3 only in the tilt of the axis equal to the latitude.

The results presented are for no shading of the apertures by other adjacent collectors or objects and do not take into consideration the inherent efficiencies of any particular collector. Table 3.2–2 shows that the incident insolation of a north-south polar orientation approaches a two-axis tracker and that a north-south horizontal tracker is capable of collecting more energy than an east-west horizontal tracker.

3.2.2 COLLECTOR SUBSYSTEM

Collector candidates were limited to one- and two-axis tracking concentrating distributed systems. Flat plate collectors were not considered because the temperature requirements are beyond the range of efficient energy collection. Although the performance of a small central receiver appears attractive, this collector concept was also not considered for the STE/LSE because it cannot meet the objective of attaining a realistic and attainable conceptual design with minimum technical and schedule risk.

The distributed collector concepts evaluated for the STE/LSE included the parabolic trough, segmented mirror (SLATS), and fresnel lens (linear and rotating array). Performance data for these collectors were obtained from the open literature or directly from the component designer. The performance of the parabolic trough and linear fresnel lens collectors were based on experimental field data for prototype designs. An improvement in performance of the fresnel lens concept is predicted for the rotating array arrangement. The improvement in performance resulted from a reduced surface area absorber, greater tracking capability and less shadowing losses. Experimental performance data for a prototype high temperature [>204°C (400°F)] SLATS collector is not available. Therefore, a performance range has been used to evaluate the SLATS collector.

	KW-HR/M^2/DAY			
	TWO-AXIS TRACKER	ONE-AXIS TRACKERS		
		EW	NS	NS POLAR
JANUARY	2.60	2.18	1.77	2.42
APRIL	6.18	4.32	5.81	6.15
JULY	5.25	3.81	5.17	4.89
OCTOBER	4.53	3.38	3.74	4.46
ANNUAL	4.64	3.42	4.12	4.48

NOTES: NO SHADING

DAILY INSOLATION BASED ON CURVE FIT OF HOURLY VALUES

TABLE 3.2–2. COMPARISON OF DIRECT INSOLATION INCIDENT ON VARIOUS COLLECTOR APERTURES

The upper limit of this range is based on the predicted performance given by Sheldahl. The basis of the Sheldahl empirical optical/thermal coefficients are subcomponent laboratory tests rather than system field tests. Primary reason for the difference between the Sheldahl predicted optical factor of 0.71 and the experimental parabolic trough optical factor of 0.60 is the reflectivity. Nonlaboratory conditions would likely reduce the SLATS reflectivity. To lessen the technical risk of the SLATS concept, the lower limit of the performance range has been assumed to be defined by an optical factor of 0.60.

Point performance at reference conditions, i.e., at 1,000 watts/M^2 (317 BTU/HR/SQ-FT) and solar incidence factor equal to unity, for the collector concepts investigated is shown in Figures 3.2–1 and 3.2–2. The performance characteristics used for the analysis of the parabolic trough are indicated by the solid curve of Figure 3.2–1. This curve represents test results for both the Sandia and University of Minnesota/Honeywell (M/H) parabolic troughs. Both the Sandia and M/H designs have a selectively coated absorber tube with a vacuum glass jacket to eliminate convection losses. The Sandia and M/H performance curve lies near the middle of the predicted performance of other commercially available parabolic troughs. Nonevacuated receivers have greater heat losses than evacuated receivers and thus exhibit a faster reduction in efficiency with increasing temperature.

An important test of a one-axis tracking collector's efficiency is not the instantaneous efficiency at solar noon, but rather the all-day efficiency curve. In addition to the conventional incidence (cosine) loss, a further reduction in efficiency of the one-axis tracking parabolic trough occurs during the day as a result of shadowing obstructions due to structural elements and end losses due to reflected light rays that either impact the trough end or miss the absorber tube. Based on experimental data for the M/H test unit (Figure 3.2–3), the reduction in optical factor during the day was accounted for by the correction factor

$$F(\alpha) = 1\text{-}0.23 \tan\alpha) \cos\alpha$$

where α is the sun-trough angle.

This correction factor was assumed to be independent of collector orientation although polar-mounted troughs will probably experience greater end losses throughout most of the year.

The predicted diurnal optical efficiencies of the SLATS collector for the four seasons are given in Figure 3.2–4. To utilize these curves for specific days in the year, these losses were approximated by a correlation similar to the parabolic trough and given by the relation

$$F(\alpha) = (1\text{-}0.10 \tan\alpha) \cos\alpha.$$

The *predicted* reduction in optical factor of the SLATS collector is less than the *actual* reduction experienced by the parabolic troughs.

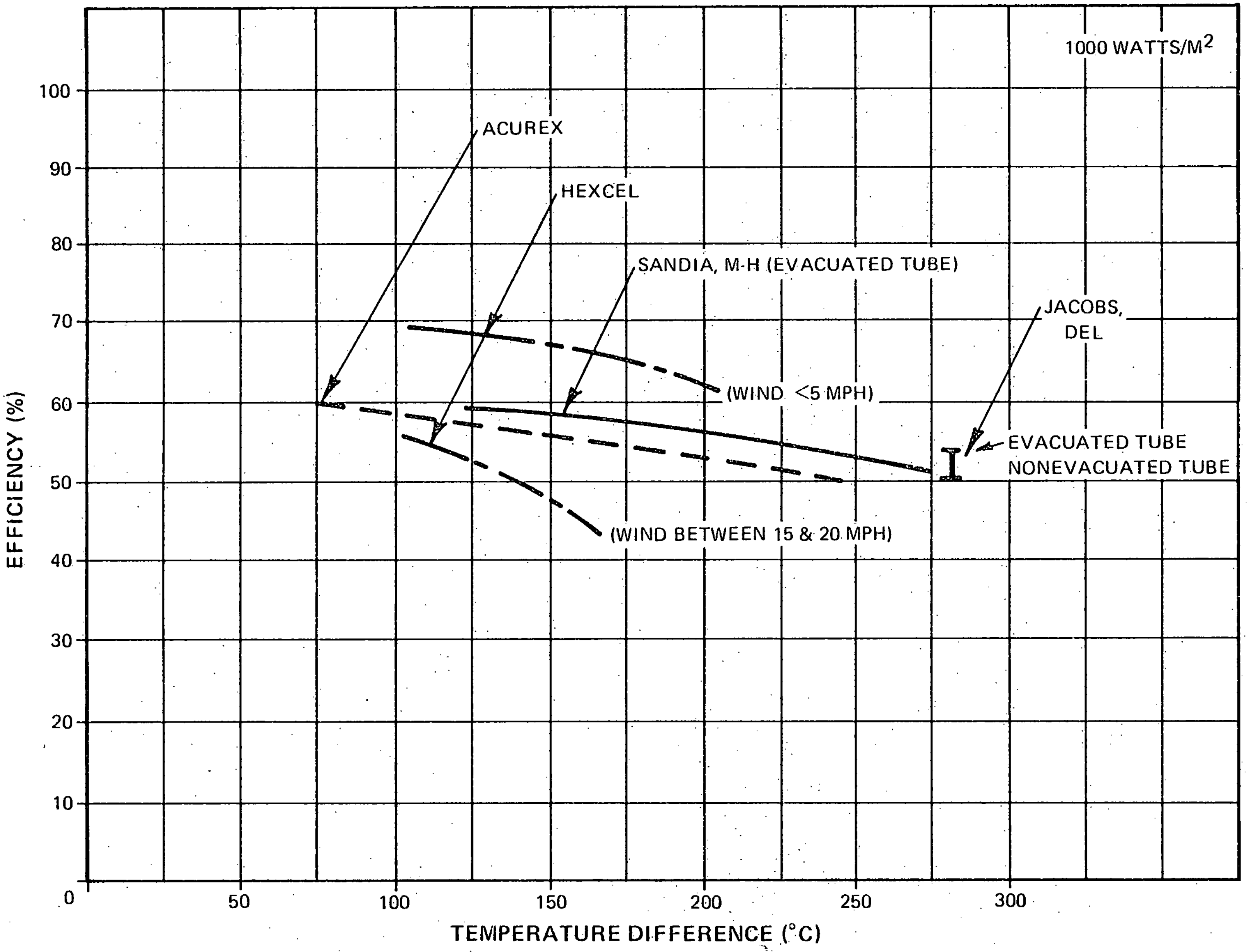


FIGURE 3.2–1. COMPARISON OF PARABOLIC TROUGH EFFICIENCIES

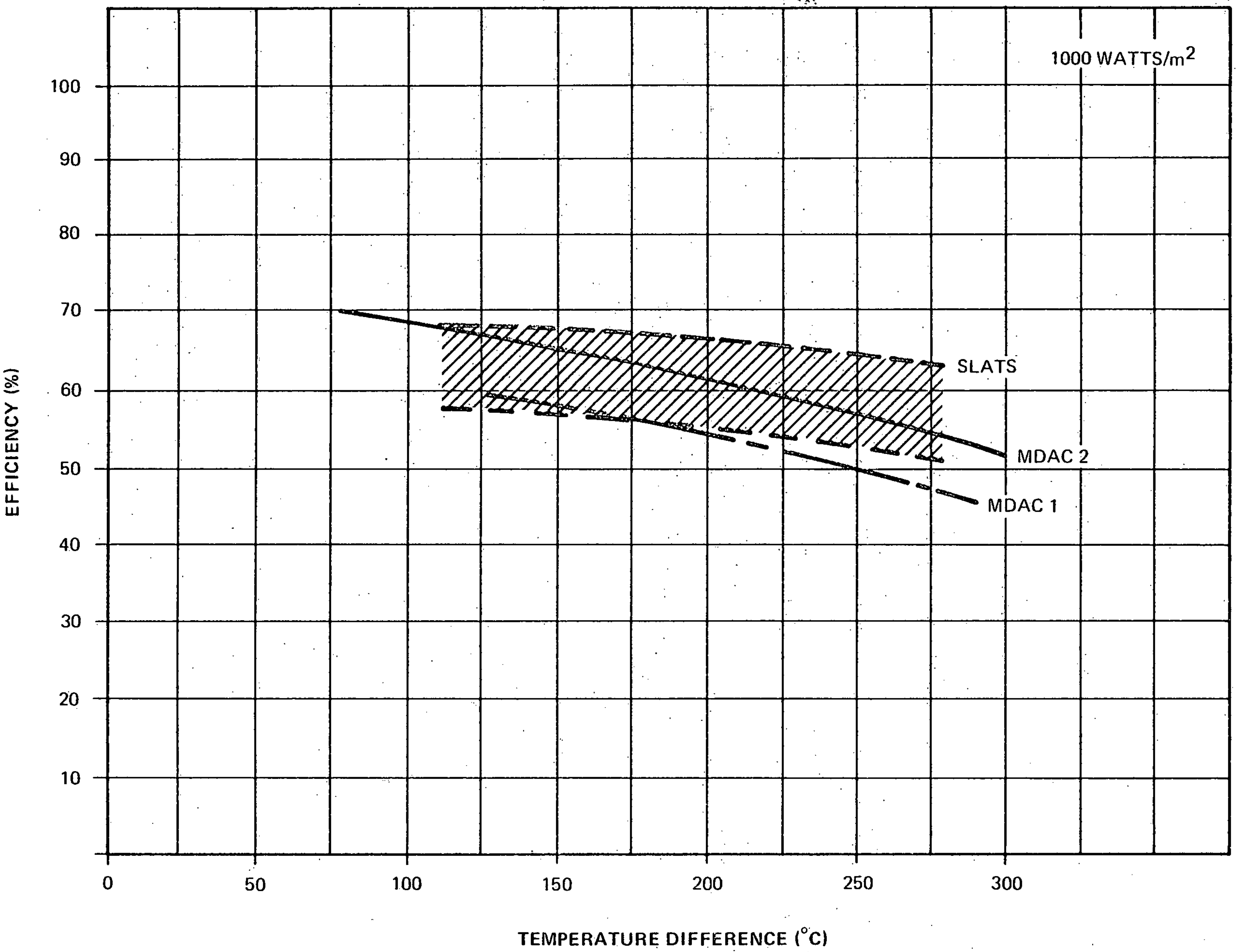
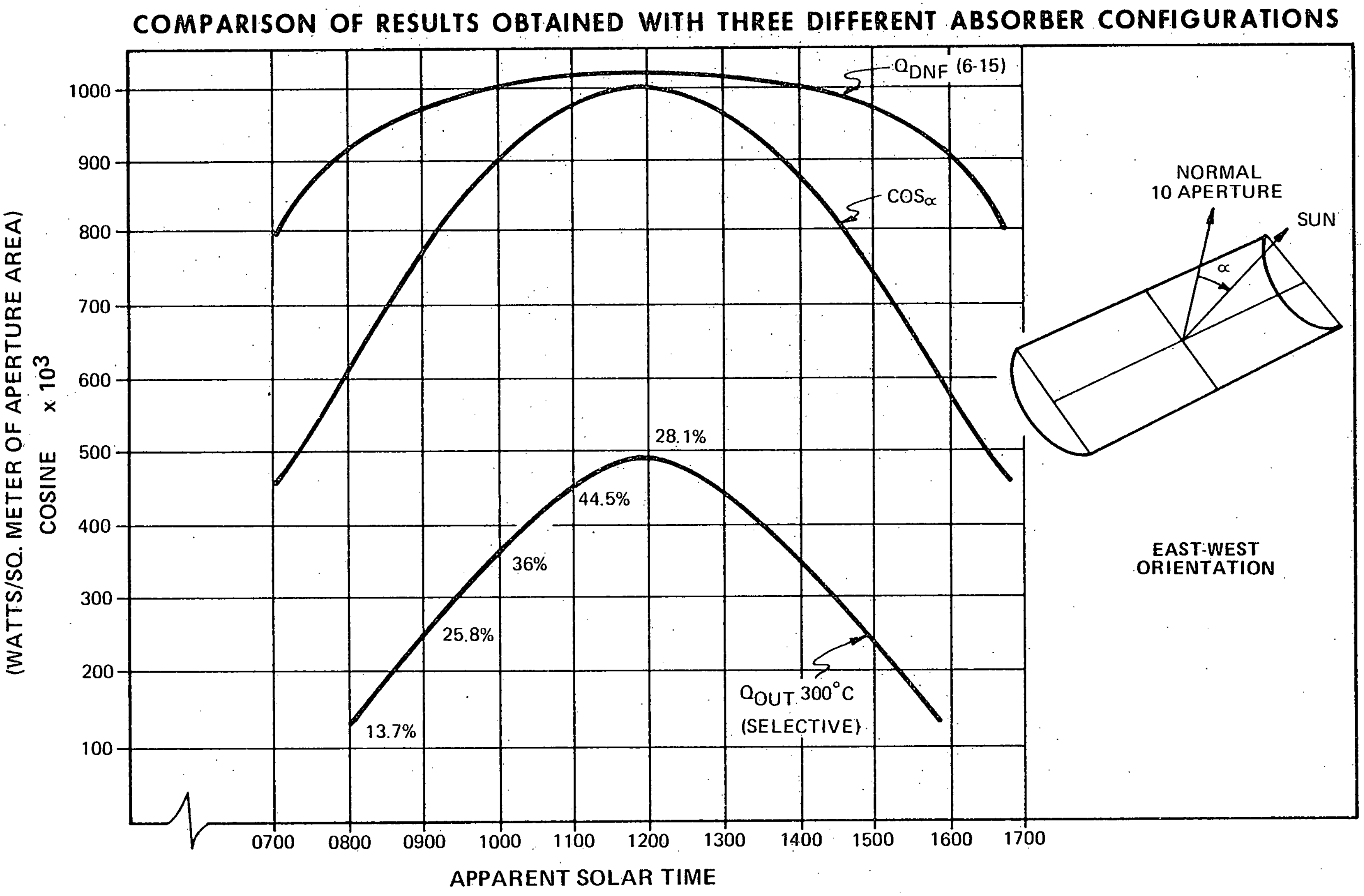


FIGURE 3.2–2. COLLECTOR EFFICIENCIES



COMPARISON OF RESULTS OBTAINED WITH THREE DIFFERENT ABSORBER CONFIGURATIONS

FIGURE 3.2–3. DAILY PERFORMANCE OF PARABOLIC TROUGH

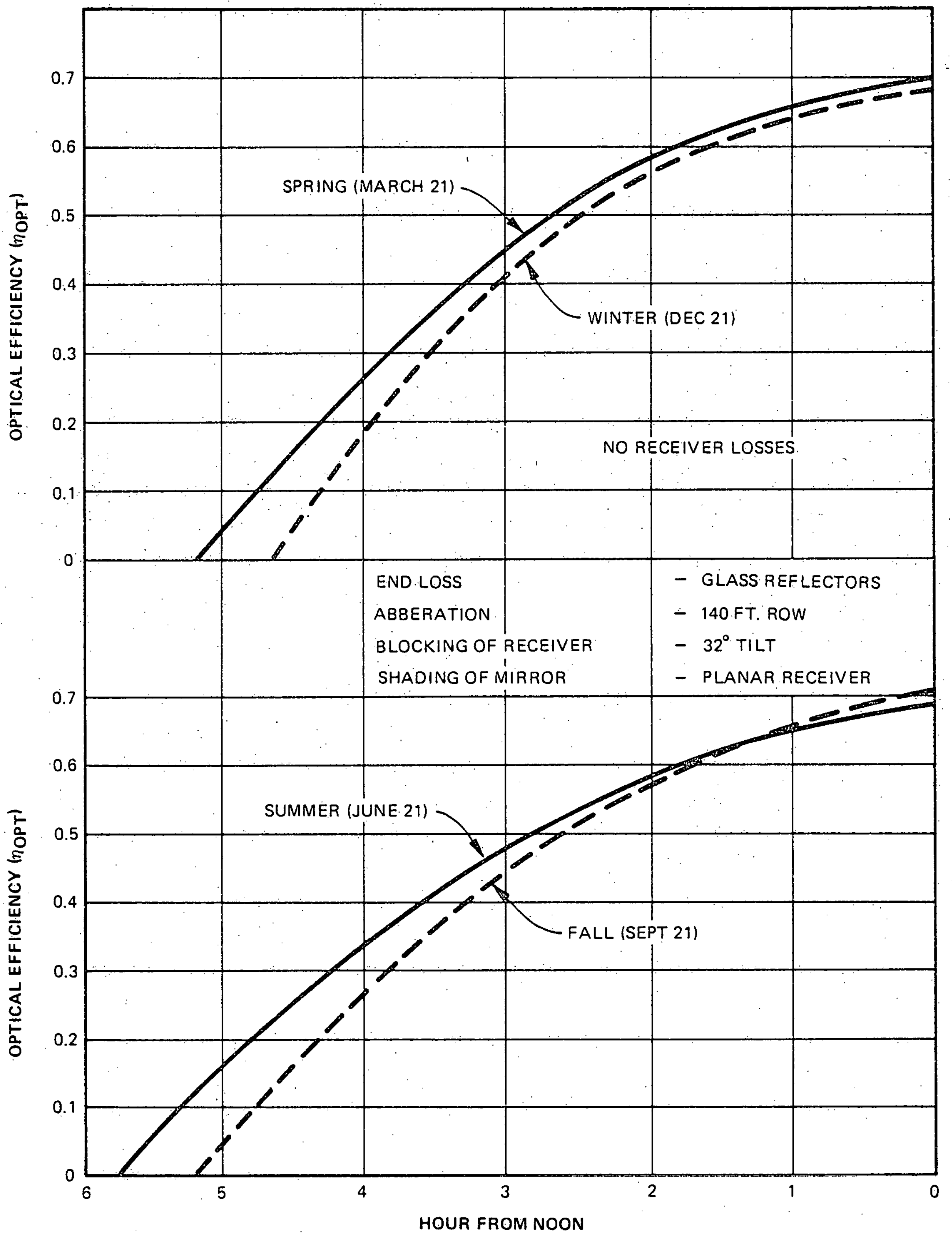


FIGURE 3.2–4. SLATS OPTICAL EFFICIENCY AS A FUNCTION OF TIME

Experimental performance of the N-S oriented two-axis tracking linear fresnel lens is denoted as "MDAC 1" in Figure 3.2–2. The test collector utilized a prototype lens with a number of optical deficiencies caused by manufacturing problems which reduced the expected optical transmission. Commercial units are expected to achieve a transmission factor of 0.84 and the experimental performance has been adjusted to reflect the projected performance. The prototype linear fresnel lens collector is limited to a tracking capability from 0 to 70 degrees in the north-south plane (horizontal to collector axis). This angle limitation prevents collection during the summer solstice between sunrise and approximately 8 hours and between 16 hours and sunset.

The rotating array fresnel lens tracks in an azimuth-elevation mode and provides full tracking capability. Predicted performance of the rotating array, denoted as "MDAC 2" in Figure 3.2–2, differs from the projected performance of the linear unit. This difference is due to the smaller diameter absorber tube used in the rotating array without any reduction in optical efficiency.

The discussion of collector performance up to this point has been applicable to individual units. In a distributed collector field, thermal losses from the piping network, shading losses by adjacent collectors, and losses due to tracking limitations must be included. The thermal losses from the piping network consists of losses from the plumbing lines interconnecting the individual collectors and from plumbing mainlines which transport the heat transfer fluid to and from groups of collectors to the energy storage or utilization point.

Collector spacing was determined from a trade study conducted in the Industrial Applications of Solar Total Energy Project. The trade study was performed for the two-axis tracking linear fresnel lens collector and determined the effect of collector spacing on performance for various locations in the United States. The reduction in the annual energy collected as the land area is reduced is shown in Figure 3.2–5. Collector spacing was reduced from the essentially no-shadowing condition (ground cover ratio of 0.2) by an equal percentage in the east-west and north-south directions and the external pipe lengths were reduced in each case to correspond to the closer collector spacing. The rate of increase in the reduction in annual energy collection is small initially, because the sun's intensity is low around sunrise and sunset and collector efficiency is low at low intensities. On a seasonal basis, the greatest reduction in collected energy occurs during the winter season and the reduction is minimized during the summer season. As shown in Figure 3.2–5, the rate of increase in the reduction of annual energy collection is small until the reduction in land area exceeds 40 percent. A reduction in area of 40 percent (corresponding to a ground cover ratio of 0.33) produced approximately a 5-percent reduction in energy collection for latitudes around 33 degrees. This reduced collector spacing produced no shading of the collectors at the 33-degree latitude location by 10 solar time during the winter solstice. This no-shading time was used to set the distributed collector spacing at the STE/LSE facility. With this criterion, the two-axis tracking linear fresnel lens collector was set at a ground cover ratio of 0.313 and the east-west-oriented one-axis tracking collector at 0.464.

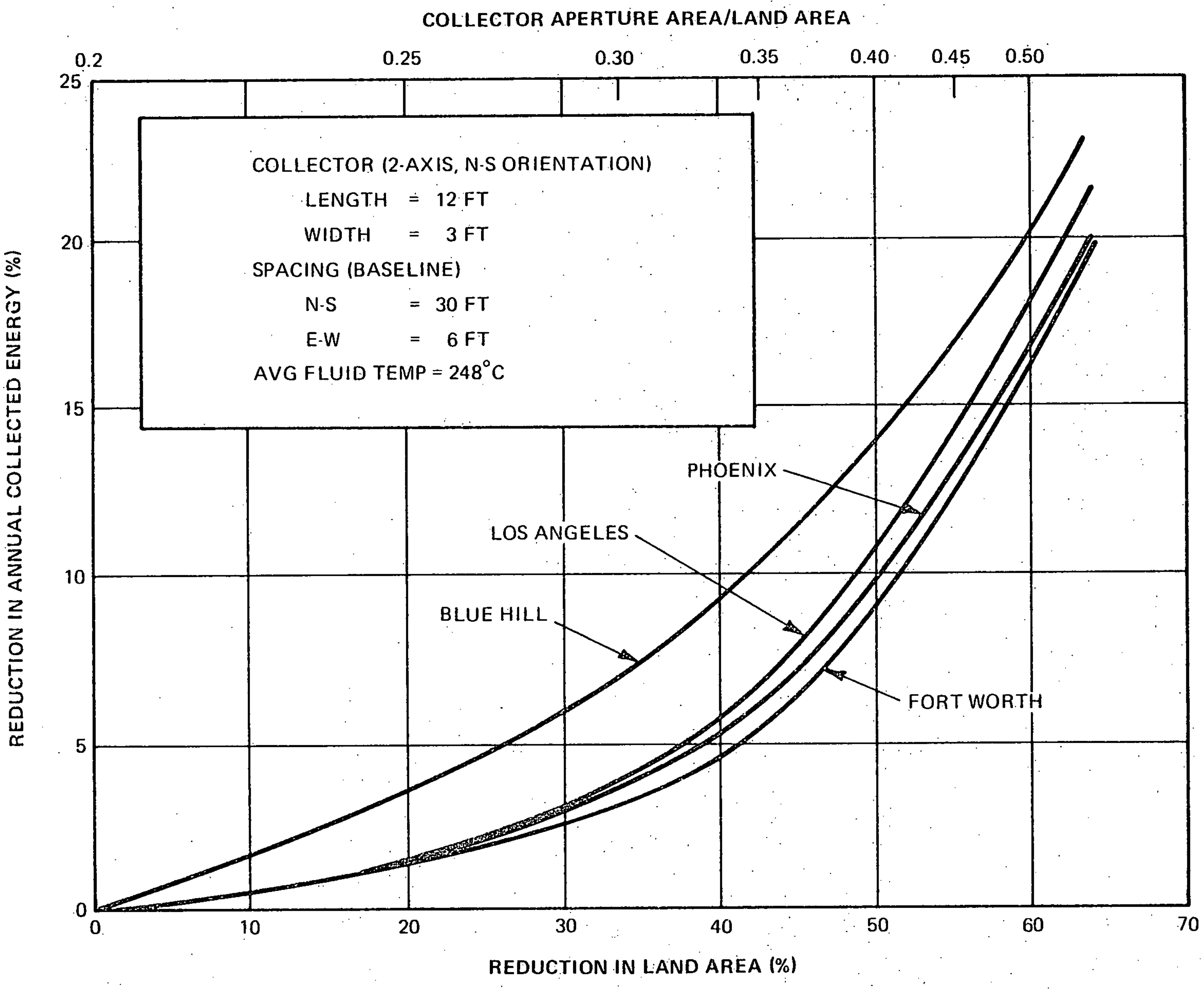


FIGURE 3.2–5. EFFECT OF COLLECTOR SPACING ON PERFORMANCE

Although time did not permit the evalution of closer spacing for the east-west orientation, a greater packing density may be more cost effective because relatively small amounts of energy are collected in the morning and evening periods due to significant cosine losses. This is not true for a north-south orientation because cosine losses are generally not as great in the morning and evening periods.

Table 3.2–3 lists the orientations, tracking modes, and ground cover ratios analyzed for the various collector concepts. Except for the fresnel lens rotating array collector, all candidate collectors were evaluated at a common ground cover ratio of 0.464 for comparative purposes. Physical dimensions and tracking mode of the fresnel lens rotating array limited the ground cover ratio to 0.353.

Using the insolation data specified by Sandia and the collector point performance and spacing previously discussed, steady state seasonal and annual performance analyses were determined for the candidate collectors. Interconnecting pipe sizes and lengths were estimated for every collector configuration. Calculations were performed for average collector fluid temperatures between 248° and 361°C (478° and 682°F). Typical clear-day-collected energy/aperture area profiles for the parabolic trough is shown in Figures 3.2–6 (winter day) and Figure 3.2–7 (summer day). The effect of the low incidence factor for the north-south-oriented horizontal parabolic trough during the winter is quite apparent. However, during the summer the N-S horizontal incidence factor is nearly unity for a large portion of the day and is reflected in the energy collection curve of Figure 3.2–7. The effect of orientation on seasonal parabolic trough performance (per unit aperture area) is illustrated in Figure 3.2–8. Note that the performance is shown for an average fluid temperature of 248°C (478°F) and a common ground cover ratio of 0.464. North-south-oriented parabolic troughs typically collect more energy than an east-west orientation on an annual basis, but the variation in output from summer to winter is minimized with the east-west orientation. For a given shadow loss, the polar-mounted north-south orientation maximizes the collector output for a parabolic trough collector. On an equal land utilization basis (GCR = 0.464), the annual energy collection of a horizontal north-south collector is greater than north-south collectors tilted at the latitude angle because of less shading and less piping. Since the land available for the STE/LSE is not sufficient to meet the demand, the north-south horizontal orientation maximizes the annual displacement for a parabolic trough.

Average annual collector field output is shown in Figure 3.2–9 for the north-south horizontal parabolic trough, SLATS, and fresnel lens collectors. The SLATS performance using the Sheldahl predictions is considered optimistic and would be similar to the performance obtained with an east-west parabolic trough with projected improvements in mirror reflectance and glass transmission. Collector state-of-the-art performance is represented by the north-south horizontal parabolic trough, SLATS reduced optical factor, and rotating array fresnel lens curves of Figure 3.2–9. Performance differences between the three state-of-the-art curves are small; therefore, the baseline selection of the north-south parabolic trough was made on a minimum technical and cost risk basis.

CONCEPT	GROUND COVER RATIO	ORIENTATION	TRACKING
PARABOLIC TROUGH	.464	E-W	1-AXIS
	.464	N-S HORIZONTAL	1-AXIS
	.313	N-S POLAR	1-AXIS
	.464	N-S POLAR	1-AXIS
LINEAR FRESNEL LENS	.313	N-S	2-AXIS
	.464	N-S	2-AXIS
SLATS	.464	E-W (33.6^{o} TILT)	1-AXIS
ROTATING ARRAY	.313	AZIMUTH-ELEVATION	2-AXIS
FRESNEL LENS	.353	AZIMUTH-ELEVATION	2-AXIS

TABLE 3.2–3. CANDIDATE COLLECTOR CONCEPTS DATA

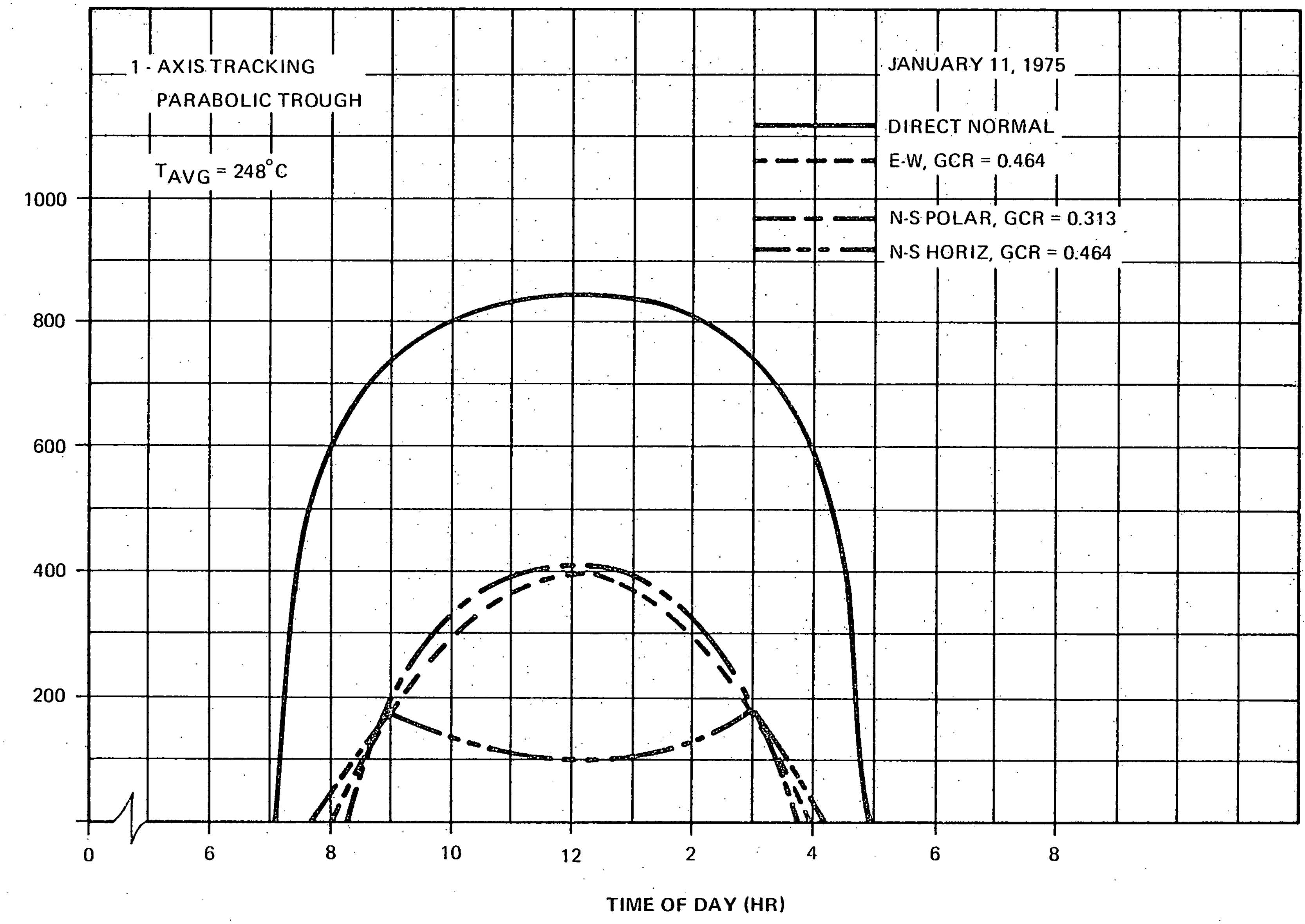


FIGURE 3.2–6. PARABOLIC TROUGH PERFORMANCE, JANUARY 11, 1975

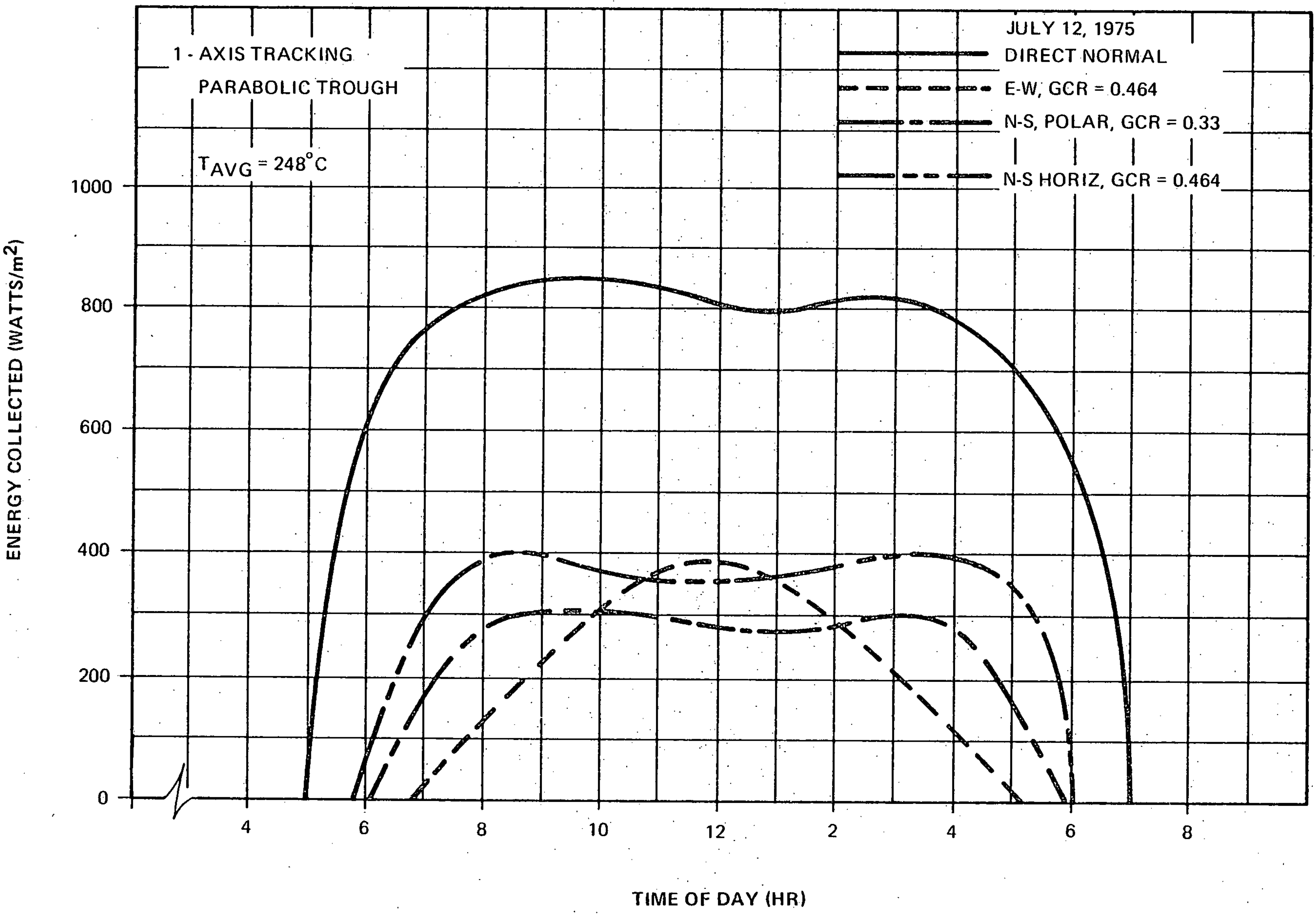


FIGURE 3.2–7. PARABOLIC TROUGH PERFORMANCE, JULY 12, 1975

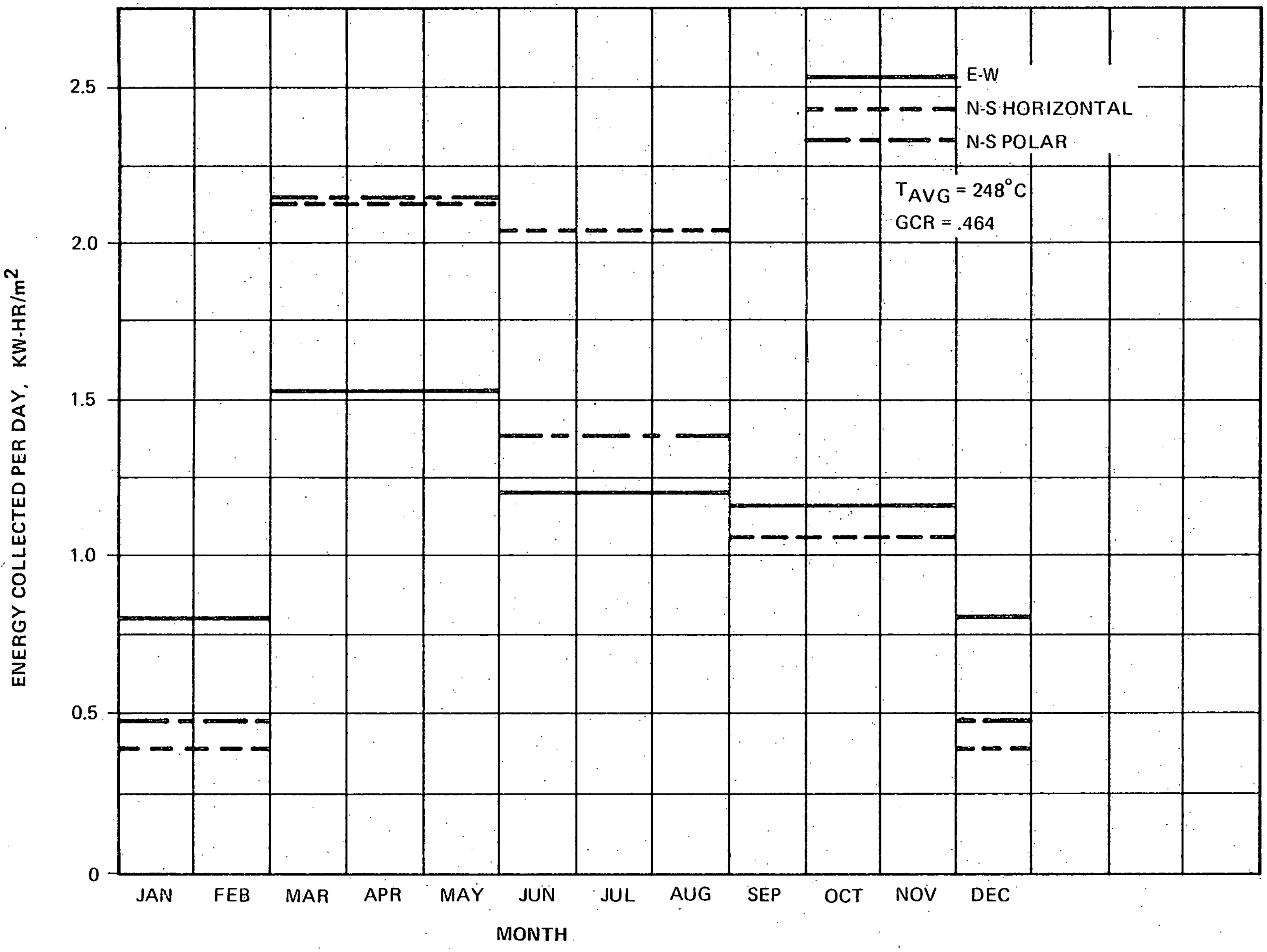


FIGURE 3.2–8. EFFECT OF ORIENTATION ON SEASONAL PARABOLIC TROUGH PERFORMANCE

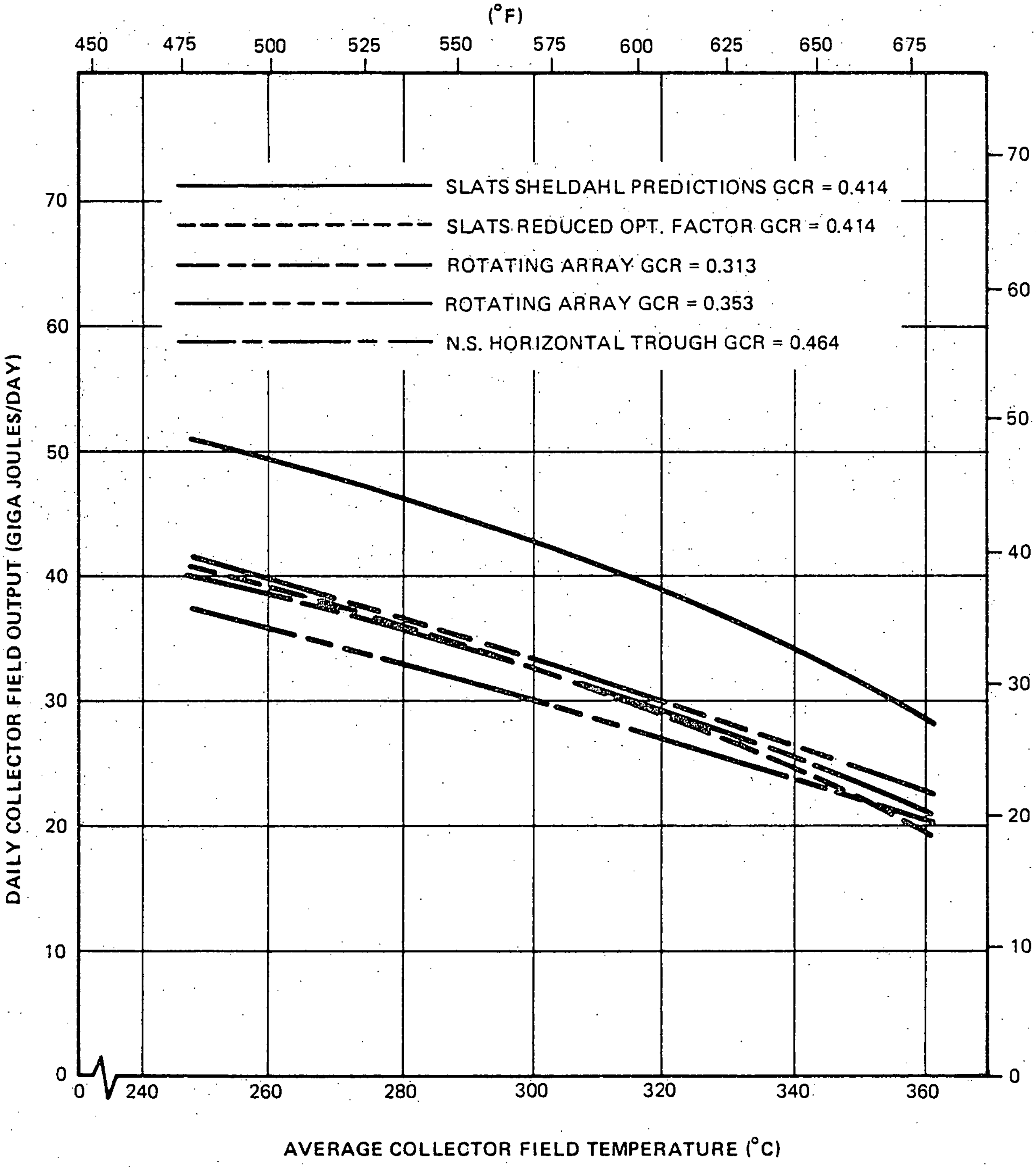


FIGURE 3.2–9. AVERAGE ANNUAL COLLECTOR FIELD PERFORMANCE

The design of the fluid flow system for the collector field consisted of: (1) calculating the required mass flow rate as a function of the number of collectors in a flow loop, (2) using these mass flow rates to calculate the pressure loss across a flow loop as a function of the number of collectors in a flow loop, (3) selecting the number of collectors to be placed in a flow loop, (4) dividing the collector field into flow loops, (5) locating feed lines to supply fluid to each of these flow loops, (6) sizing these feed lines, and (7) sizing the insulation for these feed lines. The field design conditions used are shown in Table 3.2–4.

The mass flow rate required was obtained from:

$$\dot{m} = \frac{N E_c}{C_p \Delta T}$$

where $\dot{m}$ is the mass flow rate, N is the number of collectors in a flow loop, E_c is the field design energy collection rate per collector, Cp is the specific heat at the average field fluid temperature, and ΔT is the desired fluid temperature increase across the fluid loop. The pressure loss in the absorber portion of the flow loop was obtained by equations taken from Sandia Laboratories work.* The pressure loss in the connecting piping was obtained with a pressure loss relationship obtained from Monsanto Therminol-66 data. The resulting total pressure loss per collector provided a range of acceptable numbers of collectors per flow loop. This was then used with field dimension constraints to select the number of collectors in a flow loop.

The feed lines, which feed several flow loops in parallel, were sized so that the pressure loss across the fluid loops did not differ by more than three percent. This was done to ensure a uniform fluid temperature increase across each of the fluid loops. The insulation thicknesses were obtained from insulation cost versus energy loss value tradeoffs.

3.2.3 POWER CONVERSION SYSTEM

The power conversion conceptual design configuration and operating parameters were determined from a series of trade studies conducted to maximize the overall system (power conversion, collector, and storage) performance.

3.2.3.1 SYSTEM CONFIGURATION

The preliminary loads used for these trade studies are shown in Table 3.2–5. These loads have been upgraded for use in the actual conceptual design, but the differences do not change the results of the trade studies.

The low ratios of process heat to electrical generation dictates that the system must operate at as high an efficiency (η_c) as possible for a given turbine inlet

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*M.W. Edenburn, *et al.*, *Energy System Simulation Computer Program - Subsystem*, Sandia Laboratories - Albuquerque Report SAND 75-0048, June 1975.

COLLECTOR

Type : Parabolic trough
Dimendions : 2.74 M x 3.66 M (9' wide x 12' long)
Tracking : One-axis
Orientation : North-South
No elevation (parallel to ground)
Absorber : Circular tube .0429 M (1.688") O.D.
.0396 M (1.5575") I.D.
Circular plug .0317 M (1.25") O.D.

FLUID

Therminol 66

DESIGN OPERATING CONDITIONS

Average fluid temperature in field: 277°C (530°F)
Fluid temperature increase across field: 125°C (225°F)
Energy collection rate: 12,960 BTU/HR-collector (3,797 watts/collector)

TABLE 3.2–4. FIELD DESIGN CONDITIONS

	JANUARY	APRIL	JULY	OCTOBER
ELECTRICAL	383.4 KW	383.4 KW	383.4 KW	383.4 KW
NIGHT HEATING	30.82 KW (105,195 BTU/HR)	10.15 KW (34,650 BTU/HR)	0	16.07 KW (54,850 BTU/HR)
AIR CONDITIONING	0	123.07 KW_t(35 TONS)	758.72 KW_t(215.78 TONS)	170.34 KW_t(48.44 TONS)
PROCESS STEAM	665.16 KW_t(2.27X10^6) BTU/HR)	665.16 KW_t(2.27X10^6 BTU/HR)	665.16 KW_t(2.27X10^6 BTU/HR)	665.16 KW_t(2.27X10^6 BTU/HR)

TABLE 3.2–5. DESIGN SIZING LOADS

temperature if the required electrical load is to be satisfied with minimum heat being thrown away. The process steam temperature of 169°C (337°F) requires a 177°C (350°F) condensing temperature, while the night heating and absorption refrigeration, 90°C (195°F), can condense the toluene at 93°C (200°F). For maximum system efficiency this dictates a two-stage turbine with a port between stages to extract the toluene used to generate the process steam. The outlet of the second stage can be used to furnish heat for the absorption refrigeration system, condensing at 93°C (200°F) when refrigeration is required or at 52°C (125°F) if not required. Heat is rejected to allow the system to meet the electrical load requirements. The general schematic for this configuration is shown in Figure 3.2–10.

3.2.3.2 VAPOR CYCLE VERSUS ABSORPTION CYCLE

When heat is thrown away in a cascaded Rankine cycle and there is a cooling requirement, a choice can be made between cooling by vapor cycle or absorption refrigeration if using vapor cycle refrigeration allows the condensing temperature to be lowered, thus increasing the cycle efficiency. The increased electrical load attendant with the vapor cycle system must be traded off against the increased cycle efficiency to determine the method resulting in the lowest total power conversion system load. Figure 3.2–11 is a plot of $Q_{COOL}/Q_{SEP\ ELECT}$ as a function of η_{VC}/η_{ABS} for equal system heat inputs, therefore, if $Q_{COOL}/Q_{SEP\ ELECT}$ is above the line, cooling should be by absorption cycle cooling; if below, by vapor cycle. This is reflected in the Figures 3.2–12 through 3.2–15. April's $Q_{COOL}/Q_{ABS} = 0.122$ while the breakeven $Q_{COOL}/Q_{ABS} = 0.57$ for the $\eta_{VC}/\eta_{ABS} = 1.164$ for April. For this case, the actual value of Q_{COOL}/Q_{ABS} falls below the curve so the cooling is done by vapor cycle refrigeration. In July, the actual $Q_{COOL}/Q_{SEP\ ELECT} = 1.98$ and the break even $Q_{COOL}/Q_{SEP\ ELECT} = 0.57$, as in April, so the value of $Q_{COOL}/Q_{SEP\ ELECT}$ falls above the curve and the cooling is done by absorption cycle as in October. April, July, and October are the three seasons with cooling requirements because of the use of the economizer cycle.

3.2.3.3 SYSTEM OPERATING TEMPERATURE OPTIMIZATION

When using toluene as a Rankine cycle working fluid, there is a choice between operating subcritically as in a normal steam system or supercritically, i.e., above the critical pressure and temperature. There is also a choice of turbine inlet temperature: high temperatures give higher power conversion efficiencies, but lower the collector field collection efficiency; conversely, lower turbine inlet temperatures reverse this trend. The field collection efficiency is sensitive to collector average temperature while the power conversion is sensitive to turbine inlet temperature; therefore, the performance of the vaporizer, if subcritical, or heat exchanger, if supercritical, becomes important. Figure 3.2–16 shows the effect of turbine inlet temperature on cycle efficiency. Figure 3.2–17 shows the power system heat input requirements as a function of cycle efficiency. The load drops off at the higher cycle efficiencies because the lower process heat requirements at these higher efficiencies allow more and more cooling to be done with vapor cycle which is more efficient than absorption cycle, reducing the total load.

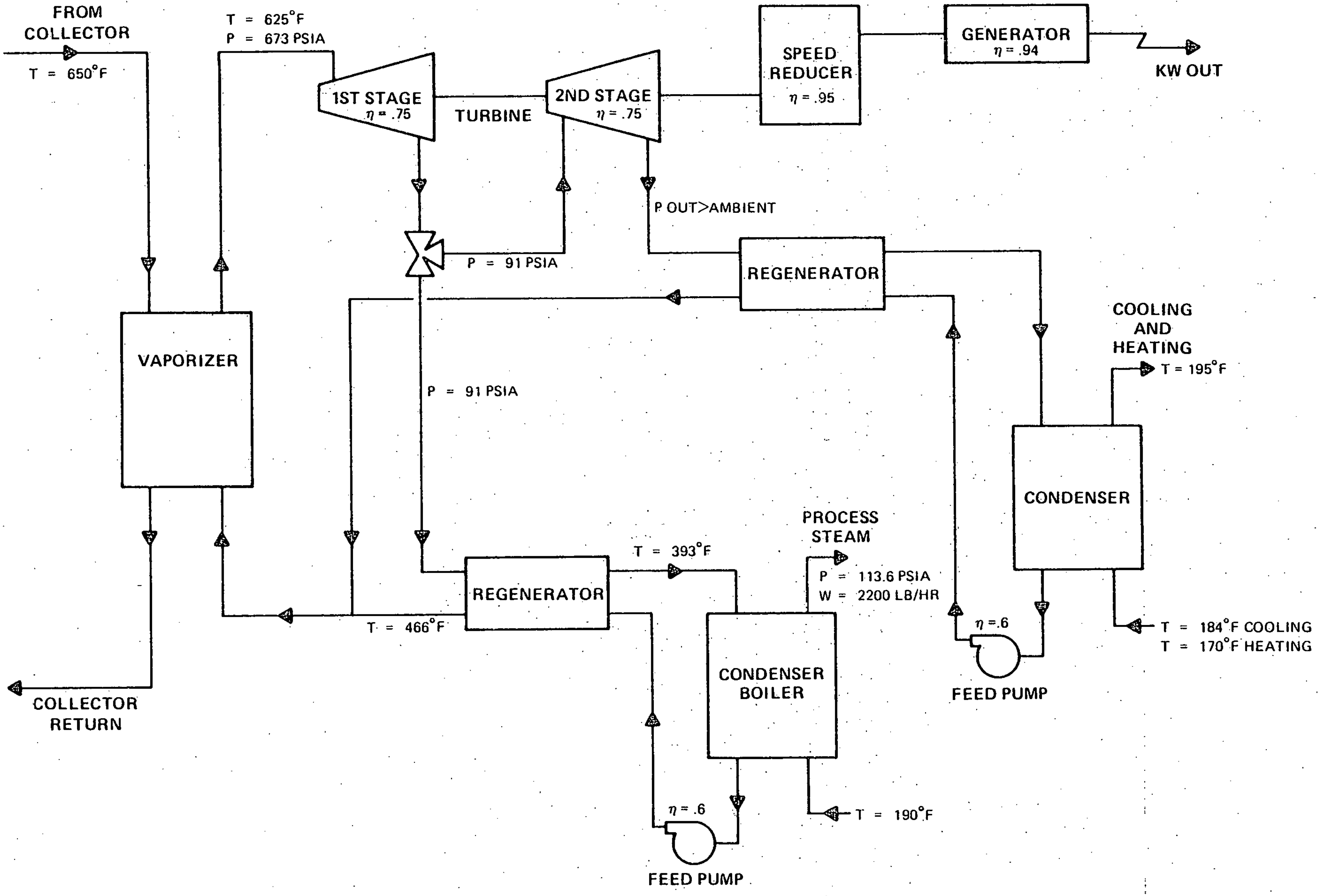

FIGURE 3.2–10. TWO-STAGE TURBINE SUPERCRITICAL TOLUENE SYSTEM - SCHEMATIC FLOW

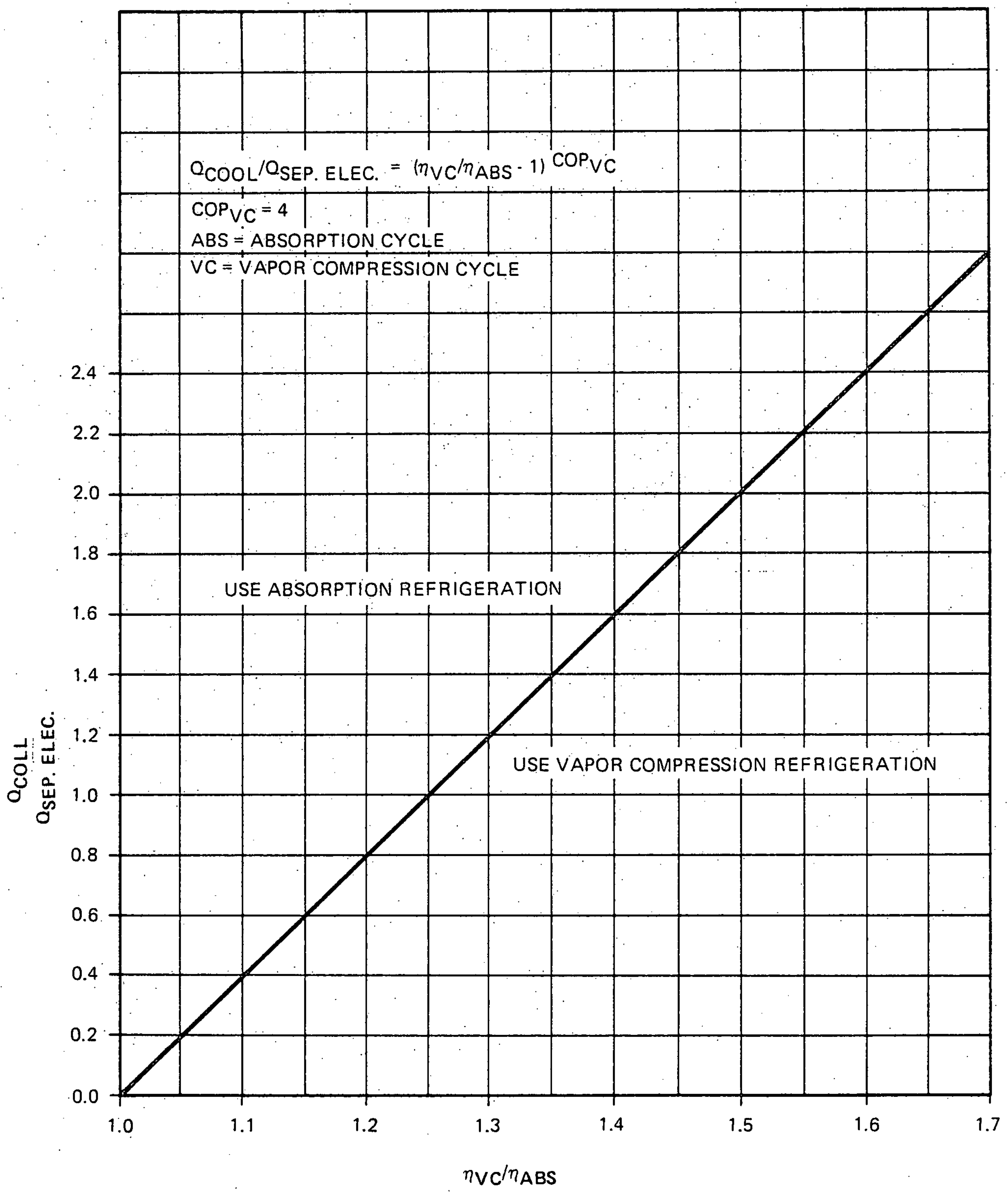

FIGURE 3.2–11. RELATIONSHIP BETWEEN REFRIGERATION CYCLES AND SYSTEM LOADS

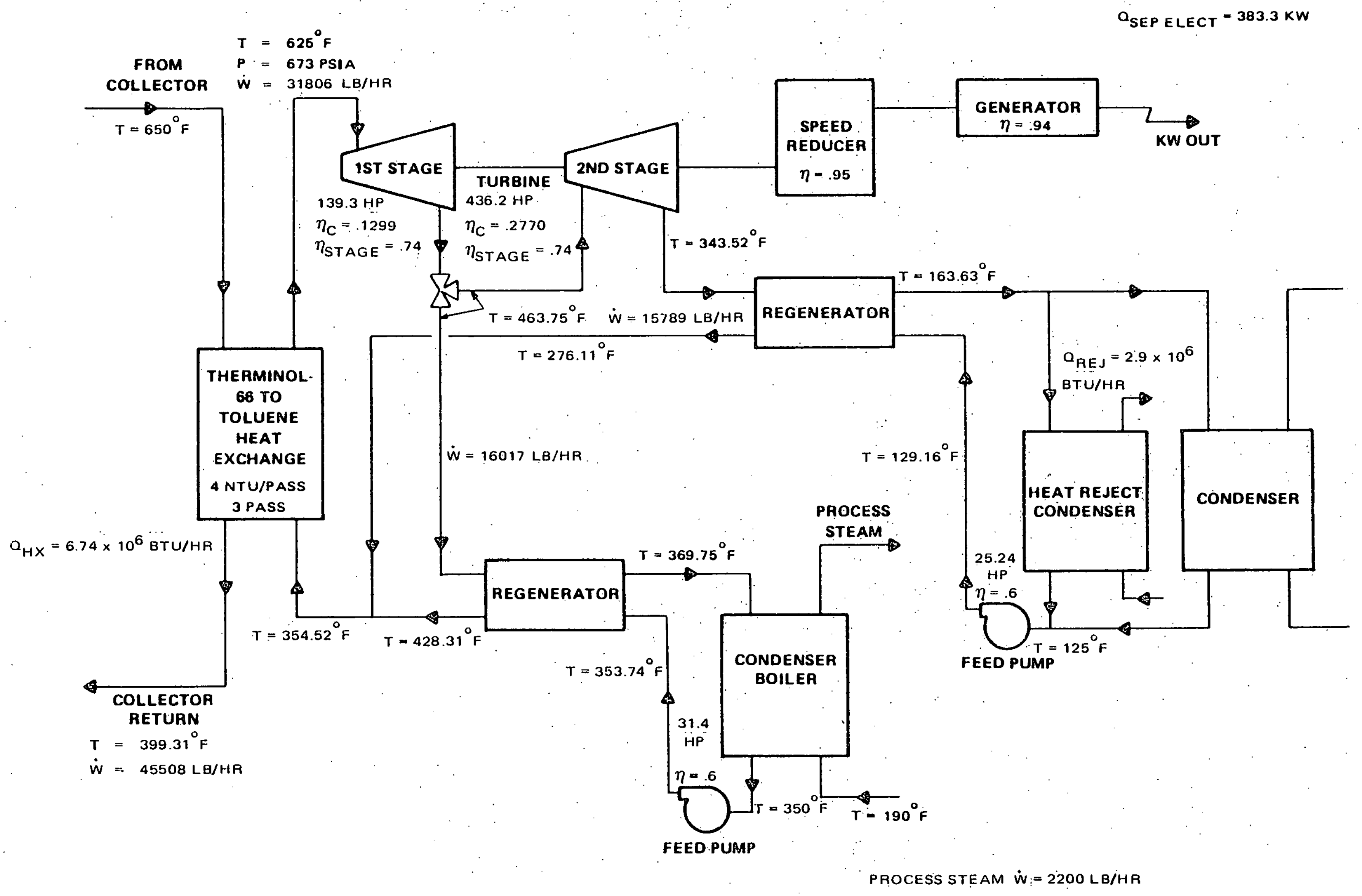

FIGURE 3.2–12. SUPERCRITICAL TOLUENE CYCLE, JANUARY

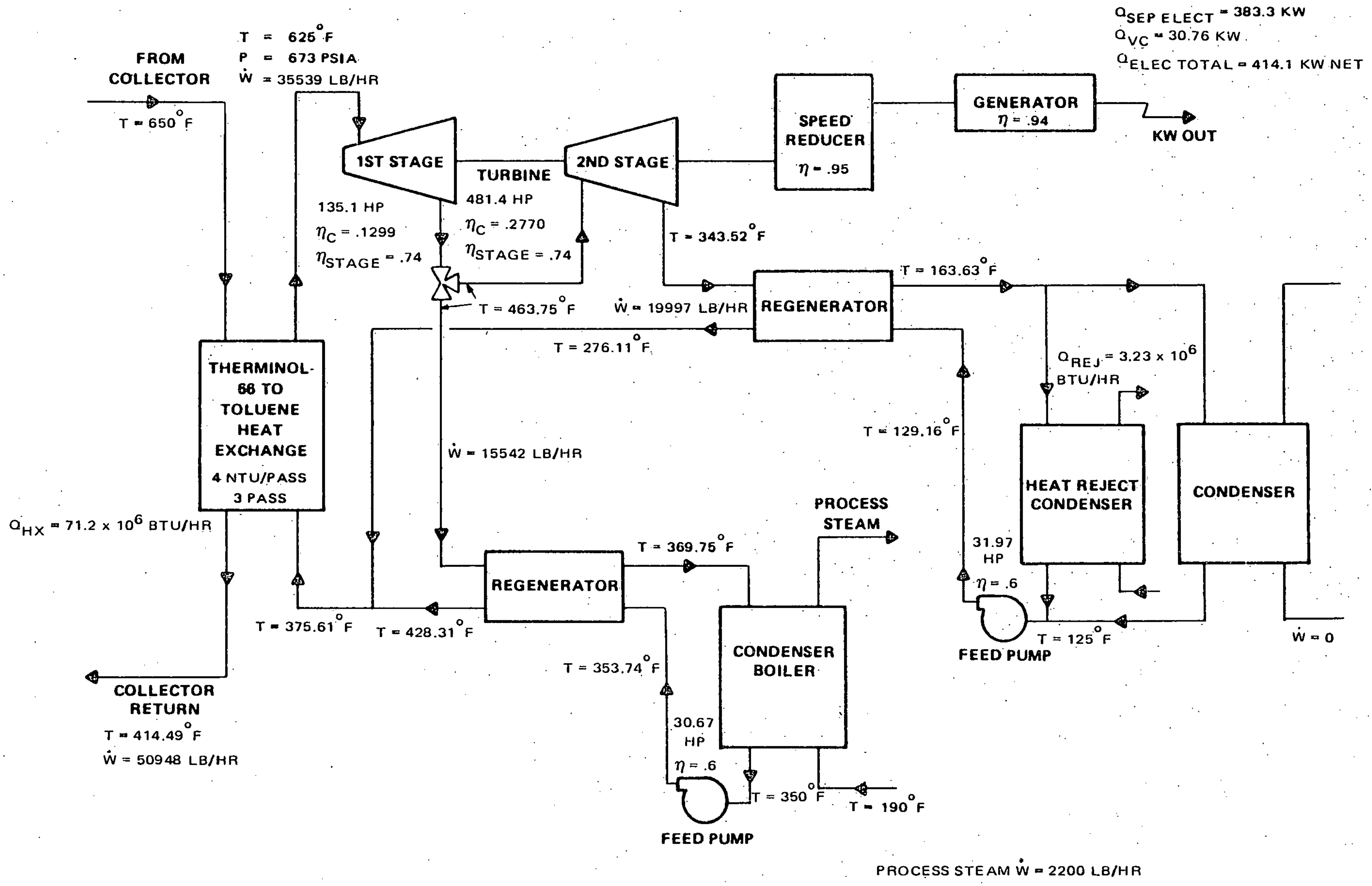

FIGURE 3.2–13. SUPERCRITICAL TOLUENE CYCLE, APRIL

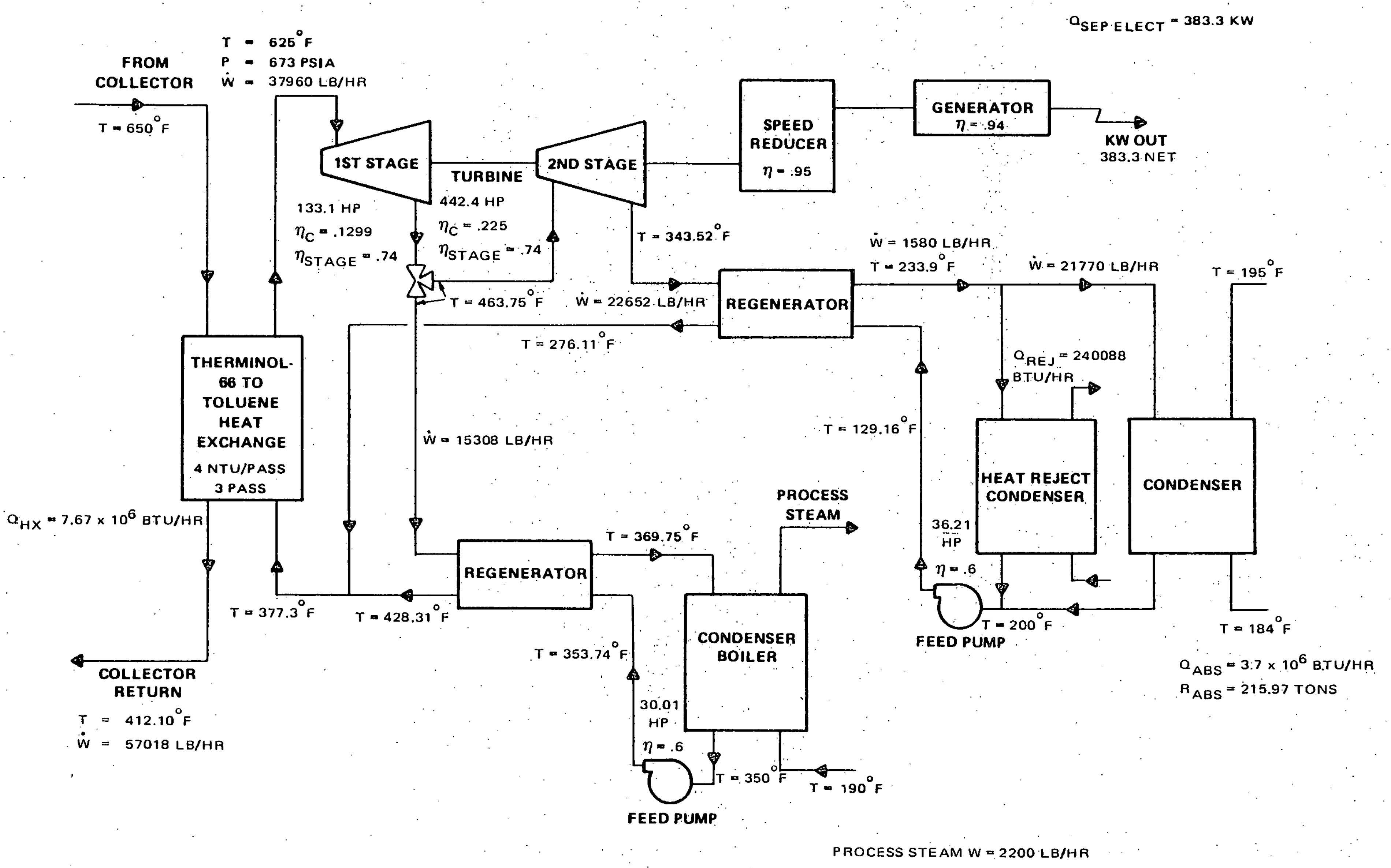

FIGURE 3.2–14. SUPERCRITICAL TOLUENE CYCLE, JULY

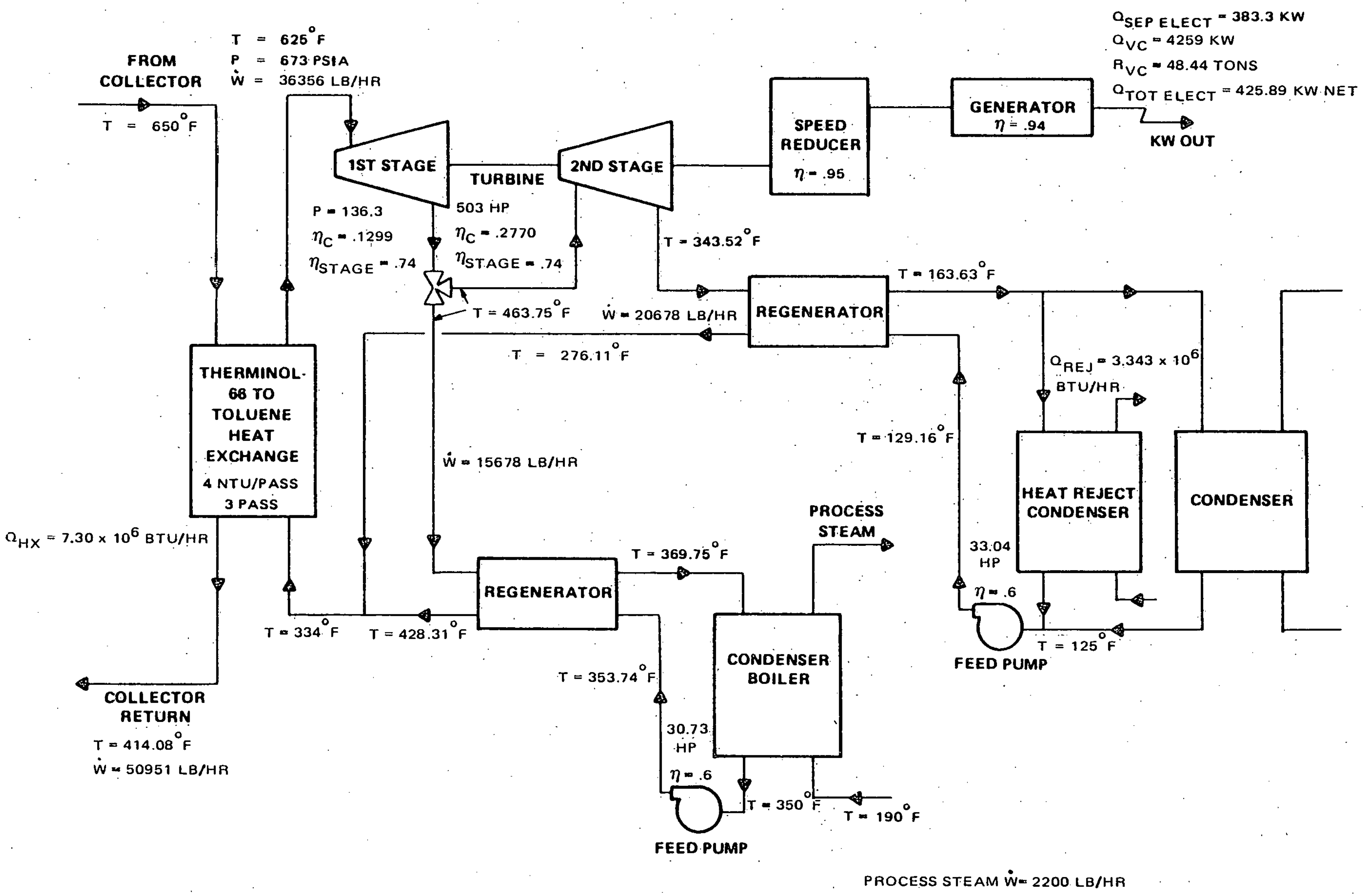

FIGURE 3.2–15. SUPERCRITICAL TOLUENE CYCLE, OCTOBER

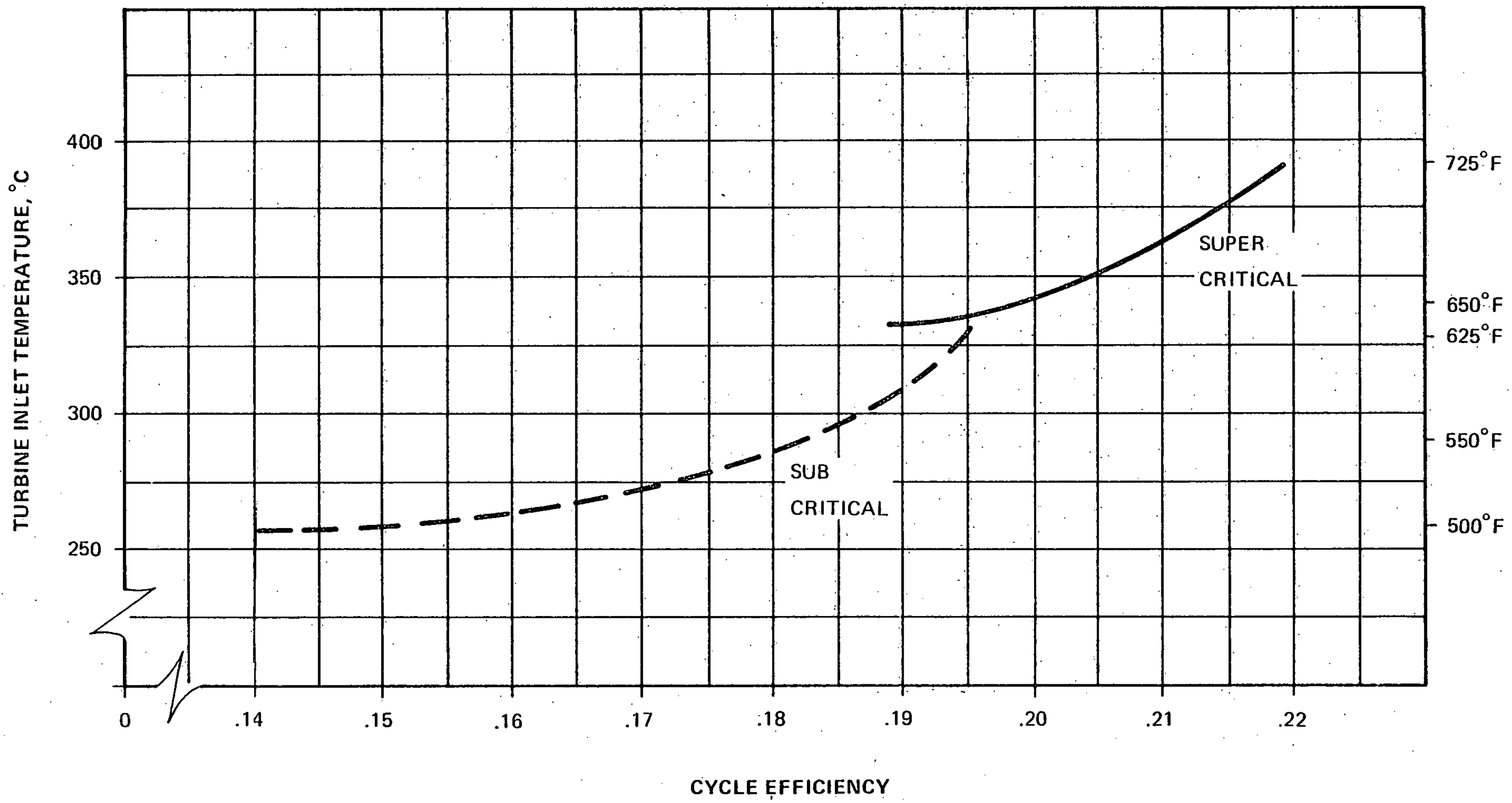

FIGURE 3.2–16. EFFECT OF TURBINE INLET TEMPERATURE ON CYCLE EFFICIENCY

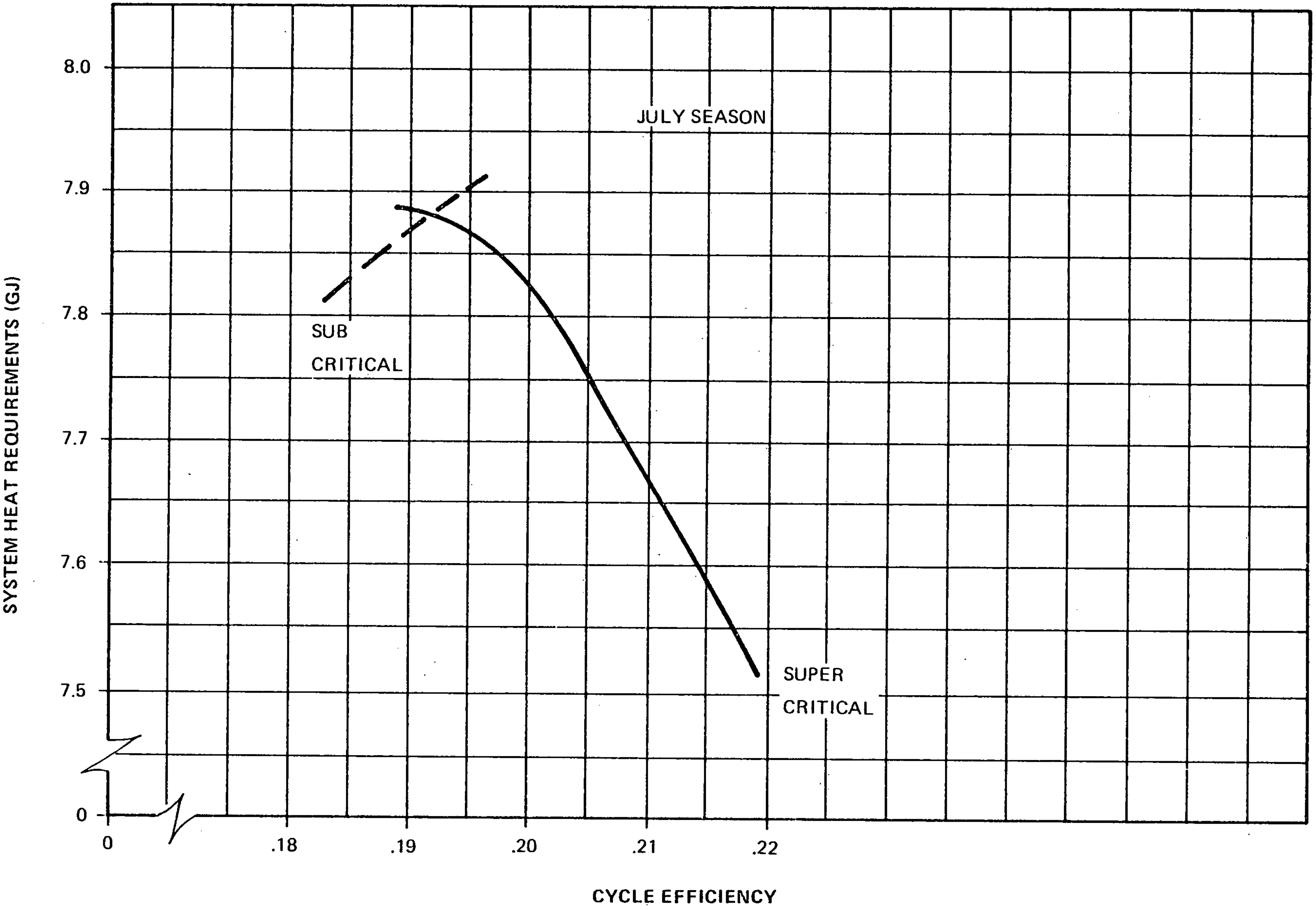

FIGURE 3.2–17. EFFECT OF SYSTEM HEAT INPUT REQUIREMENTS ON CYCLE EFFICIENCY

Supercritical operation and subcritical operation is shown in Figure 3.2–18 comparing turbine inlet temperature with average collector temperature for the two types of cycles.

The supercritical cycle does not involve a change of phase in the toluene and, therefore, can use a heat exchanger which allows a larger temperature difference on the collector side of the heat exchanger than can be obtained with the boiler and subcritical cycle. This results in a higher turbine inlet temperature for a given collector average temperature and thus a higher power conversion system efficiency for any given collector efficiency. For a supercritical cycle the results of the trade study described in Subsection 3.2.5 show that the optimum turbine inlet temperature was the lowest at which the system could be run supercritically, 329°C (625°F), with a collector outlet temperature of 343°C (650°F).

3.2.3.4 SELECTED POWER CONVERSION SYSTEM CONFIGURATION

The system configuration selected for the conceptual design phase is shown in Figures 3.2–12 through 3.2–15 for the four months representing the four seasons. The design loads used for the four months are shown in Table 3.2–5.

The key features of the system are as follows:

Supercritical toluene cycle.

Two stage turbine with interstage bleed for process steam.

Night heating load generated during facility operation from process steam and stored for night use.

Refrigeration load stored as hot water as required to buffer load peaks and valleys. System sees constant load.

Refrigeration uses absorption unit during July season, vapor cycle rest of year when required.

Electrical load in excess of that required by total energy system is made up by rejecting heat from the heat rejection condenser to balance the thermal to electrical ratio.

Heat exchanger is a 4 NTU/PASS-3 Pass heat exchanger which maximizes the temperature difference on the heat transfer fluid side when compared to a preheater, vaporizer, superheater combination.

3.2.4 THERMAL STORAGE/FLUID LOOP

3.2.4.1 STORAGE SIZE (ENERGY CAPACITY)

The size of the Thermal Storage System (TSS) in terms of energy is very strongly a function of the facility's duty cycle. The Industrial Applications of Solar Total

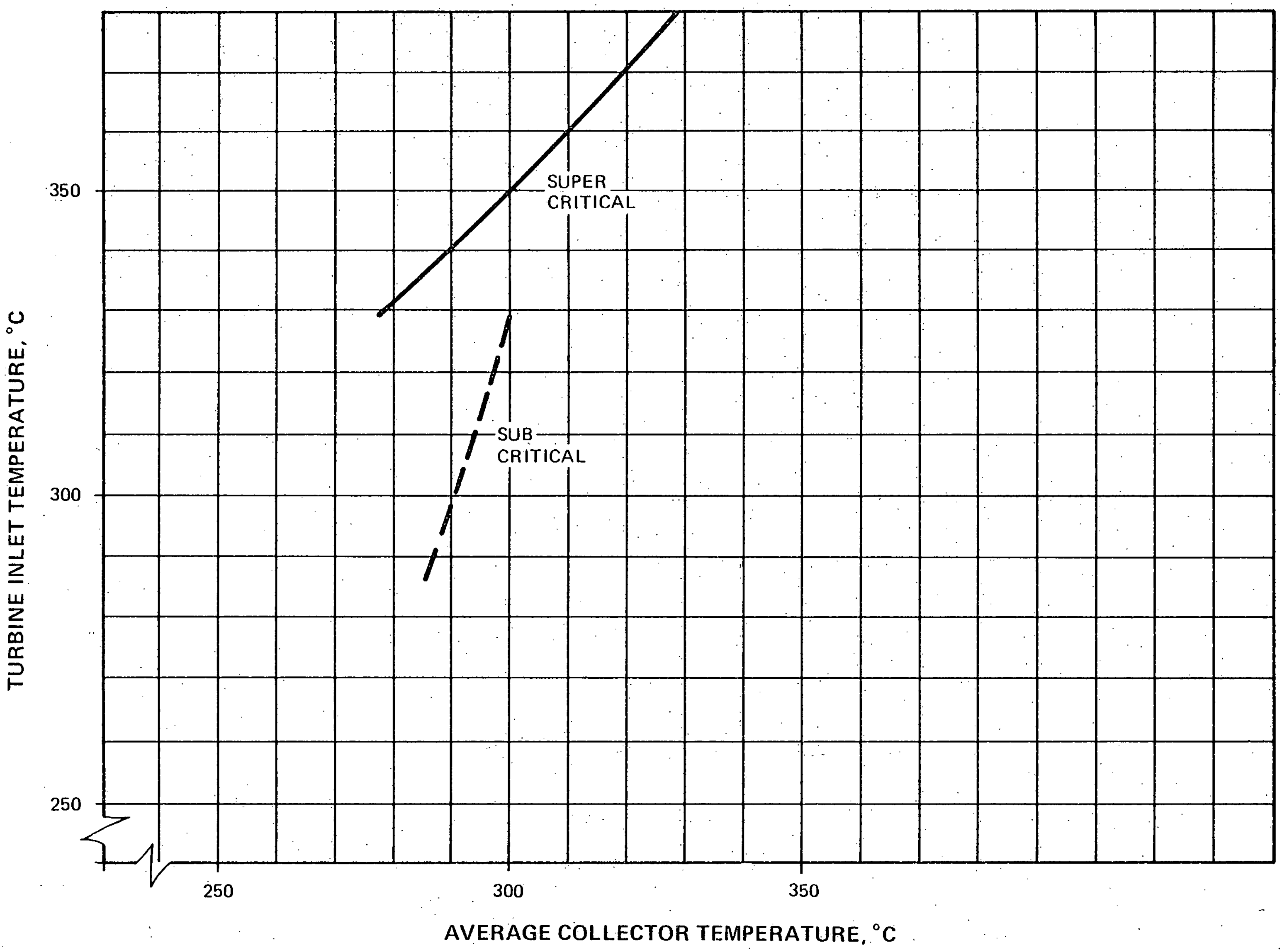

FIGURE 3.2–18. VARIATION OF AVERAGE COLLECTOR TEMPERATURE WITH TURBINE INLET TEMPERATURE

Energy study* concluded that the most cost effective system for facilities that operate on a five-day week is to size storage large enough to accumulate the weekend output from the collector field for use by the STES during the facility's operating hours. Additional contingency capacity is also required to account for startup of the auxiliary fossil-fueled heater or to allow the timely conversion of the facility to utility grid operation (i.e., waiting so as not to come on the grid during peak utility demand times). A value of four hours of system operation during the peak load season (July) was assumed for this contingency. This was based on allowing one hour for heater startup and a minimum of three hours of operation for utility peak avoidance (1-1/2 hours on either side of peak occurrence).

The method used to size the TSS was to graphically track the output of the collector field and the required storage capacity over a typical operating week, using baseline collector field performance determined by using the Sandia seasonal weeks. Figure 3.2–19 shows the results of such a tracking for the July season. The July season was used for sizing purposes because the field collects the most amount of energy during the weekend in this season, even though the April season provides the biggest daily average collection over a seasonal week. The total collector time for each day was determined and the collection rate was assumed constant over this time period. The dotted line shows the cumulative energy collected each day peaking at collector cutoff each day. For purposes of establishing the required storage capacity, the storage was assumed to be at the contingency level at sunup on Saturday morning. The storage level (shown with the solid line) increases at a rate of $\dot{Q}_{coll}$ until collector shutdown Saturday afternoon. The level then remains constant until the collector field starts collecting on Sunday morning. The level remains constant until sunup on Monday morning. The storage level continues to increase until facility start-of-business on Monday morning. This peak on Monday morning establishes the required storage capacity, including the four hours of contingency. The storage level drops from this point at a rate of $\dot{Q}_{coll} - \dot{Q}_{system}$ until field cutoff on Monday afternoon. Storage level continues to drop at a rate of $\dot{Q}_{system}$ until close-of-business Monday PM. This cycle repeats until the storage level penetrates the contingency level on Wednesday afternoon. At this time, the heater goes on standby/warmup mode and comes on line after one hour of operation out of contingency storage. The heater operates at an output of $\dot{Q}_{system}$ or $\dot{Q}_{system}$-$\dot{Q}_{coll}$ depending on the field output. During this time, the storage level remains constant. After close-of-business on Wednesday PM, the heater remains on long enough (in this case for one hour) to replenish the storage up to the contingency level. This cycle repeats for the rest of the week with the storage level ending up at the contingency level early Saturday morning. The amount of solar energy supplied to the facility is the summation of the daily cumulative values throughout the week. The amount of fossil fuel energy required out of the fossil-fueled heater is the summation of the cumulative daily heater output values for the week. The actual required fossil fuel is the heat output divided by an appropriate efficiency. Similar weekly operational cycles were plotted for the other representative seasons to

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*ERDA Contract EY-C-76-03-1132.

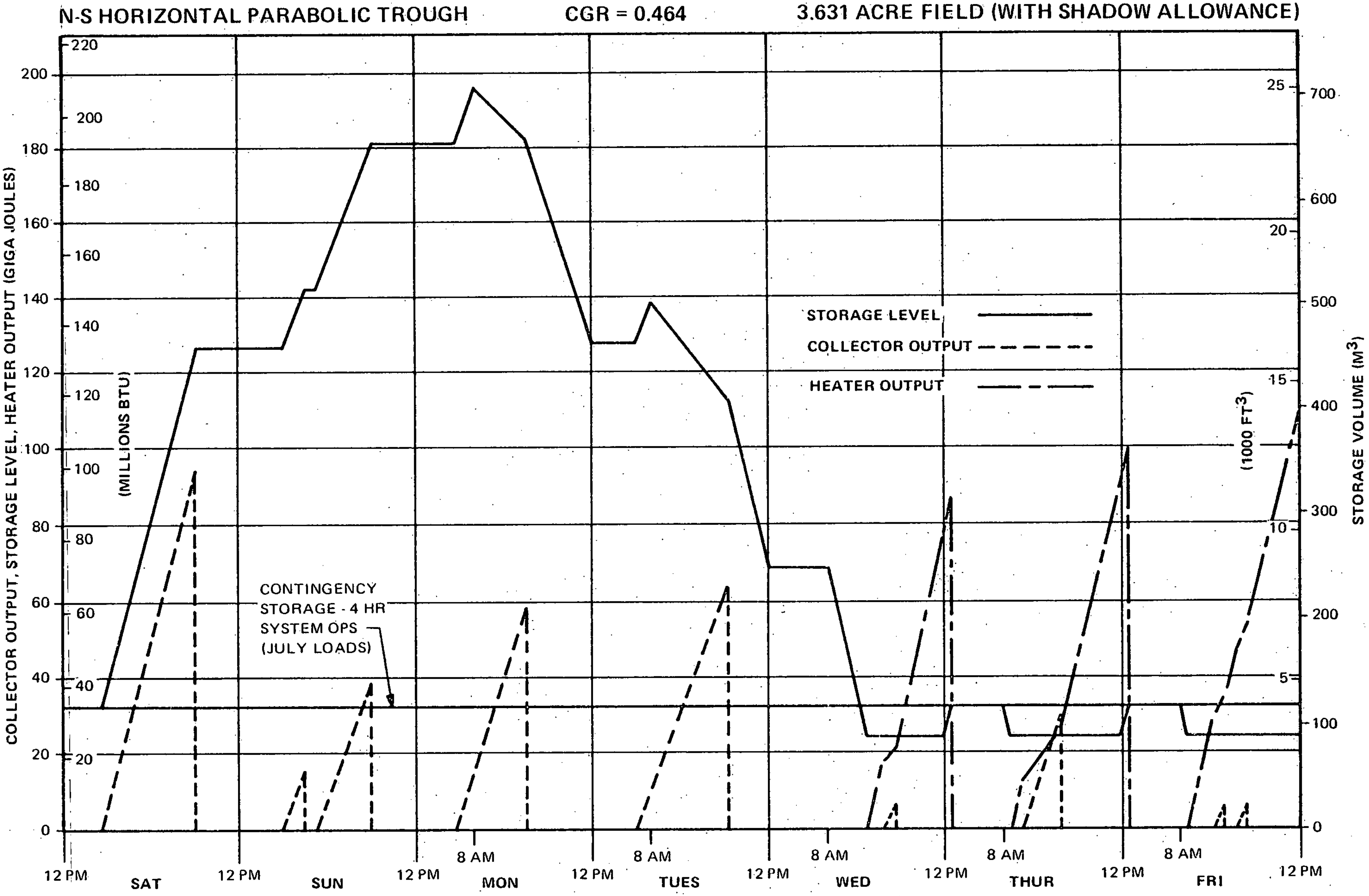


FIGURE 3.2–19. WEEKLY OPERATION CYCLE - SUMMER (JULY) SEASON

verify that July was in fact the sizing case. As can be seen in Figures 3.2–19 through 3.2–22, the storage capacity is at a maximum in July.

3.2.4.2 CONCEPT SELECTION

The candidate TSS concepts which were considered during this study were: multi (3) tank (hot tank/cold tank) systems, and single tank thermoclines, both single and dual mediums. A list of these candidates is shown in Table 3.2–6, along with their possible advantages and disadvantages. A discussion of these pros and cons follows.

Multi-tank systems offer the advantage of not relying on thermocline stability for their operation and would have been considered as candidates had thermocline stability been a question. This was not considered likely, however, in light of the results of recent tests conducted by Rocketdyne for the MDAC 10-MWe Pilot Plant design. Figure 3.2–23 shows some of the test results verifying thermocline stability over a 4-1/2-hour time period at a constant extraction rate. The rock also acts as a deterrent to convection circulation caused by heat transfer through the tank walls which reduces the fluid temperature at the wall and sets up natural convection currents which, through mixing, tend to break down the thermocline. One possible advantage to single medium systems could be the possible incompatibility of the dual storage mediums or possible particulate contamination of the fluid by small particles sloughing off the rock. However, test results have shown the former not to be a problem with Therminol-66 and rock, and proper fluid maintenance (filtering) alleviates the latter.

It is possible to reduce substantially the cost of thermal storage by sharing the thermal storage function between a liquid and a much cheaper medium such as crushed rock. The dual-medium thermal storage concept uses a bed of an inexpensive solid as the primary storage medium, together with the Therminol-66 which flows through the rock to input or extract energy from the solid bed. Figure 3.2–24 shows the results of a cost trade done for single versus dual media for the MDAC 10-MWe Pilot Plant TSS. The difference between active and passive load has to do with whether the rock adds hydrostatic load to the tank walls (passive) or is self-supporting (active). Recent tests have shown that the active assumption is valid in that the rock is self-supporting. Multi-tank systems are obviously more expensive than single tank systems because of the additional tankage.

Based on the lower predicted cost and an acceptance of the thermocline stability verification tests being conducted by Rocketdyne, the single-tank dual-media system was selected as baseline for the conceptual design.

A summary of the design features of the major components (shown schematically in Figure 3.2–25) is given in Table 3.2–7.

Two other parts of the TSS not summarized in the table are the Ullage Maintenance and Fluid Maintenance Units. Detailed discussions of these systems appear in Appendix B of this report.

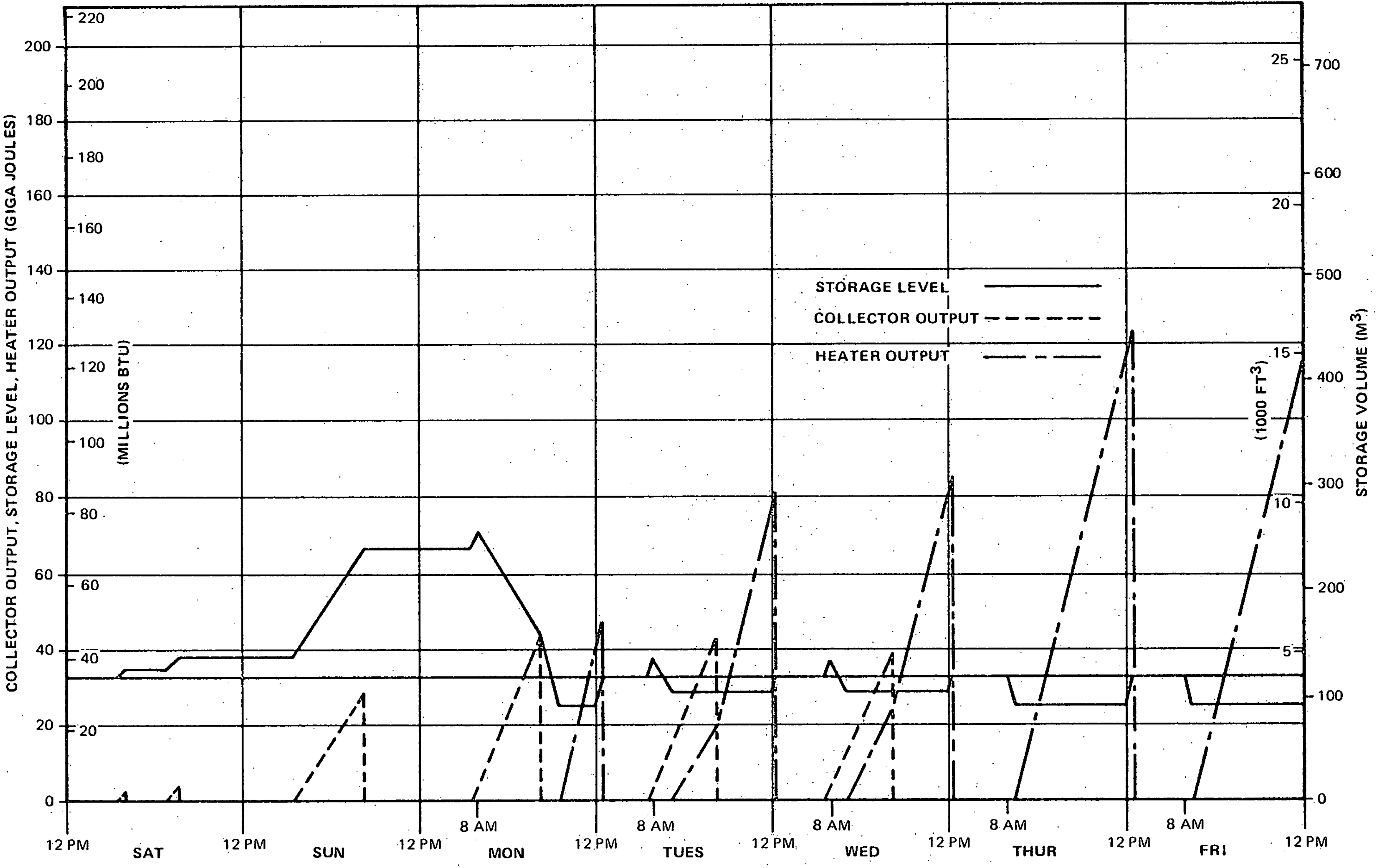

N-S HORIZONTAL PARABOLIC TROUGH CGR = 0.464 3.631 ACRE FIELD (WITH SHADOW ALLOWANCE)

FIGURE 3.2–20. WEEKLY OPERATION CYCLE - FALL (OCTOBER) SEASON

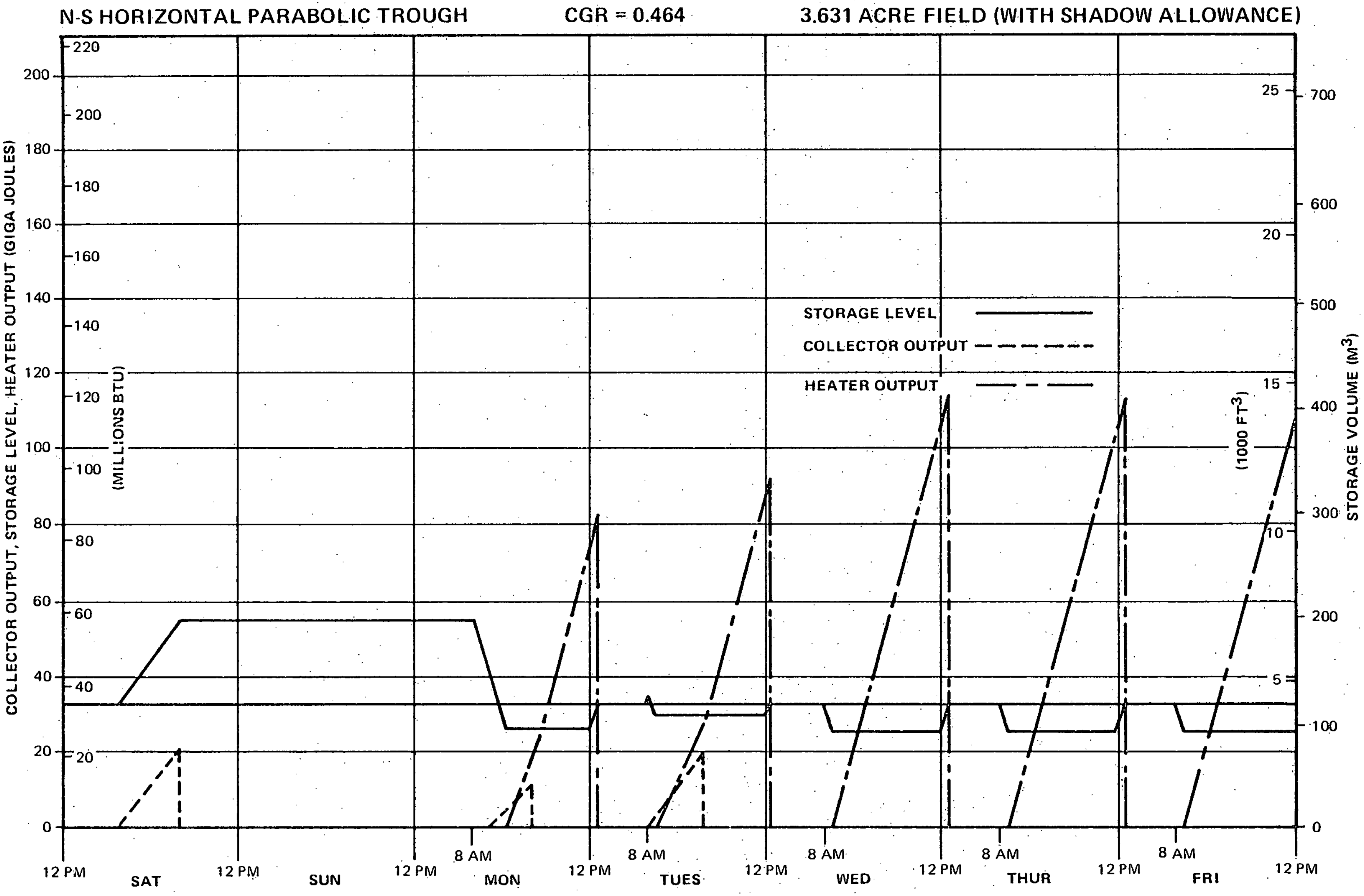


FIGURE 3.2–21. WEEKLY OPERATION CYCLE - WINTER (JANUARY) SEASON

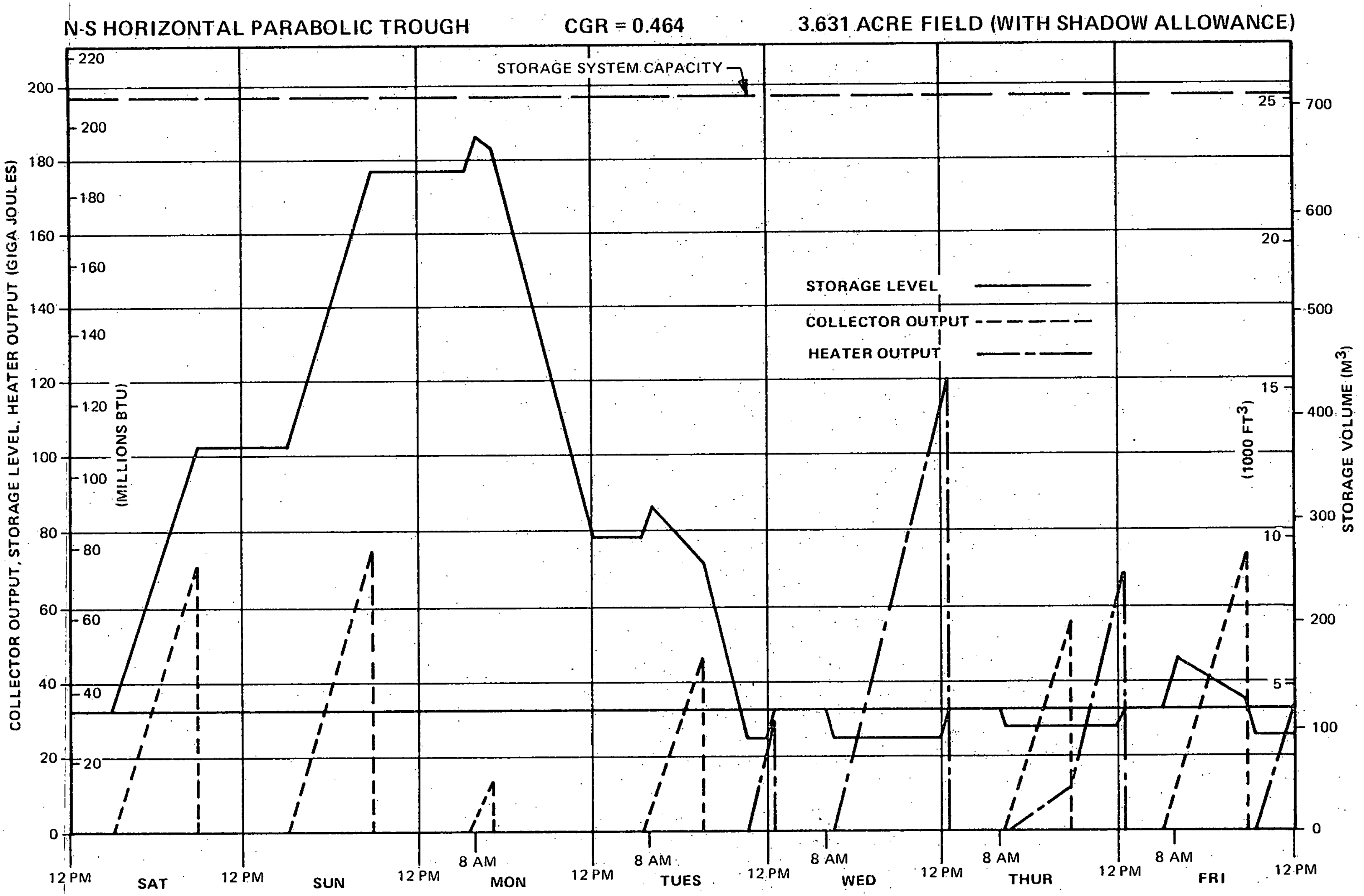


FIGURE 3.2–22. WEEKLY OPERATION CYCLE - SPRING (APRIL) SEASON

CANDIDATES	ADVANTAGES	DISADVANTAGES
1. MULTI (3) TANK SINGLE MEDIA	HIGHLY PREDICTABLE PERFORMANCE	50% MORE TANK VOLUME, ADDITIONAL PLUMBING AND CONTROLS, HIGH MEDIA COST
2. SINGLE TANK SINGLE MEDIA THERMOCLINE	LESS TANK VOLUME THAN NO. 1	THERMOCLINE STABILITY, HIGH MEDIA COST
3. SINGLE TANK DUAL MEDIA* THERMOCLINE	LESS TANK VOLUME THAN NO. 1, SUBSTANTIALLY LOWER MEDIA COST	RELIES ON THERMOCLINE, POSSIBLE PARTICULATE FOULING MEANS MORE COMPLEX FLUID MAINTENANCE UNIT
* SELECTED FOR BASELINE		

TABLE 3.2–6. COMPARISON OF CANDIDATE THERMAL STORAGE CONCEPTS

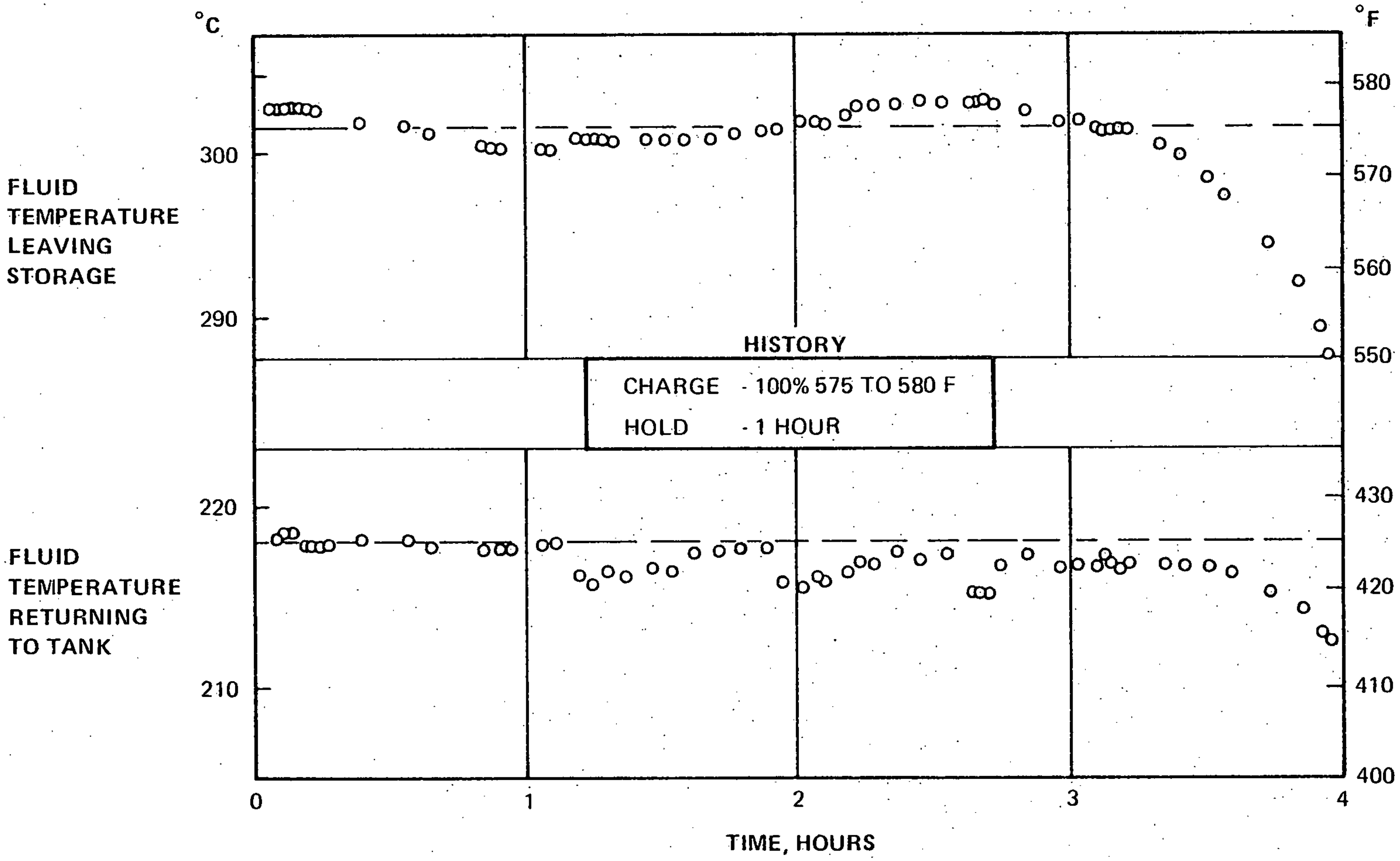


FIGURE 3.2–23. TYPICAL PERFORMANCE DATA DURING EXTRACTION

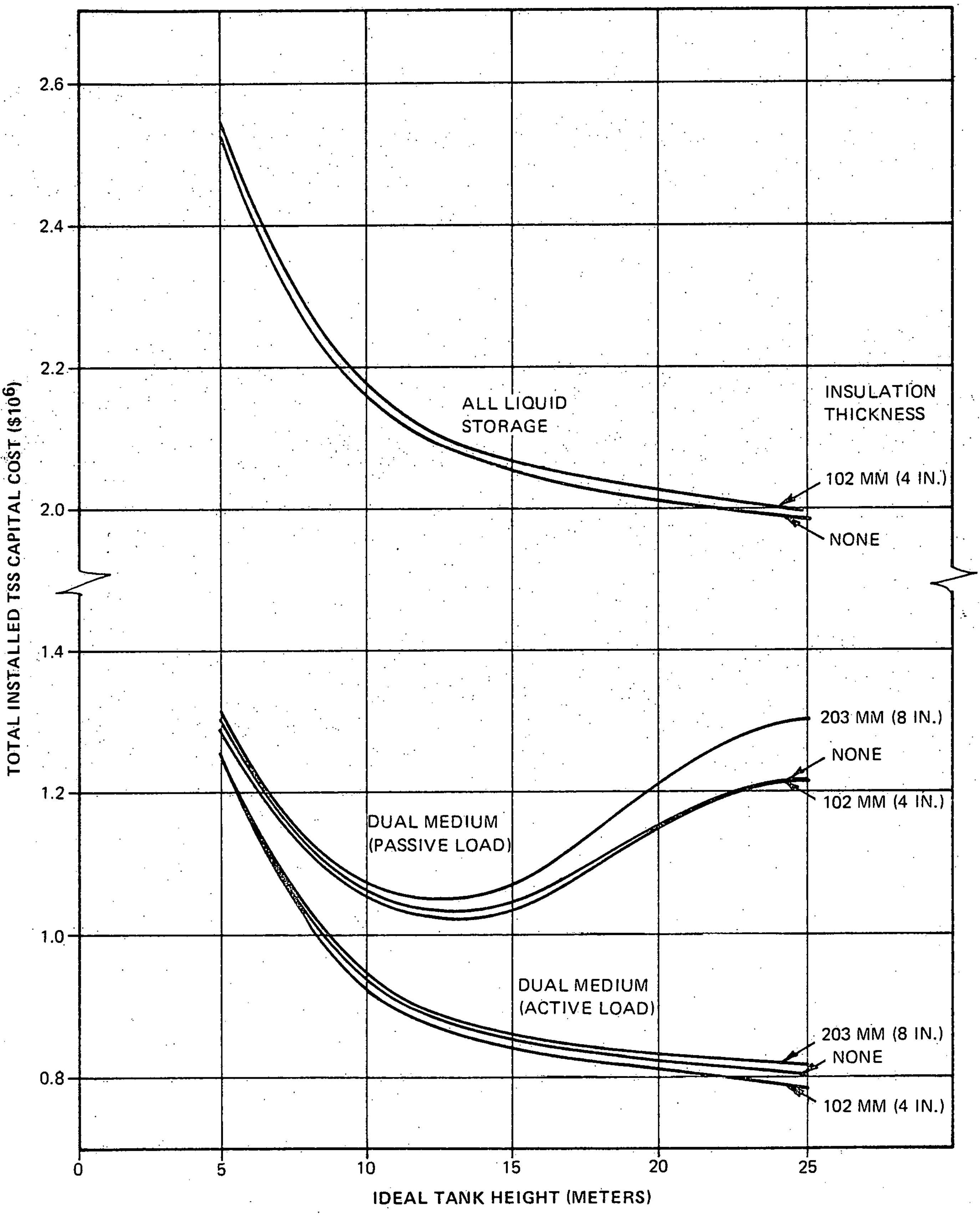


FIGURE 3.2–24. SINGLE VERSUS DUAL MEDIUM STORAGE COST TRADEOFFS

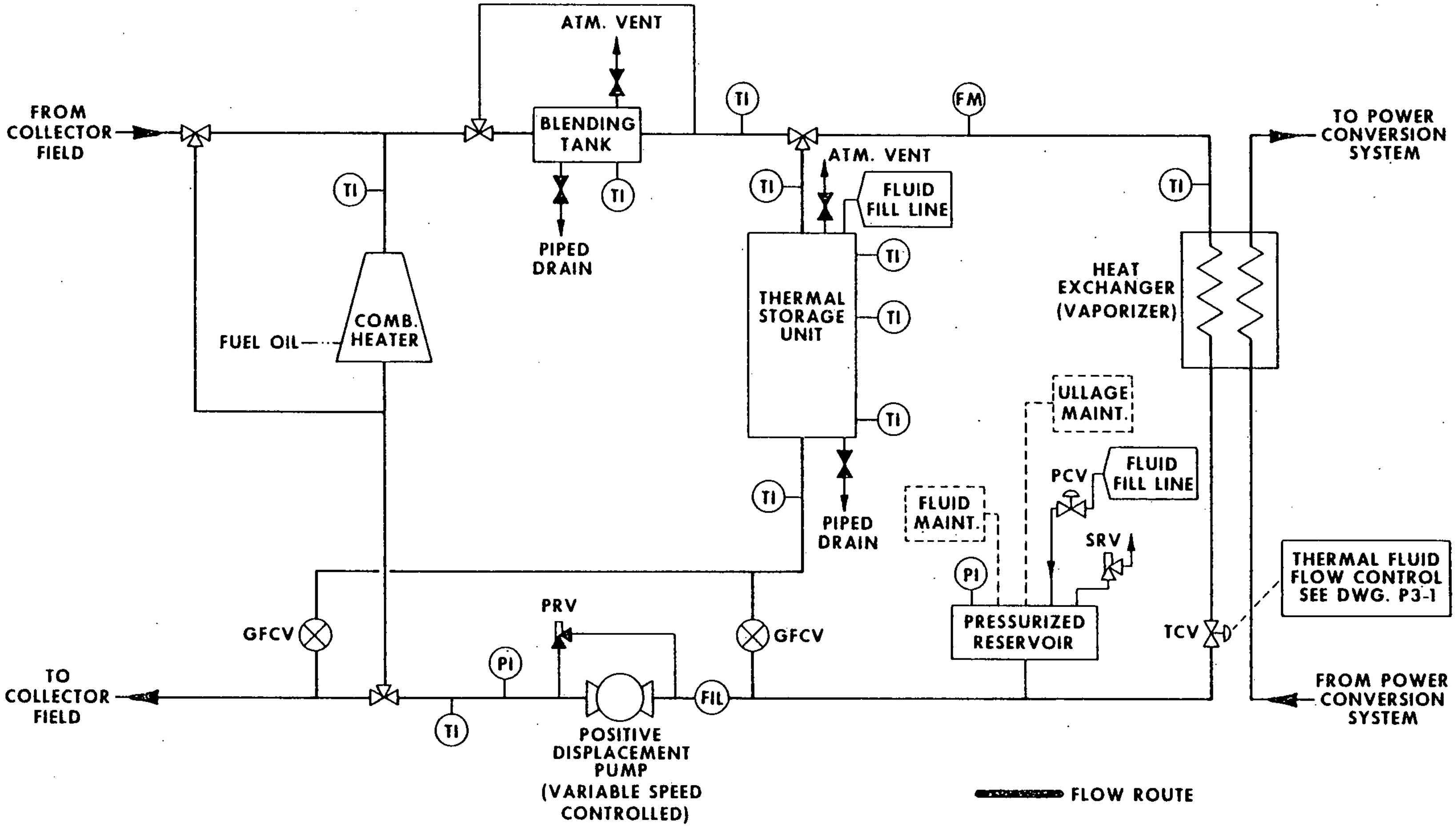


FIGURE 3.2–25. THERMAL STORAGE/FLUID LOOP PROCESS FLOW SCHEMATIC

THERMAL STORAGE UNIT:	SINGLE TANK, CYLINDRICAL, AXIS VERTICAL, ABOVE GROUND
TANK SIZE:	9.75 M (32 FT) DIAMETER BY 9.75 M (32 FT) HIGH; 736 M^3 (26,000 FT^3)
SOLID STORAGE MEDIA:	GRAVEL AND COARSE SAND (2:1 ROCK: SAND BY VOLUME); NOMINALLY 25 MM ROCK, 2 MM SAND; 0.25 VOID FRACTION; 1,721,856 KG (1898 TONS)
HEAT TRANSFER FLUID:	THERMINOL 66; 197,983 LITERS (52,310 GAL)*
OPERATING TEMPERATURE RANGE:	211 to 343^{0}C (412 to 650^{0}F); MAXIMUM EXIT TEMPERATURE RANGE DURING EXTRACTION = 6^{0}C (10.8^{0}F)
TANK CONSTRUCTION:	FABRICATED OF ASTM A537 STRUCTURAL STEEL WITH FIELD-WELDED CONSTRUCTION
TANK INSULATION:	114 MM (4-1/2 INCH) THICK OPEN PORE FIBERGLASS ON ROOF AND SIDES; CORRUGATED ALUMINUM WEATHER COVER
FOSSIL FUELED HEATER:	COMMERCIAL MODULATING FLASH HEATER, 2.8 MW (9.5 X 10^6 BTU/HR) RATING
FLUID PUMP:	VARIABLE SPEED, POSITIVE DISPLACEMENT, 14.9 KW (20 HP) 0.0126 M^3/SEC (200 GPM)
MAIN LINES:	101.6 MM (4 INCH) SCHEDULE 40, 101.6 MM (4 INCH) OF INSULATION
BLENDING TANK	SINGLE TANK, CYLINDRICAL, HORIZONTAL AXIS ABOVE GROUND
TANK SIZE:	2.3M (7.5 FT) DIAMETER BY 2.3M (7.5 FT) LENGTH, 9.4M^3 (331 FT^3) VOLUME
OVERFLOW TANK:	SINGLE TANK, CYLINDRICAL, VERTICAL AXIS, ABOVE GROUND
TANK SIZE:	3.9 M (12.69 FT) DIAMETER BY 3.9 M (12.69 FT) HIGH 45.5 M^3 (1605 FT^3) VOLUME

*INCLUDES COLLECTOR LOOP AND BLENDING TANK FLUID

TABLE 3.2–7. THERMAL STORAGE/FLUID LOOP BASELINE DESIGN PARAMETERS

3.2.4.3 THERMAL STORAGE SYSTEM HEAT LOSSES

Heat losses are estimated to be less than five percent of the extractable energy over a 24-hour time period. Loss data as a function of storage size is shown in Figure 3.2–26. This loss was not included directly in the sizing of the TSS. However, it can be considered as part of the contingency storage, detracting somewhat from the utility peak avoidance capability.

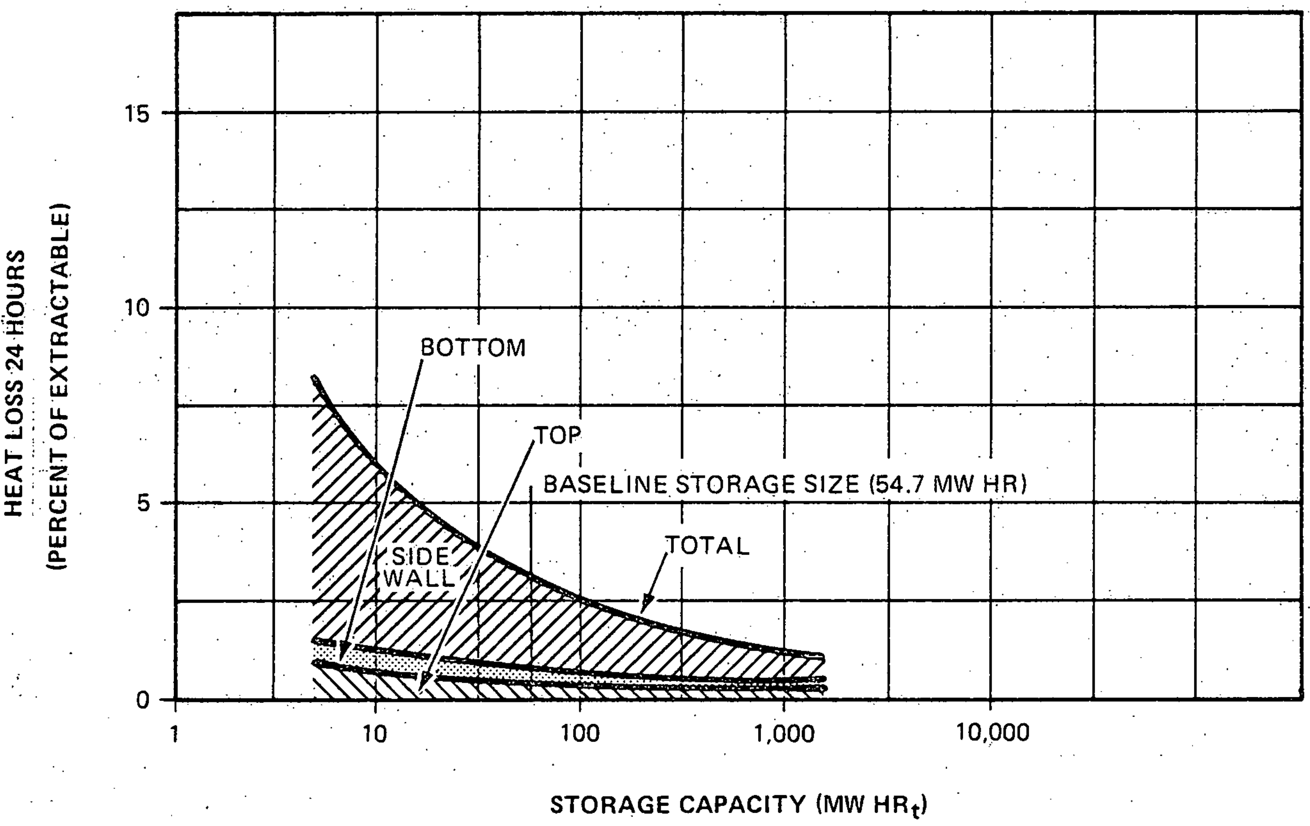


FIGURE 3.2–26. ESTIMATED THERMAL STORAGE SYSTEM HEAT LOSS

3.2.5 SYSTEM INTEGRATION

A trade study was made to determine system operating temperatures; the pertinent assumptions used during the trade are shown in Table 3.2–8. The results of this trade also influenced the selection of the power conversion cycle and the collector/thermal storage fluid. Systems were analyzed using the initial estimates of the facility's July season loads. Both organic and steam Rankine cycles were analyzed. Cycle performance was calculated over a range of operating temperatures. These data are shown in Figure 3.2–27. As can be seen, both the subcritical and supercritical tolerance cycles out-perform the steam cycle in terms of cycle efficiency. The higher cycle efficiency directly relates to a greater electrical generation capability for equal system input energy with a constant

- JULY LOADS AND COLLECTOR PERFORMANCE
- ORGANIC RANKINE AND STEAM RANKINE CYCLE
- VARY TURBINE INLET TEMPERATURE OVER RANGE OF SUBCRITICAL AND SUPERCRITICAL TOLUENE AND STEAM CYCLE OPERATION
- MAXIMIZE SYSTEM EFFICIENCY WHERE:

$$n_{SYSTEM} = n_{CYCLE} \times n_{COLLECTORS}$$

TABLE 3.2–8. SYSTEM OPERATING TEMPERATURE TRADE STUDY

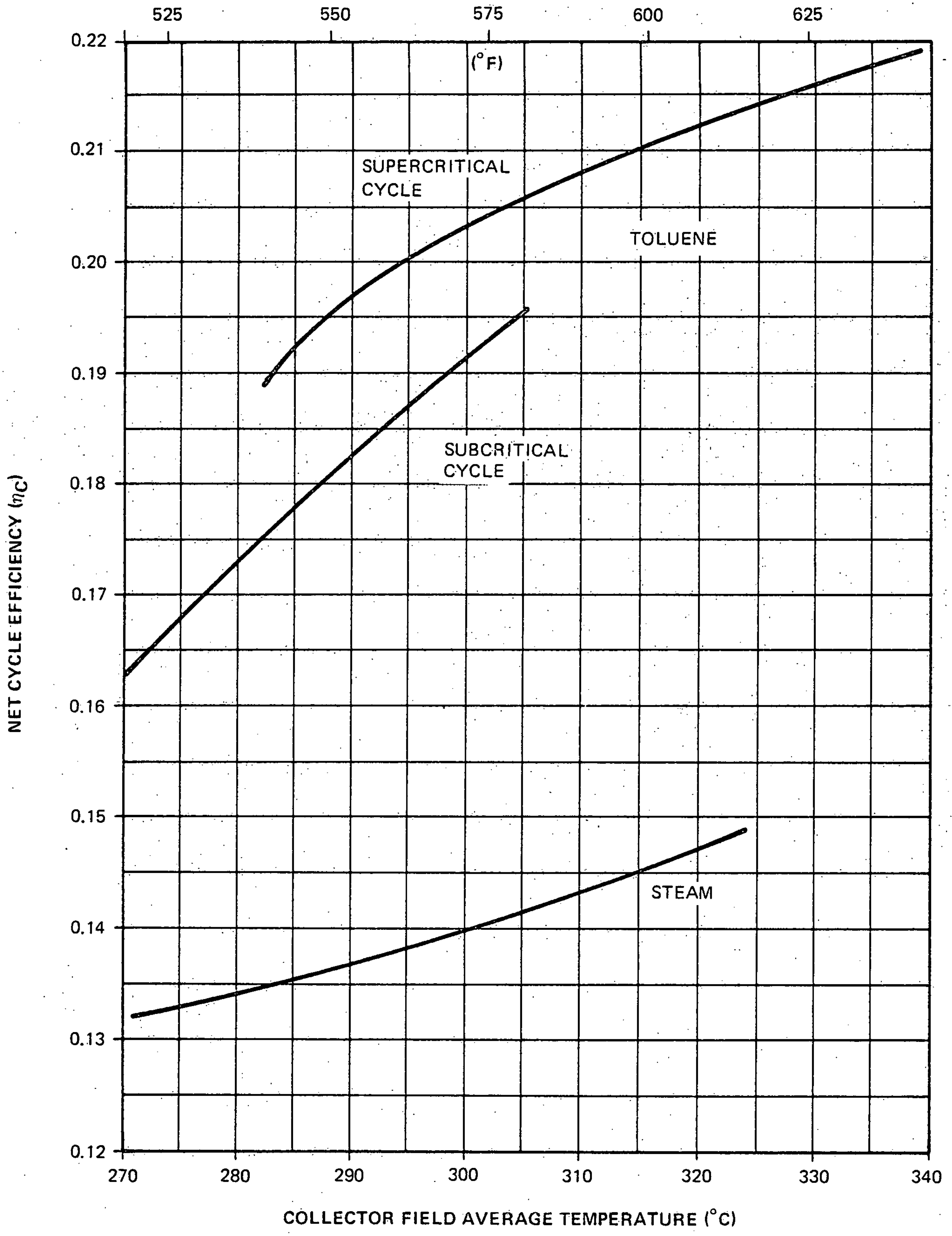


FIGURE 3.2–27. CYCLE PERFORMANCE, JULY LOADS

condenser load. (During the July season, the facility process heat and absorption air conditioning loads were used as condensing loads for the cycle.) The objective of the trade study was to maximize system efficiency where:

$$\eta_{\text{system}} = \eta_{\text{cycle}} \times \eta_{\text{collector}}$$

The collector performance for the baseline collector/field configuration is shown in Figure 3.2–28. Using the July performance the system efficiency was calculated using the above equation. The results of this calculation are shown in Figure 3.2–29. As can be seen, the combination of increasing collector performance with decreasing cycle performance with reduced temperature creates an optimum point for both the supercritical toluene and the steam cycles. However, the sharp decrease in cycle efficiency for the subcritical cycle overwhelms the improved collector performance as temperature is reduced; thus, no optimum is reached.

Based on the higher system efficiency and other factors discussed in Subsection 3.2.3 of this report, the supercritical toluene cycle was selected as baseline. As can be seen in the figure, the optimum operating temperature occurs at about 290°C (554°F). In order to evaluate the impact of this temperature on the rest of the solar system it is necessary to analyze the collector field output temperatures in relation to the average temperature used in the system efficiency derivation. Figure 3.2–30 shows the relationship of output temperature with average temperature for the organic Rankine cycle. As can be seen at the optimum system temperature of 290°C (554°F), the output temperature is approximately 353°C (667.4°F), Point A in Figure 3.2–30. This exceeds the bulk temperature limits for the organic heat transfer fluids considered as candidates for LSE 2. [Therminol-66: 343°C (650°F); Caloria 43: 315°C (600°F)]. Operating within the Caloria 43 limits restricts the cycle to subcritical operation. Operating the system within the Therminol-66 limits by reducing the required collector output temperature to 343°C (650°F) (Point B in Figure 3.2–30) relates to an average collector temperature of 280°C (536°F) which is still close to the optimum operating temperature shown in Figure 3.2–29. All the other collector/field options analyzed were also at or near optimum at this temperature [280°C (536°F)]. This data is presented in Appendix B of this report. For this reason Therminol-66 was selected for the collector/field heat transfer fluid.

In order to establish the impact of this selection on the thermal storage system the volumetric specific heat of a thermal storage system using Therminol-66 was analyzed. Figure 3.2–31 shows the effect of operating temperature on a Therminol-66 and a Therminol-66 and rock thermocline storage system. As can be seen, the specific heat is fairly insensitive to operating temperature change over the range of interest for the baseline supercritical cycle. There is only a three percent difference in specific heat and, therefore, in storage size over the range of interest.

Table 3.2–9 summarizes the conclusions of the system operating temperature trade study.

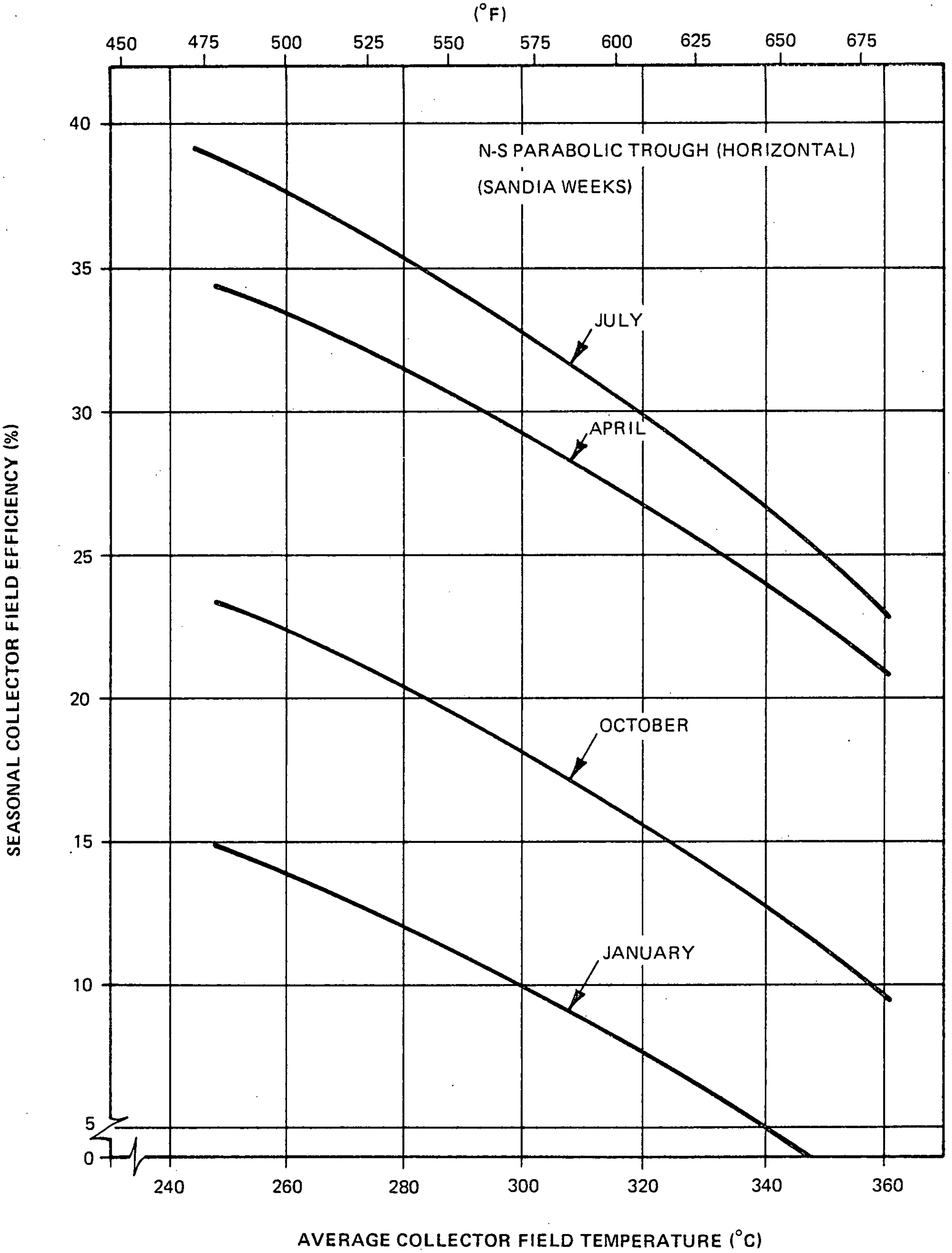


FIGURE 3.2–28. COLLECTOR PERFORMANCE FOR BASELINE COLLECTOR/FIELD CONFIGURATION

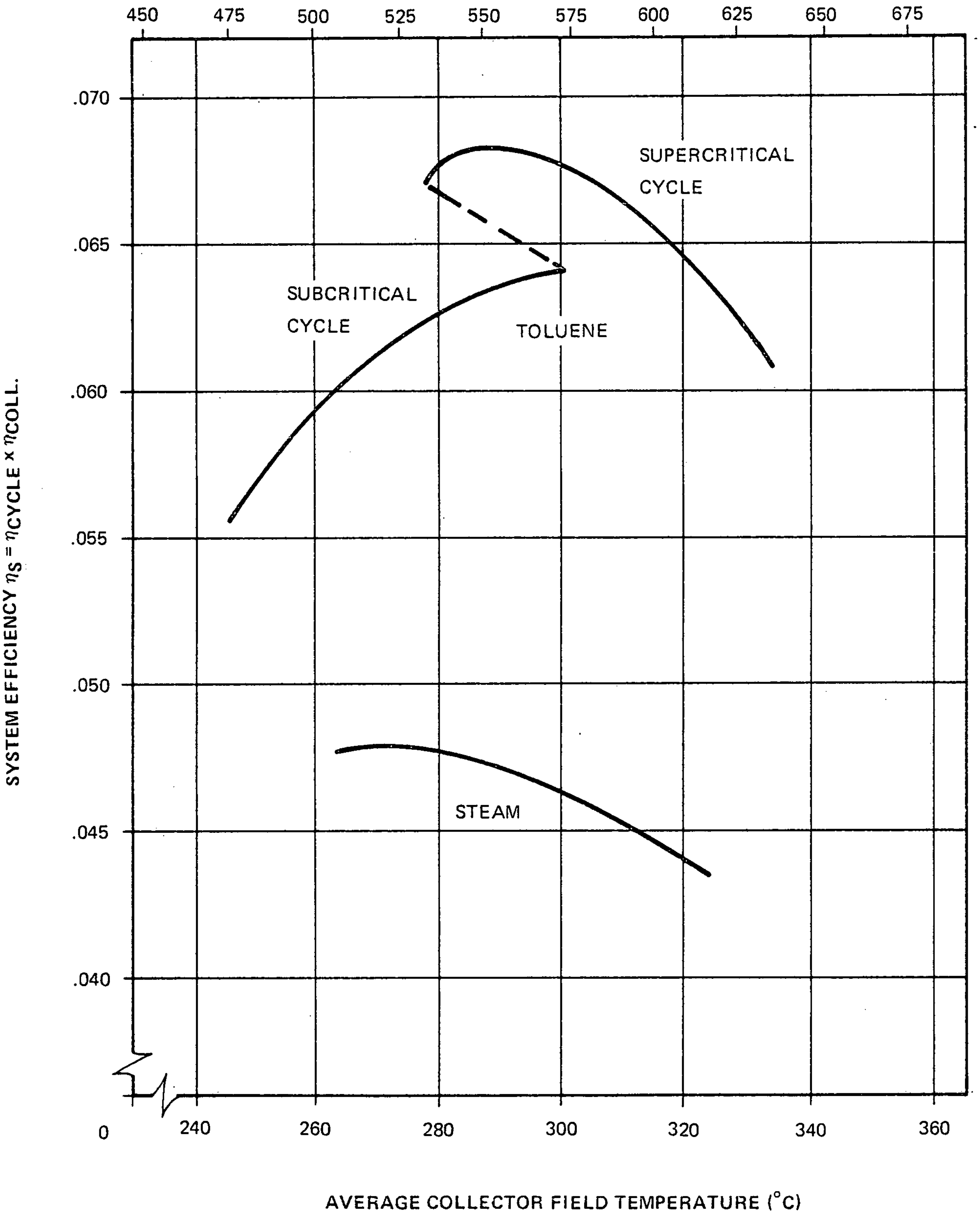


FIGURE 3.2–29. SYSTEM EFFICIENCY, NORTH-SOUTH PARABOLIC TROUGH (JULY SEASON - SANDIA WEEK)

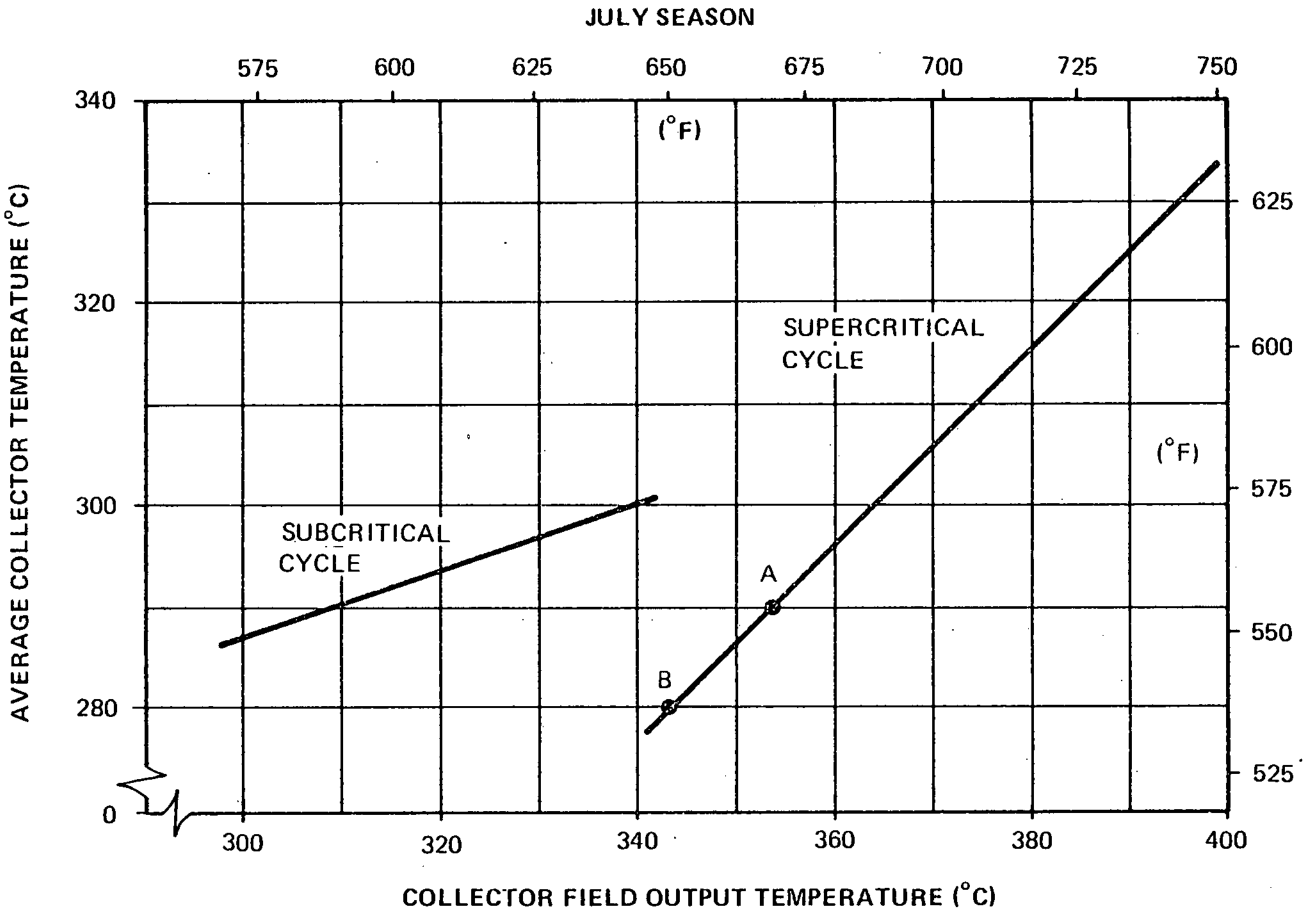


FIGURE 3.2–30. RELATIONSHIP OF COLLECTOR AVERAGE AND OUTPUT TEMPERATURES

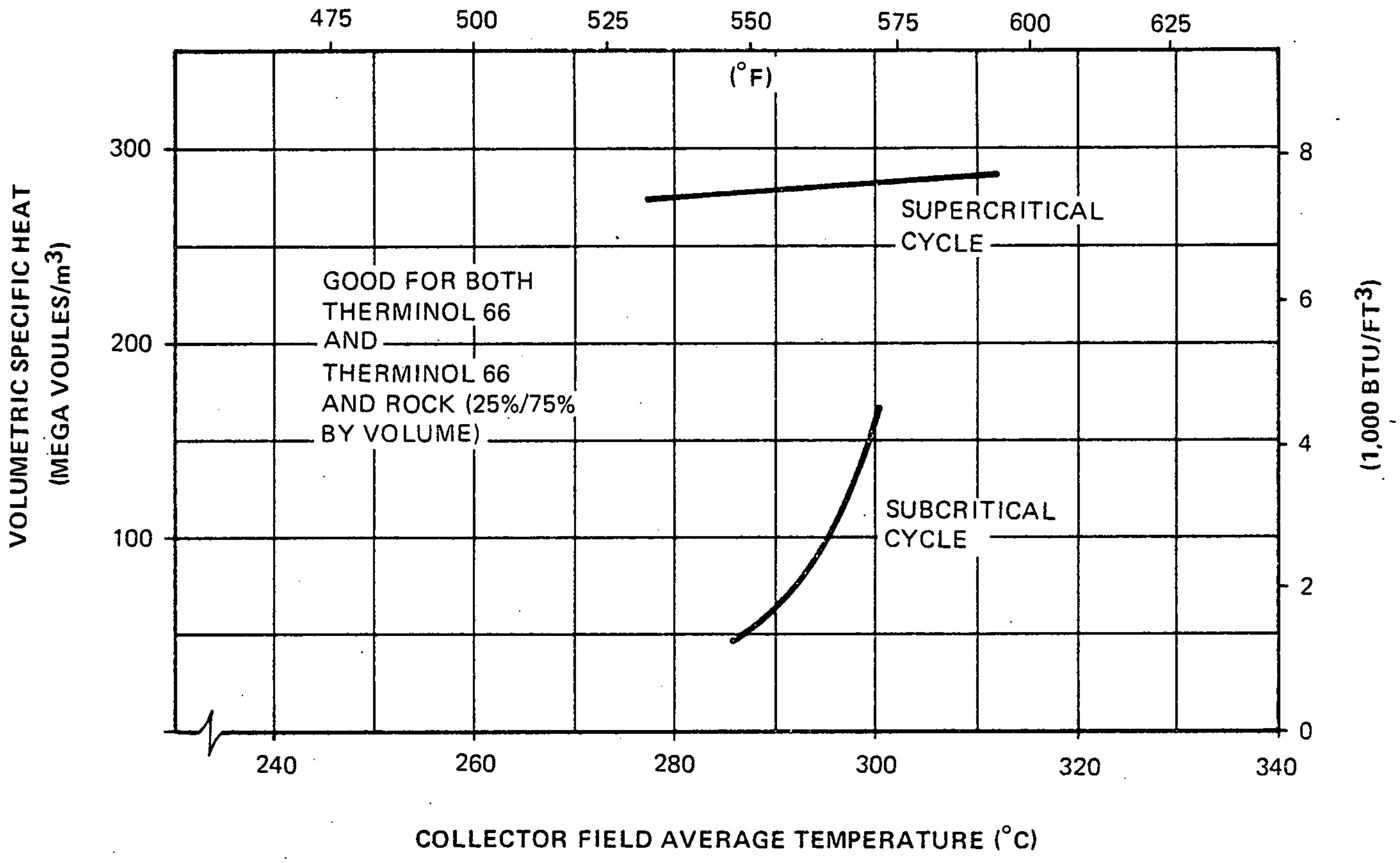


FIGURE 3.2–31. EFFECT OF COLLECTOR FIELD AVERAGE TEMPERATURES ON STORAGE SIZE

- SUPERCRITICAL CYCLE OFFERS PERFORMANCE ADVANTAGE
- 280°C COLLECTOR FIELD AVERAGE TEMPERATURE AT OR OR NEAR OPTIMUM FOR ALL FIELD CONFIGURATIONS
- COLLECTOR OUTPUT TEMPERATURE EQUAL TO OR BELOW 343°C (650°F)
- SELECTED OPERATING TEMPERATURE COMPATIBLE WITH THERMAL STORAGE SYSTEM (THREE PERCENT DIFFERENCE IN STORAGE SIZING CRITERIA OVER TEMPERATURE RANGE)
- THERMINOL 66 SELECTED AS BASELINE HEAT TRANSFER FLUID

TABLE 3.2–9. SYSTEM OPERATING TEMPERATURE TRADE STUDY RESULTS

SUBSECTION 3.3

3.3 PERFORMANCE ANALYSIS

A performance analysis was made of the collector field. The transient analysis consisted of overnight cooldown, morning startup and an arbitrary cloud cover simulation. The overnight and morning cases were repeated for two insolation cases. These two cases represent a winter day (January 11) and a summer day (July 12).

The particular conditions for the cases are:

	Winter Day	**Summer Day**
Date	January 11	July 12
Collector flow	2.33 KG/S (18,500 LB/HR)	7.18 KG/S (57,018 LB/HR)
Inlet temperature	204°C (399°F)	211°C (412°F)
Ambient temperature	4.4°C (40°F)	15.6°C (60°F)

The insolation data along with net heat input to the collectors are fully described for these two cases in Subsection 3.2.2.

This analysis was performed using the MDAC-W P5595 Thermal Energy Conversion System Analyzer Computer Program. The P5595 is a system performance prediction program. It simulates thermodynamic fluid loop systems in both steady-state and transient modes. A system is described to program, through input data, as a collection of individual components, e.g., heat exchangers, pipe runs, pumps, control valves, flow splits and mixes, etc.

The program performs heat balances based on boundary conditions (time varying for transient simulation) and pressure drop calculations for each component, proceeding individually from component to component in the direction of flow. In addition, pressure drop/flow balances may be made between parallel flow branches.

The transient thermal model of the collector field is based on the collector field details described in Subsection 1.3.1.

A pump speed controller was used to increase nominal flow when the collector field outlet temperature reached 343.3°C (650°F). The characteristics of this controller are:

$$V = \frac{7.48\ Q_{net}}{C_p\ (650 - T_{in})} - 0.3\ (T_{SL} - T_5) - 0.004\ (650 - T_{out})\ \Delta t$$

where:

V = volume flow GPM

Q_{net} = net heat absorbed BTU/MIN

C_p = thermal heat capacity BTU/LBM °F

T_{in} = inlet temperature °F

T_{SL} = set point for proportional controller °F

$$T_{SL} = (T_{in} - T_{out})/2$$

T_5 = collector fluid temperature at field mid-point °F

T_{out} = collector fluid outlet temperature °F

Δt = P5595 computational time step seconds

In addition, to prevent overshoot when 343.3°C (650°F) is first reached at the outlet, the error integral is reset to 0.0 and subsequently trimmed to stay with the bounds of ±538°C/S (±1000.0°F/SEC).

The main driver of the control function is the first term which uses an insolation sensor and sets the flow proportional to the net heat absorbed. The second term modulates the flow based on a midfield temperature sensor and thus provides anticipation to stabilize the outlet temperature. The third term represents integral control and minimizes the error at the fluid outlet.

3.3.1 OVERNIGHT COOLDOWN

Overnight cooldown simulations were made for both high and low insolation days. The runs were started prior to sunset to achieve equilibrium conditions. A lumped model was used for these cases, i.e., individual heat balances for the collectors and the interconnecting piping were not used. Therefore the calculated temperatures represent a mass average temperature of the fluid in the collector field. In reality the fluid in the collector will be colder than the calculated average while the fluid in the interconnecting piping will be warmer due to the insulation.

Transient average temperatures for both days between sunset and sunrise are shown in Figure 3.3–1.

3.3.2 MORNING STARTUP

Morning startup performance predictions were made for both high and low insolation days. The initial temperature conditions used were those at sunrise calculated in the overnight cooldown cases. Collector field outlet temperatures are shown in Figure 3.3–2 starting at sunrise through noon (when equilibrium operation has been fully reached).

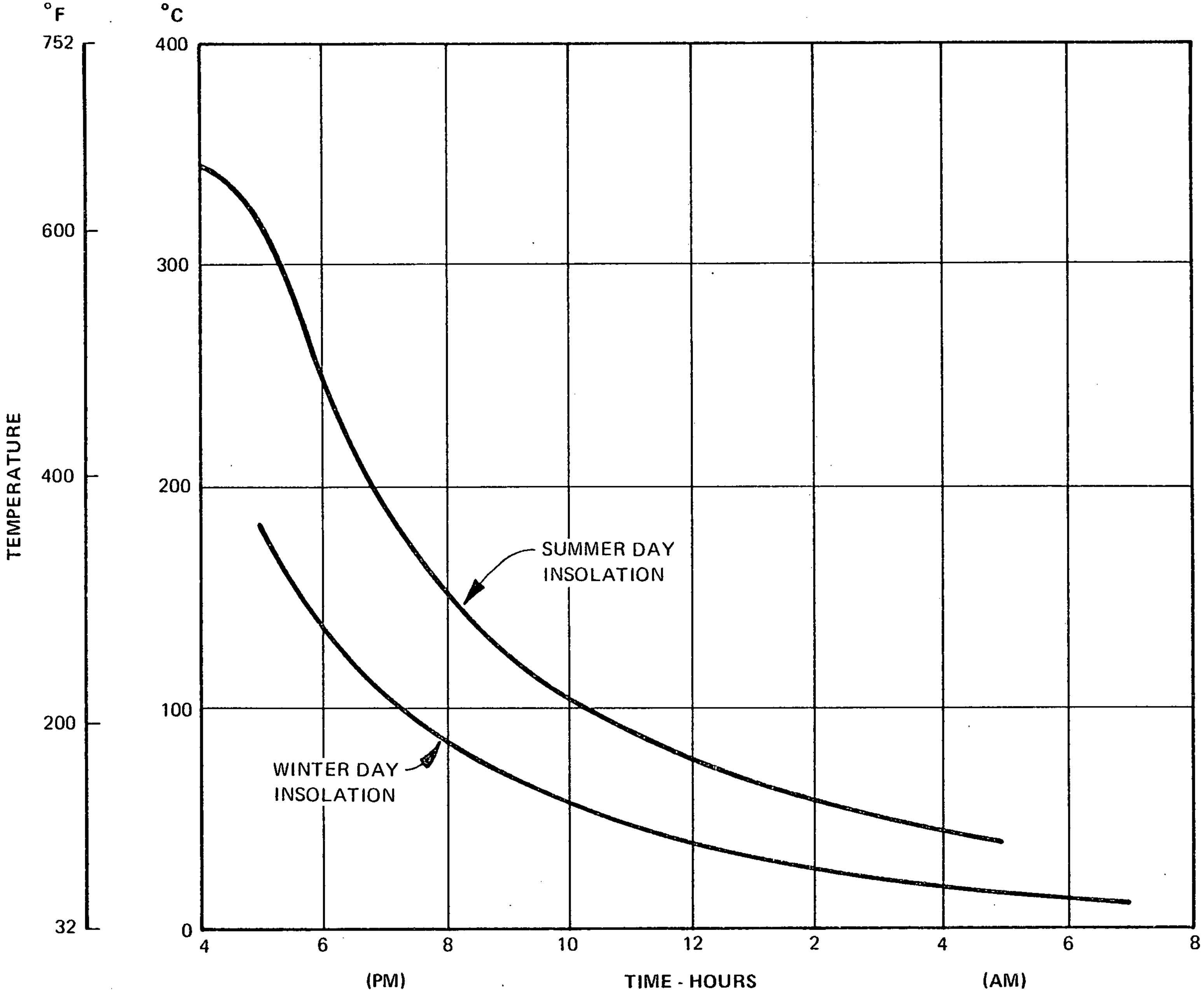


FIGURE 3.3–1. COLLECTOR FLUID TEMPERATURE - OVERNIGHT COOLDOWN

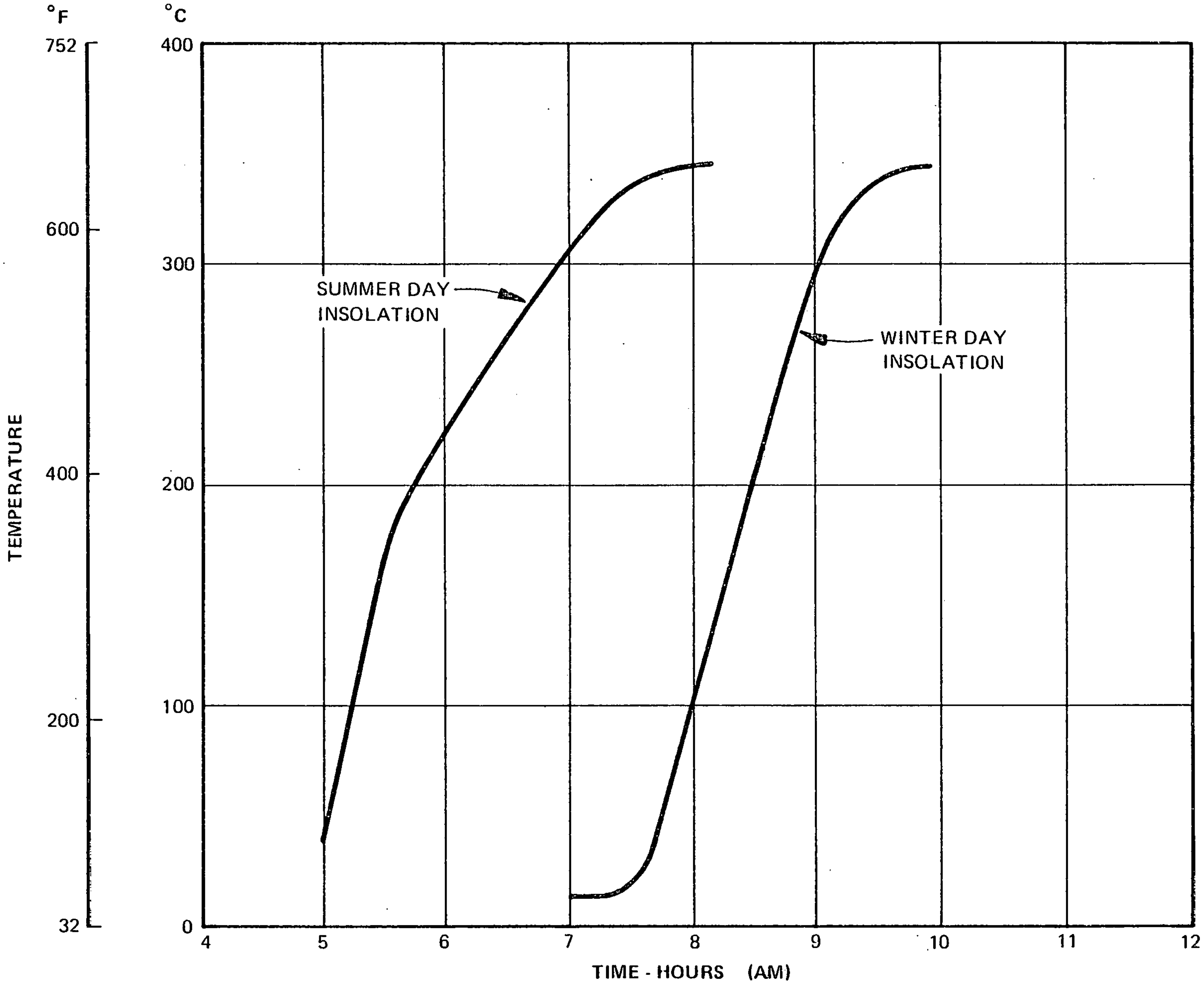


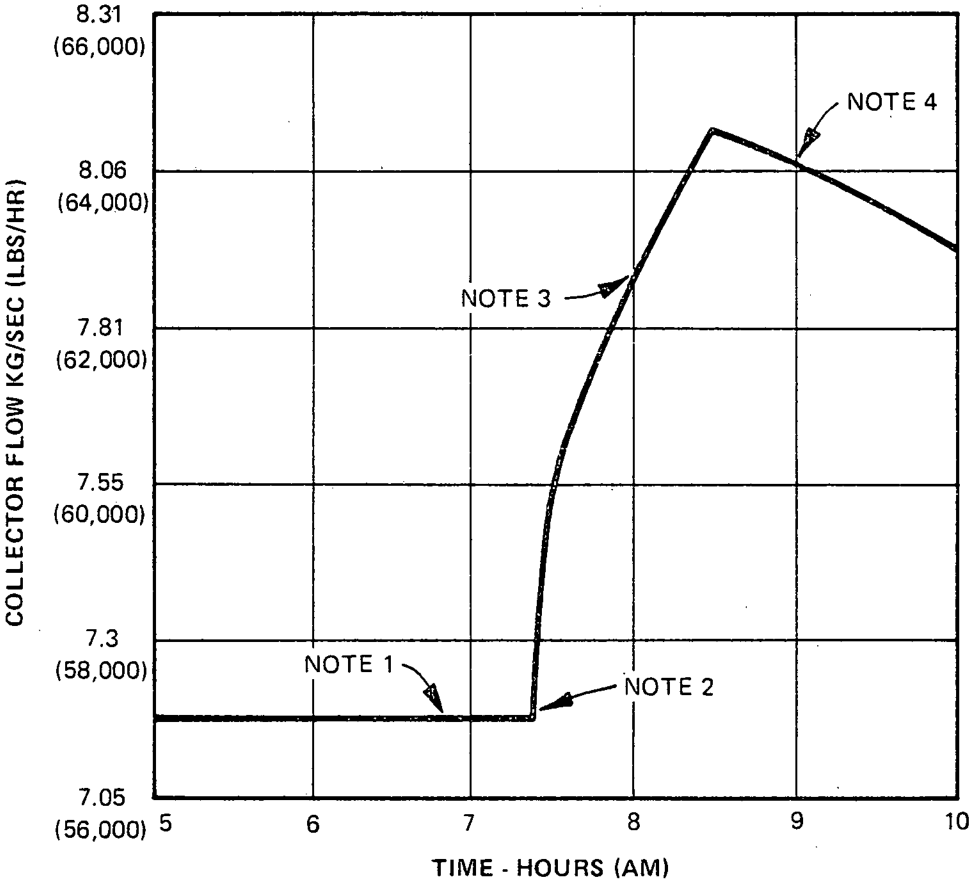
FIGURE 3.3–2. COLLECTOR FIELD OUTLET TEMPERATURE - MORNING STARTUP

The high insolation case attains the design outlet temperature three hours after sunrise. Somewhat prior to this (about 1/2 hour) the anticipating function of the controller begins to increase flow to prevent overshoot.

The collector field flow history is shown in Figure 3.3–3. The flow in excess of the design flow of 7.18 KG/S (57,018 LB/HR) is diverted to the thermal storage unit.

3.3.3 CLOUD COVER CASE

An arbitrary reduction in insolation was superimposed on the July 12 insolation profile to simulate a cloud cover passage. The collector field outlet temperature and insolation profile are shown in Figure 3.3–4.



NOTES:

1. DESIGN FLOW.
2. MID FIELD SET POINT REACHED, FLOW INCREASES.
3. OUTLET SET POINT APPROACHED WITHIN 1.2°F.
4. INTEGRAL FUNCTION DECREASES FLOW TO MINIMIZE ERROR SIGNAL DURING ESSENTIALLY CONSTANT INSOLATION.

FIGURE 3.3–3. COLLECTOR FLOW HISTORY - MORNING STARTUP, SUMMER DAY

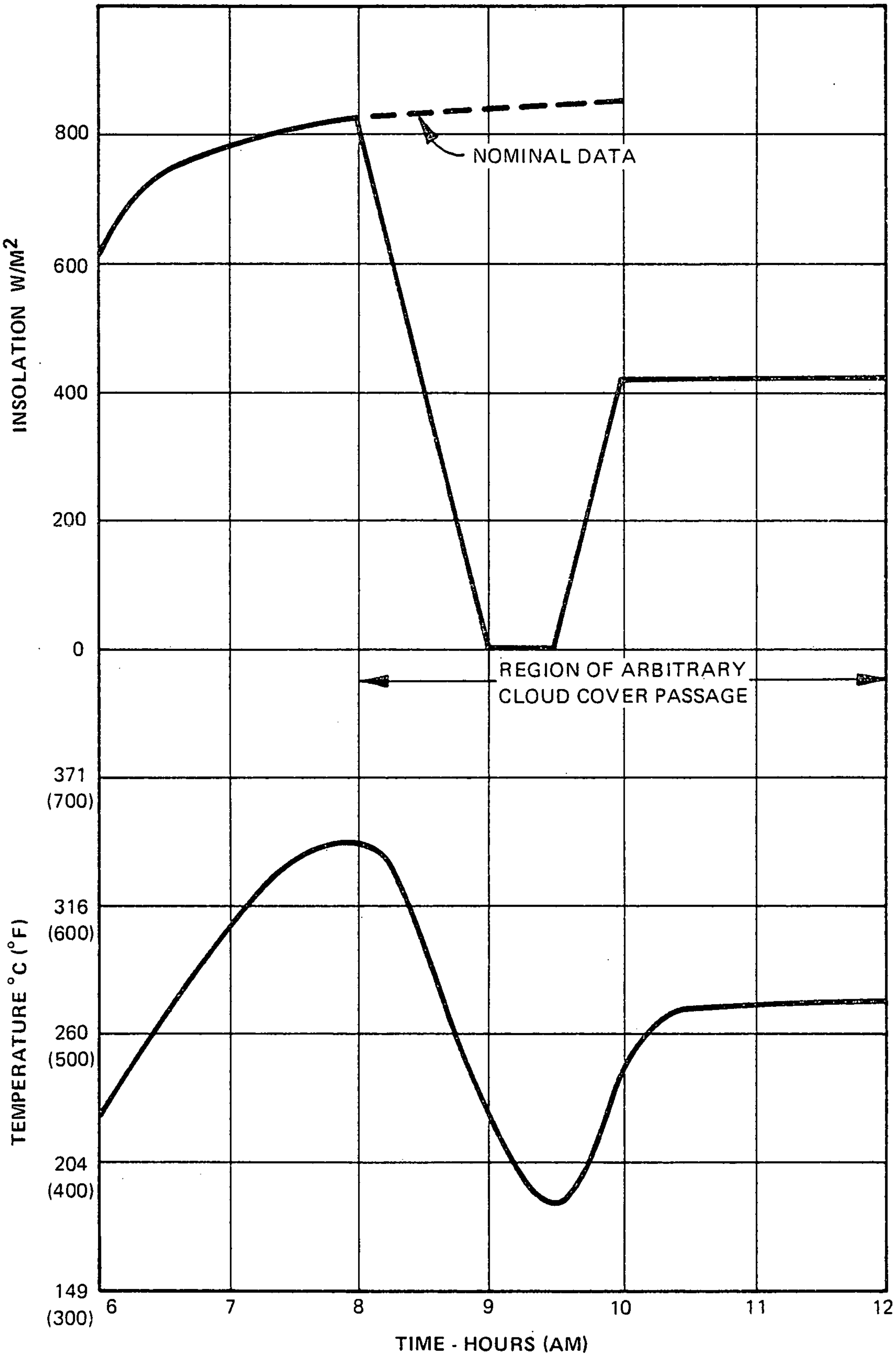


FIGURE 3.3–4. CLOUD COVER PERFORMANCE - SUMMER DAY

SUBSECTION 3.4

3.4 OPERATIONAL PLAN

The operational plan investigated the following operational modes for the STES: (a) Storage depleted-operation with heater, (b) Collector field operating at temperature but not at required flow rate, (c) Weekend collection, (d) Operation from storage, (e) Morning startup, and (f) Collector field at temperature and required flow rate. Schematics depicting these modes are presented in Figures 3.4–1 through 3.4–6.

3.4.1 MORNING STARTUP - EARLY SUN (Figure 3.4–1)

System operation is initiated on a signal from the insolation sensor. Cold fluid from the field passes through the modulating combustion heater where it is heated to the required 343°C (650°F). It then passes through the blending tank where temperature excursions are dampened. Heat is extracted from the hot oil in the heat exchanger since the power conversion cycle is also in a startup mode (bypassing the turbine). The colder fluid is returned to the field. When the fluid from the field reaches the desired 343°C (650°F) and the required flow rate, flow through the heater is stopped.

3.4.2 COLLECTOR FIELD OPERATING AT TEMPERATURE - NOT AT REQUIRED FLOW RATE (Figure 3.4–2)

When the fluid from the collector field reaches the required 343°C (650°F), this flow is routed directly to the Therminol-to-toluene heat exchanger with the cold fluid being routed back to the field. As the in-line flow meter senses that the flow from the field is reduced, the flow rate is increased to the rate necessary to satisfy the power conversion requirement with the additional flow routed through the thermal storage unit (if not depleted) or the combustion heater, exiting at 343°C (650°F) and mixing with the same temperature flow from the field.

3.4.3 COLLECTOR FIELD FLUID AT TEMPERATURE AND PROPER FLOW RATE (Figure 3.4–3)

As the insolation increases, the fluid comes to the required temperature (as sensed by temperature sensor on the collector hot fluid line) and the proper flow rate is maintained by the variable speed control pump. In this operational mode, the hot fluid travels directly to the blending tank, to the heat exchanger, and is then returned to the field. All bypass lines are closed.

3.4.4 OPERATION FROM STORAGE (Figure 3.4–4)

During second shift operation (or after field collection has stopped), the energy in the thermal storage unit is used to operate the system. The hot Therminol is pumped from the thermocline storage unit, passes through the heat exchanger, and the colder fluid is returned to storage.

FLUID / THERMAL STORAGE LOOP

A M STARTUP/STORAGE DEPLETED/EARLY SUN

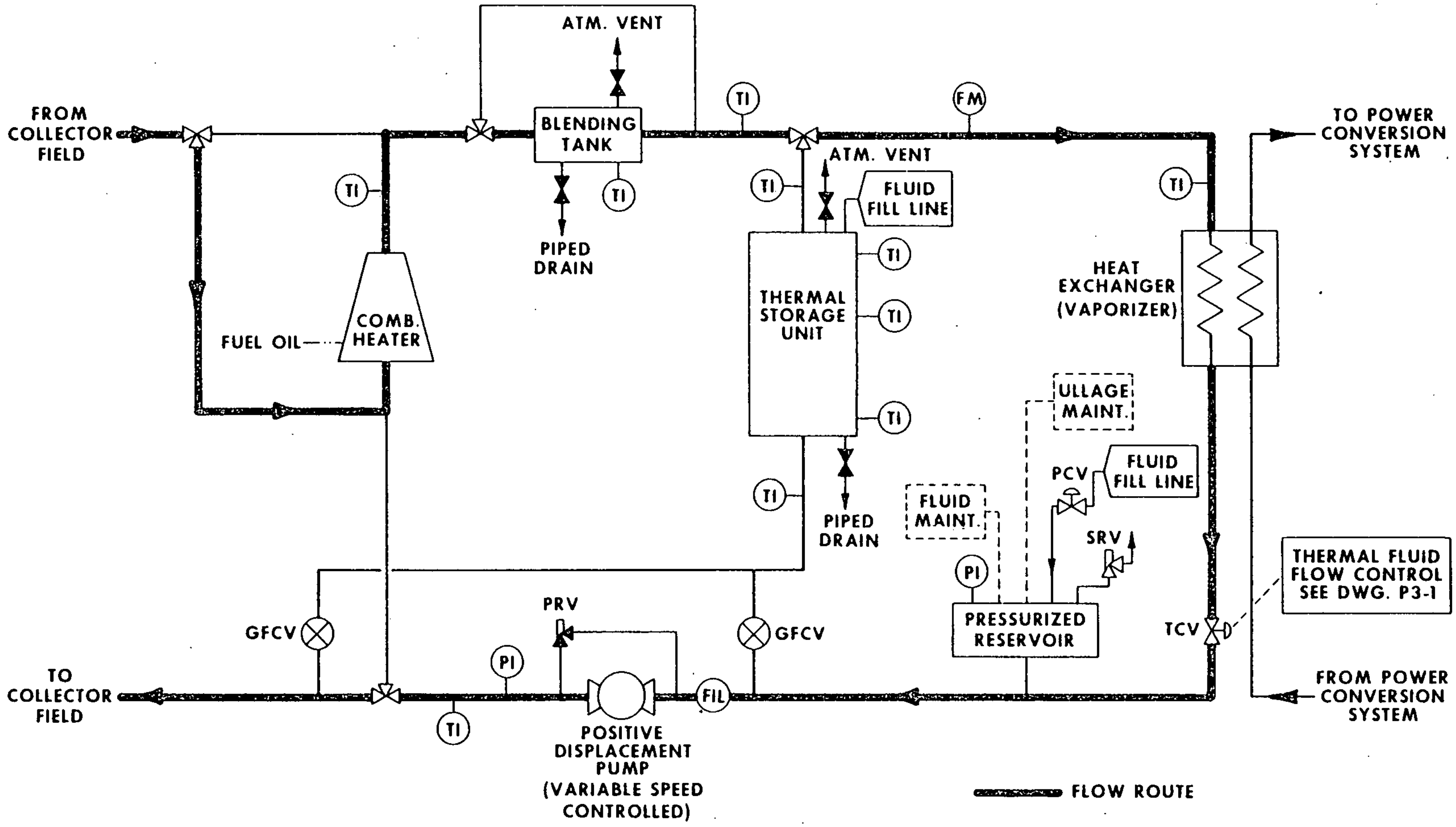


FIGURE 3.4–1. MORNING STARTUP - OPERATIONAL PLAN SCHEMATIC

FLUID / THERMAL STORAGE LOOP

FIELD OPERATING AT TEMPERATURE NOT AT FLOW RATE

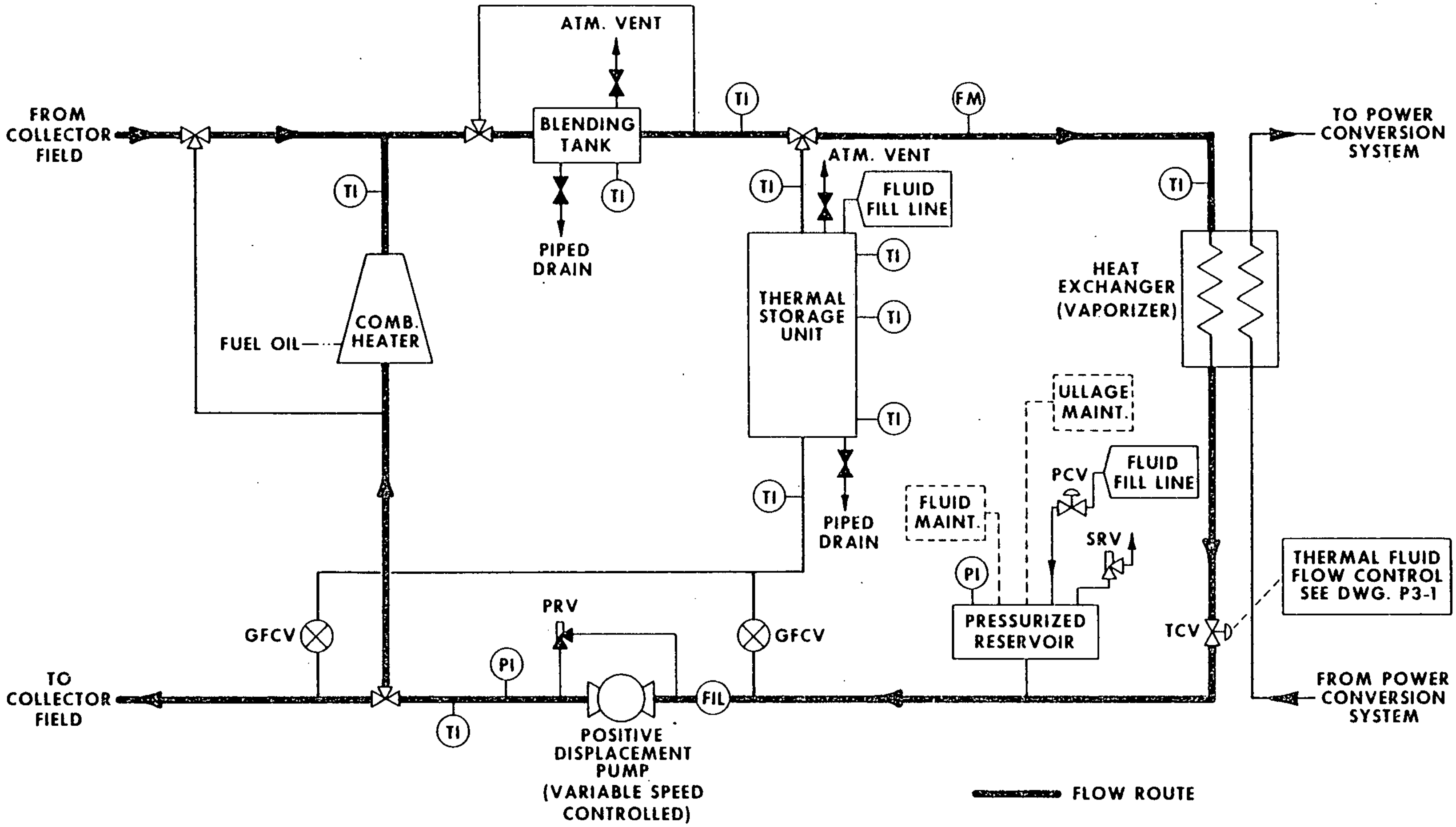


FIGURE 3.4–2. FIELD OPERATING AT TEMPERATURE BUT NOT AT FLOW RATE - OPERATIONAL PLAN SCHEMATIC

FLUID / THERMAL STORAGE LOOP

FIELD AT TEMPERATURE AND PROPER FLOW RATE

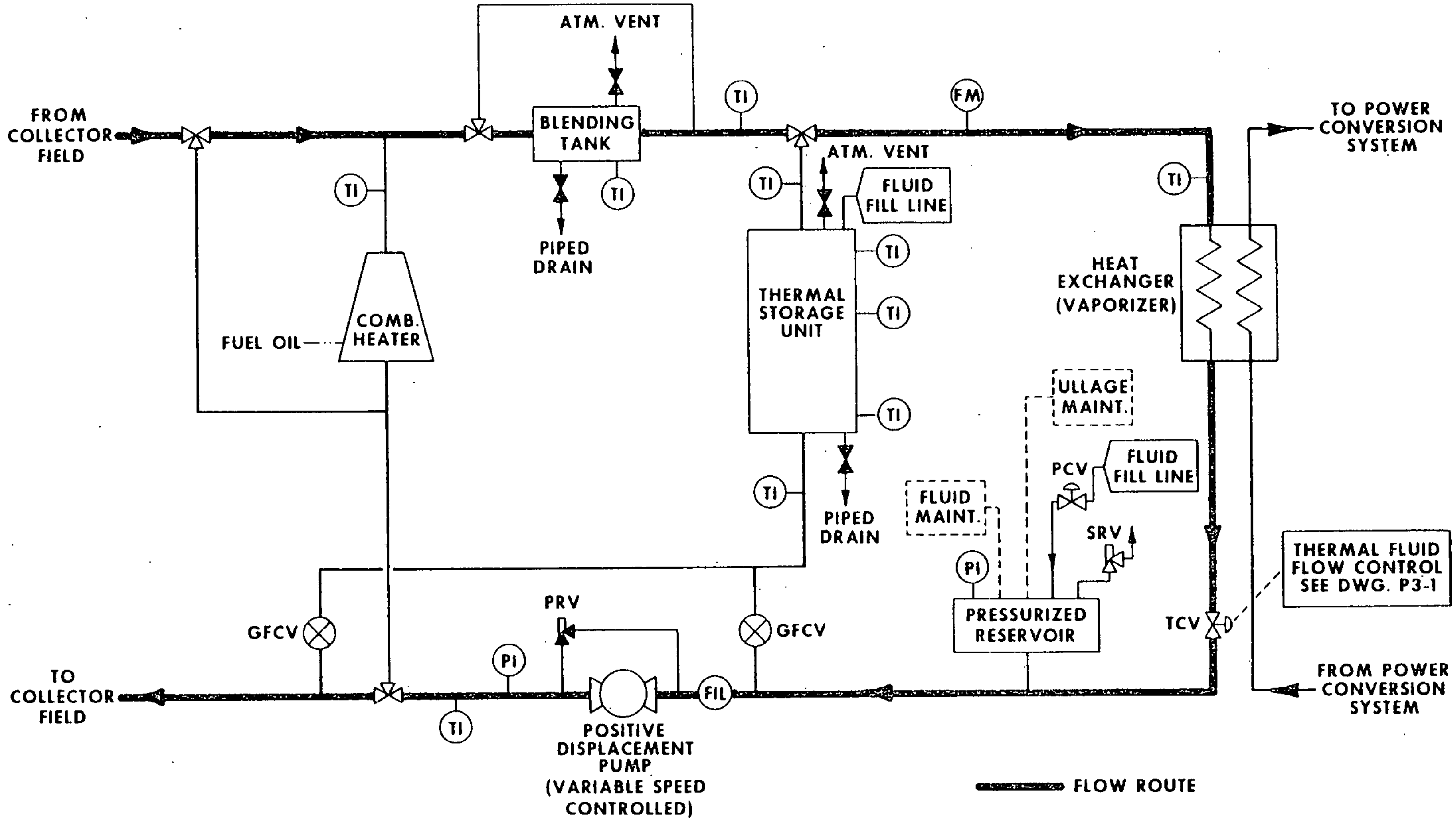


FIGURE 3.4–3. FIELD AT TEMPERATURE AND PROPER FLOW RATE - OPERATIONAL PLAN SCHEMATIC

FLUID / THERMAL STORAGE LOOP

OPERATION FROM STORAGE

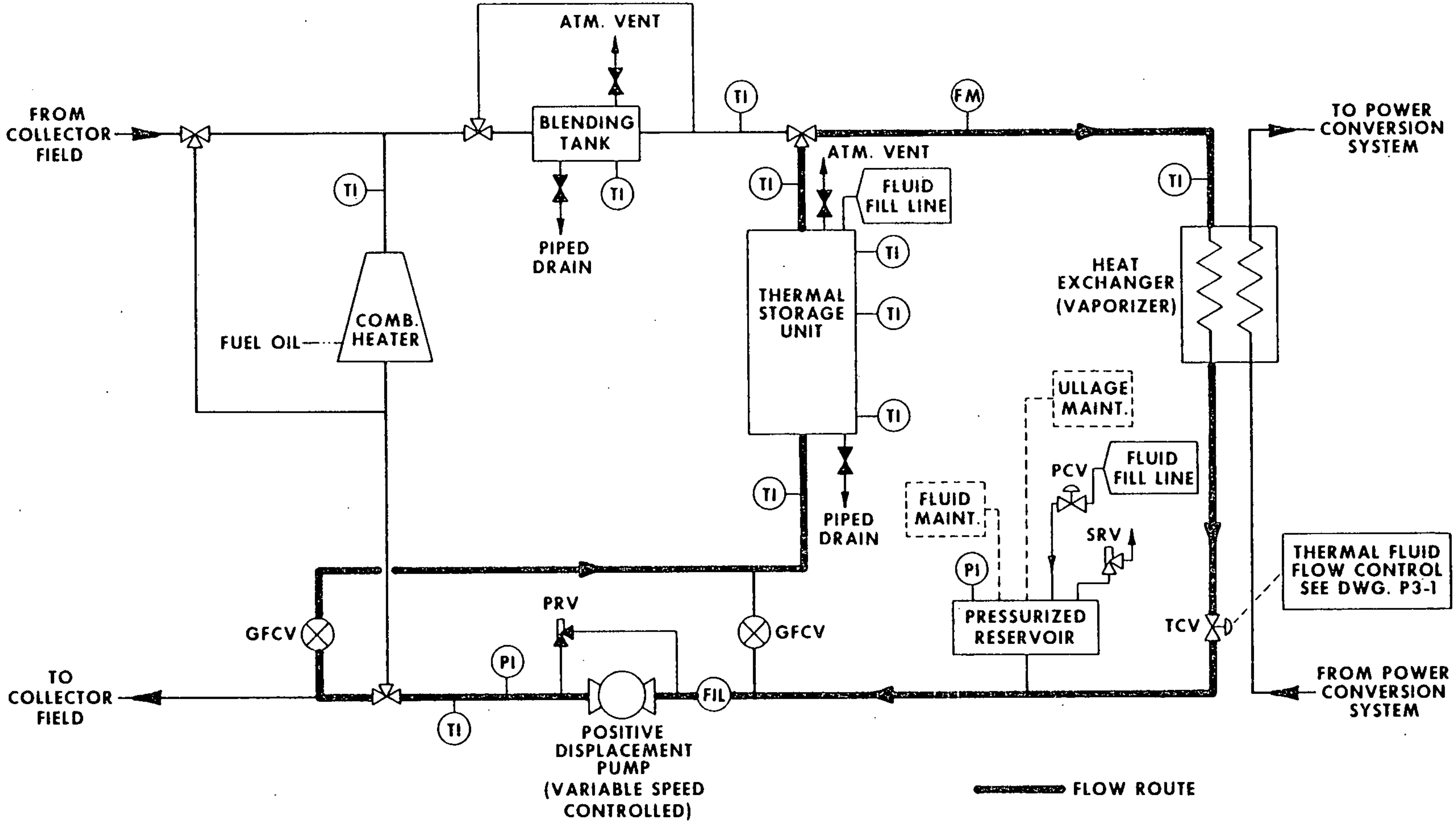


FIGURE 3.4–4. OPERATION FROM STORAGE - OPERATIONAL PLAN SCHEMATIC

3.4.5 WEEKEND COLLECTION (Figure 3.4–5)

During the weekend, since the knitting mill is not operating, all of the collected energy is stored. The operation is the same as previously described with the exception that the hot fluid is stored in the thermal storage unit.

3.4.6 STORAGE DEPLETED - OPERATION WITH HEATER (Figure 3.4–6)

For the case where energy collection from the field has stopped and storage has been depleted but the facility is still operating, the system will switch to operation with the modulating combustion heater. Sensing storage depletion, flow is diverted through the pump to the heater where the fluid is heated to the required 343°C (650°F). Temperature excursions are dampened with the blending tank, and the fluid continues to the heat exchanger where the necessary energy is extracted by the power conversion toluene Rankine Cycle.

3.4.7 TEST PLAN

3.4.7.1 COLLECTOR SUBSYSTEM

A. Cold Flow

Purpose: Verify collector flow loop integrity and hydraulic characteristics.

Procedure: Fill collector flow loop with heat transfer oil and pressurize to maximum operating pressure. Visually check for leaks. Flow oil through all flow loops. Add balancing orifices as required to equalize loop flow distribution.

B. System Startup

Purpose: Verify system startup in the postulated startup mode. Determine collector startup time. Establish outlet temperature to within the specified temperature range. Check out instrumentation and control subsystems. Leak check at operating temperature.

Procedure: Flow through collectors to heat oil to a selected level. Repeat at various flow rates. Monitor flow rate and fluid temperature sensors.

C. Steady State Performance

Purpose: Demonstrate system operational and performance characteristics during steady state operational periods. Verify control of the outlet fluid temperature within the specified temperature range.

FLUID / THERMAL STORAGE LOOP

WEEKEND COLLECTION

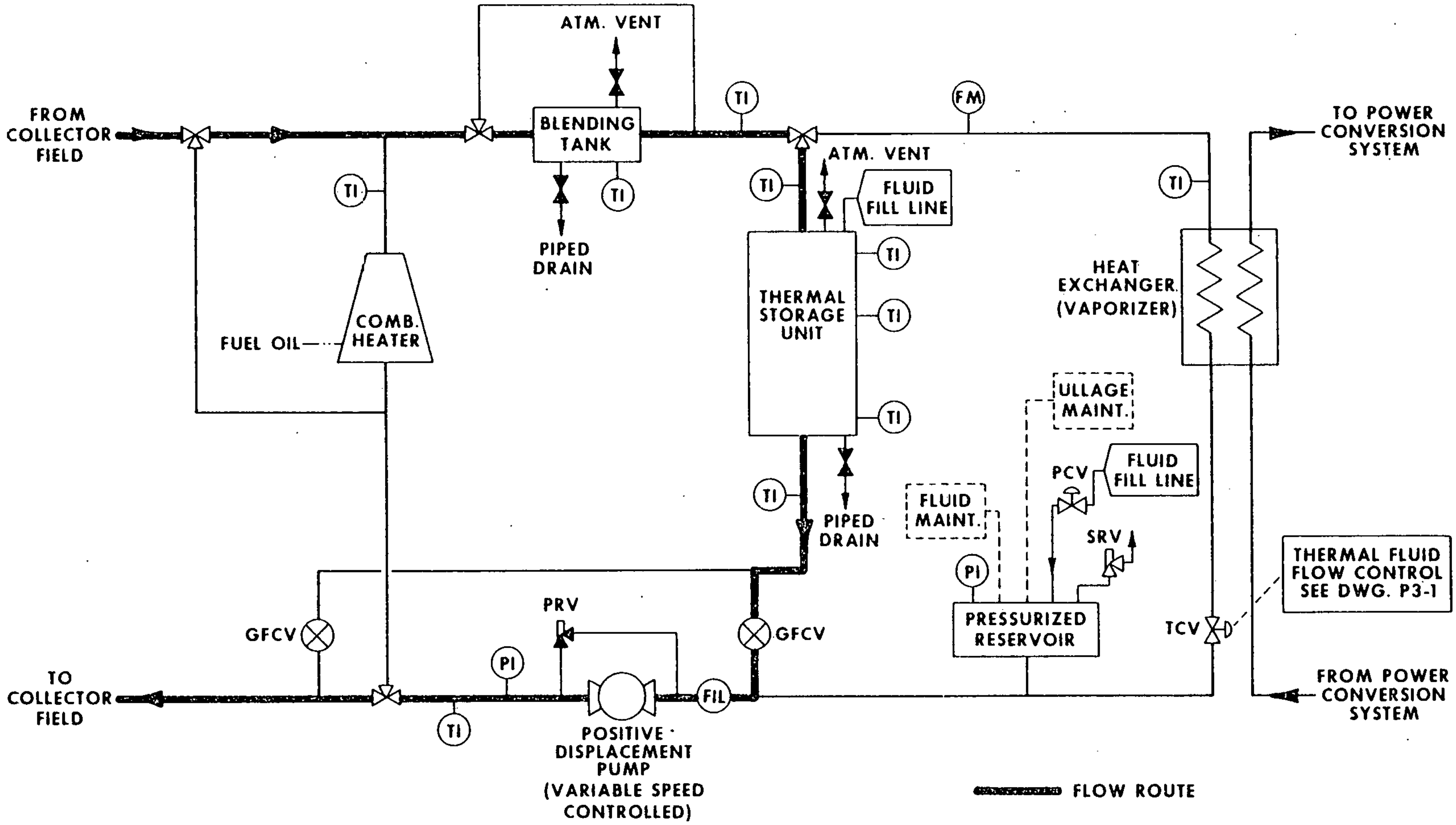


FIGURE 3.4–5. WEEKEND COLLECTION - OPERATIONAL PLAN SCHEMATIC

FLUID / THERMAL STORAGE LOOP

STORAGE DEPLETED, OPERATION WITH HEATER

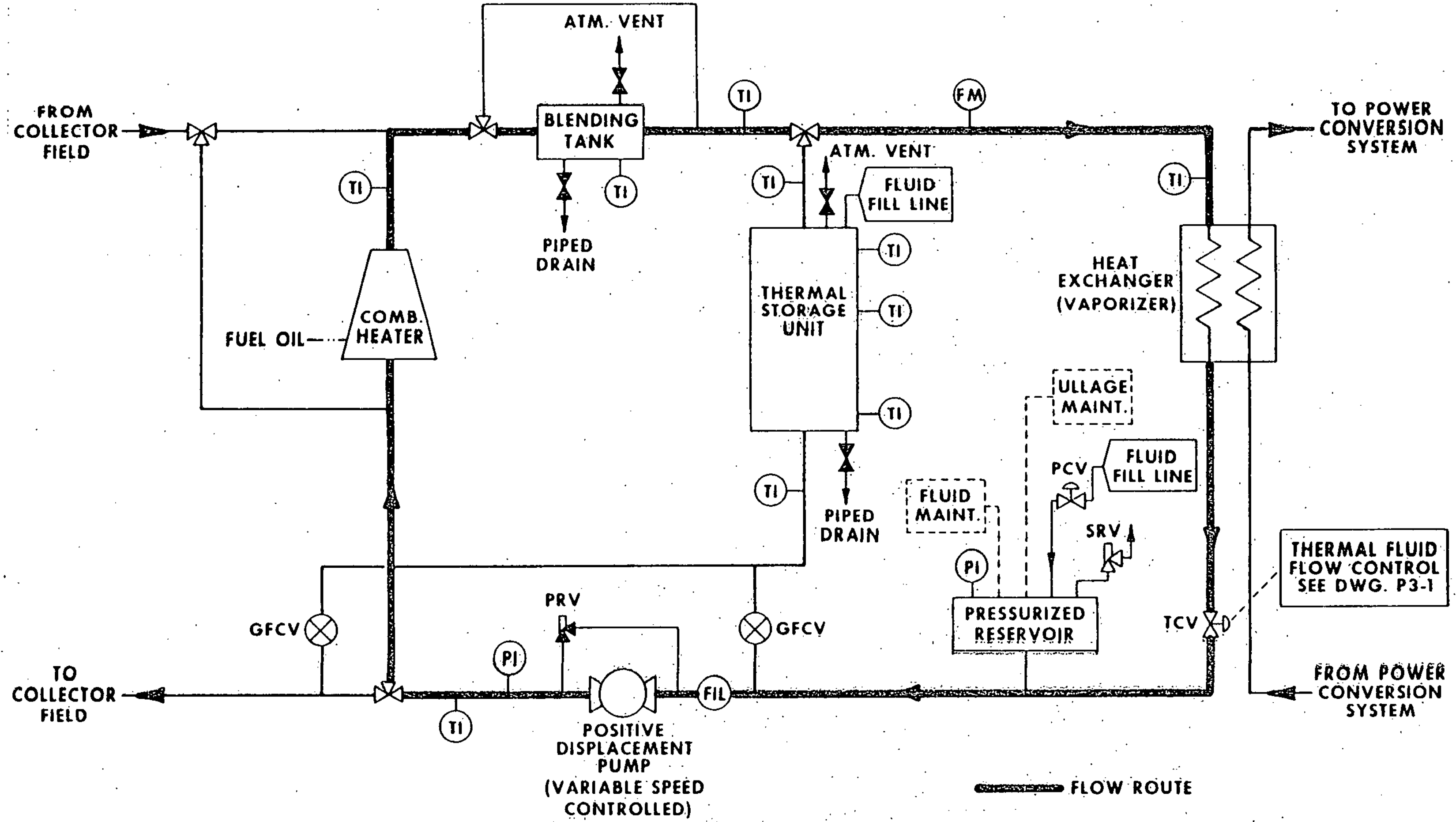


FIGURE 3.4–6. STORAGE DEPLETED, OPERATION WITH HEATER - OPERATIONAL PLAN SCHEMATIC

Procedure: Heat oil to selected level. Wait until oil reaches a reasonably steady state temperature; then obtain data at various flow rates.

D. Transient Operation

Purpose: Establish operational and control characteristics of subsystem during passage of cloud transients. Verify subsystem shutdown and defocusing procedures. Define operational limiting criteria.

Procedure: Flow through collectors to heat oil to a selected level. Repeat at various flow rates. Monitor flow rate and fluid temperature sensors. Perform test on partly cloudy day.

3.4.7.2 THERMAL STORAGE/FLUID LOOP

A. Test: Cold Flow All Loops

Purpose: Leak checks, valve operational check, pump checkout.

Procedure: Fill and pressurize fluid loop, pump at various flow rates through all various flow paths, monitor flow rates and visually check for leaks.

B. Test: Charge Thermal Storage with Heater

Purpose: Verify heater operation and performance, check out expansion overflow tank. Check out thermal storage instrumentation. Leak check at operational temperatures. Determine heat losses during hold at full capacity. Establish heater startup time.

Procedure: Fire up heater, bring up to temperature in two steps. Bring thermal storage up to operational return temperature 211°C (411°F), starting at T_{return} charge thermal storage to maximum operational temperature at 343°C (650°F), vary flow rate through range of expected collector field flow rates, monitor thermocline position during charging operations, lock up system for 24-hour hold once fully charged and monitor fluid temperatures throughout tank during hold to determine heat losses.

C. Test: Deplete Thermal Storage Via Heat Exchanger with Dummy Load

Purpose: Check out heat exchanger, verify storage performance during depletion, establish heat losses at various storage levels, simulate seasonal performance (flow rates).

Procedure: Flow out of storage through heat exchanger without load to bring heat exchanger up to temperature, once at temperature, run at various flow rates to simulate seasonal variation, monitor ΔT's across heat exchanger, monitor thermocline position during test. Hold at various levels of capacity and monitor fluid temperatures throughout tank to simulate overnight holds at less than full capacity to determine heat losses.

D. Test: Deplete Storage While Operating Heater in Parallel with Dummy Load

Purpose: Determine flow mixing capability of combined heater and storage operation.

Procedure: Same as C except with mixed flow. Vary heater flow to simulate collector field operation. Monitor mixing valve operation via flow rate monitor. Monitor pump operation to verify pump performance during dynamic flow conditions.

E. Test: Checkout of Ullage and Fluid Maintenance Units

Purpose: Verify operation and performance of ullage and fluid maintenance units, establish fluid losses during system operation at design loads.

Procedure: Operate ullage and fluid maintenance units during preceding tests, monitor inert gas pressures and flows, examine filters before and after above tests for particulate matter, establish amount of volatiles removed from system to determine fluid losses as a function of time.

F. Test: Charge Thermal Storage with Collector Field

Purpose: Determine and verify combined collector field thermal storage performance and operations.

Procedure: Same as A above except use collectors instead of heater.

G. Test: Deplete Storage in Parallel with Field Operation with Dummy Load

Purpose: Determine flow mixing capability of combined field/storage operation.

Procedure: Same as D above except use collectors instead of heater.

H. Test: All Up Systems Check

Purpose: Verify total system performance and operations.

Procedure: Run power conversion system off of parallel field/storage operation.

3.4.7.3 HEATER TESTS

(Other than above)

A. Test: Bring Field On Line with Heater

Purpose: Verify startup procedures.

Procedure: Run heater in series with field to warm up field, dump hot fluid into storage. Start with field and storage at ambient temperature, start with field at ambient temperature and storage at T_{return} 211°C (411°F).

3.4.7.4 POWER CONVERSION SYSTEM

A. System Tests

1. Hydrostatic Pressure Test

Pressure test all toluene piping and components to 1.5 times design pressure (PRV's and SRV's gagged). Hydrotest procedures and test fluids to be determined on Phase III and IV.

2. Safety Valve Set Pressure Check

Check pressure release settings of all toluene safety vavles using them as installed pressure indicators. These pressure indicators will be calibrated to standard dead weight gauges.

3. Cold Flow System Test

This test will verify the operation of the pumps, instrumentation control valves and control system under cold flow conditions. If the feed pumps are turbine shaft mounted then this test will use an electric motor driven startup pump.

4. Hot System Tests

A system test patterned after the ASME standard turbine test procedure will be used to determine the turbine performance at various steady state load points and during transient operation.

Sufficient test instrumentation will be installed and calibrated to measure turbine, heat exchanger and pump performance during these tests. Data will be obtained from all auxiliary equipment during this test to determine actual auxiliary power requirements.

B. Test Goals

Major test goals to be established during the hot system test are:

1. To verify toluene vaporizer performance during operation above the critical point of toluene. This includes the ability of the vaporizer to deliver toluene at the turbine design pressure and temperature over a range of toluene flow rates and thermal system heat input.

2. To verify turbine performance at the design point and to obtain data to calculate turbine efficiency and power output at off design points and to compare this actual performance with manufacturers predicted performance.

3. To verify heat exchanger performance, particularly the second stage condenser, which supplies heat to the absorption chiller and the first stage condenser/boiler, which supplies process steam. These heat exchanger performance data will be compared to design prediction.

4. To measure gross and net electrical output in Kilowatts and compare with predicted values.

5. To verify the overall system stability during steady state and transient operation, and to determine the adequacy of the control system.

3.4.7.5 PROCESS STEAM SYSTEM

A. System Tests

The following tests with the exception of Item (4) will be performed on the process steam system prior to the power conversion system tests described in 3.4.7.4.

1. Hydrostatic Pressure Test

   All process steam lines including the first stage condenser/boiler and condensate lines will be hydrostatically tested to 1.5 times design pressure.

2. Safety Valve Set Pressure Check

   Check pressure release settings of all steam and condensate safety valves using them as installed pressure indicators. These pressure indicators will be calibrated to standard dead weight gauges.

3. Cold Flow System Tests

   A cold flow test will be performed to verify operation of the condensate pump, instrumentation, control systems and water treatment systems. Temporary piping will be installed to return this softened water to the condensate storage tank.

4. Hot System Test

Hot steam/condensate system tests will be conducted in conjunction with the hot power conversion System Test described in paragraph 3.4.7.4.

B. Test Goals

1. To verify the integrity of the Process Steam System.

2. To verify the performance of the components in the Process Steam System.

3. To verify that the Process Steam System will deliver process steam to the factory at the required flowrate, pressure and temperature.

3.4.7.6 CIRCULATING WATER SYSTEM

A. System Tests

The following tests with the exception of Item (3) will be performed on the circulating water system prior to the Power Conversion Systems Tests described in 3.4.7.4.

1. Hydrostatic Pressure Test

All piping and components in the circulating water system will be hydrostatically tested to 1.5 times design pressure.

2. Cold Flow System Tests

A cold flow system test will be performed to verify operation of the various circulating water pumps, instrumentation, control systems and valves.

3. Hot System Test

A hot system test will be conducted in conjunction with the hot Power Conversion System tests described in 3.4.7.4. This test will include the following items:

Verify predicted performance of the absorption chiller by C.O.P. calculations from test data at various heat loads.

Verify predicted performance of the chiller cooling water system and cooling tower. Cooling tower performance will be determined from the Cooling Tower Institute standards.

Verify predicted performance of the air cooled heat exchanger.

Verify performance and perform system balances on the chilled water and hot water cooling and heating systems for the knitwear factory.

B. Test Goals

1. To verify the integrity of the Circulating Water System.
2. To verify the performance of the chilled water and hot water systems for factory cooling and heating.

SUBSECTION 3.5

3.5 COMPONENT AND SUBSYSTEM DEVELOPMENT

This section describes several items which will require further study and developmental tests during the Phases III and IV of this program. These development programs will provide the additional data required to prove the feasibility of the conceptual design described in this report.

3.5.1 COLLECTOR PERFORMANCE

A test program to verify collector performance at the proposed operating conditions should be conducted early in Phase III; unless, it can be adequately demonstrated by current ongoing tests that the collector performance assumed in Phase II is reliable and conservative.

3.5.2 THERMAL FLUID TEST PROGRAM

A test program or an existing data review to determine the temperature stability characteristic of the Therminol-66 should be initiated early in Phase III. The conceptual design presented in this report uses Therminol-66 at a maximum bulk temperature of 343.3°C (650°F) at the vaporizer and probably somewhat higher upstream of this point, a question of long term temperature stability of the Therminol may be raised. The maximum allowable Therminol-66 film temperature is reported to be 373.9°C (705°F).

The test program would be a laboratory program consisting of measuring the thermal degradation of the fluid as functions of time and temperature. If there are already sufficient stability data on the Therminol-66, then a data review would be sufficient. The Phase III preliminary design will also define the temperature distribution of the Therminol-66 system to identify any possible hot spot areas.

3.5.3 ORGANIC TURBINE AND POWER CONVERSION SYSTEM

At the start of Phase III a decision must be made on the following two choices:

(1) Should the Organic Rankine Cycle (ORC) power conversion system be purchased as separate components from several suppliers and assembled and checked out by the engineer/constructor.

(2) Should the ORC power conversion system be purchased as a completely checked out and developed system by a single supplier.

If choice (1) is made, the component development program would be restricted to the turbine and the speed reducer since all the other components would be expected to be standard supplier designs. Choice (1) would also provide the greatest number of qualified component suppliers for bidding purposes.

Choice (1) however, would present a great number of interface problems between the component suppliers and the engineer/constructor. Also choice (1) may compromise system design since, in these systems, the turbine, feed pump, regenerator and condenser designs are usually an integrated skid mounted unit, with flow paths, pressure losses, controls and packaging considered as a system.

If choice (2) is made the number of qualified ORC system suppliers would be greatly reduced. To our knowledge the only two qualified system suppliers would be:

(1) Sundstrand Energy Systems, Rockford, Illinois
(2) Barber-Nichols Engineering Co., Arvada, Colorado

These two companies are primarily turbine designers who have supplied both organic turbines and complete ORC systems.

If either of choices (1) or (2) is made, it is considered extremely important that the turbine supplier be used to evaluate the conceptual design; as proposed, since the turbine/gearbox/feed pump will most likely be the major development item.

Sundstrand and Barber-Nichols have been contacted during the Phase II conceptual design, and have indicated the two-stage turbine, supercritical cycle is feasible from a turbine design standpoint. Sundstrand expressed some concern as to the closeness of the turbine design point to the critical point of toluene and to the complexity and cost of the two-stage turbine concept. Sundstrand has indicated they have a 600 KW, subcritical, toluene, single-stage turbine ORC system under contract with ERDA, and they would prefer to propose a modified design of this 600 KW unit.

3.5.4 RECOMMENDATIONS

Based on the above discussion the following recommendations are made:

Verify collector performance at the proposed operating conditions.

To have Monsanto Chemical Company run a thermal stability test program, or a review of existing data on Therminol-66 to verify its long term suitability for use at temperatures of 343.3°C (650°F) and higher.

The ORC power conversion system should be purchased as a completely developed system from a single supplier [Choice (2) above].

Early in Phase III a bidder list of qualified ORC system suppliers should be prepared.

The qualified ORC system bidders should be sent RFP's describing the conceptual design developed in Phase II and requesting as response to this RFP the following:

(a) Feasibility of conceptual design.

(b) Proposed alternates to the conceptual design.

(c) Engineering development and delivery costs of 1, 10, 100 systems and schedule for the bidders proposed design.

(d) Experience statement in regard to ORC system design.

SUBSECTION 3.6

3.6 PROCUREMENT PLAN

Table 3.6–1 shows the estimated procurement lead times for the major items of the STES process and electrical equipment. These lead times are from award of contract.

The equipment lead time data were developed from Stearns-Roger purchasing sources and contacts with the various manufacturers. Much of this equipment is standard with the power industry and delivery data should therefore be reliable.

Early procurement is essential for two items: solar collectors and power conversion system. Approved bidders and procurement specifications should be given highest priority for these items during Phase III and IV.

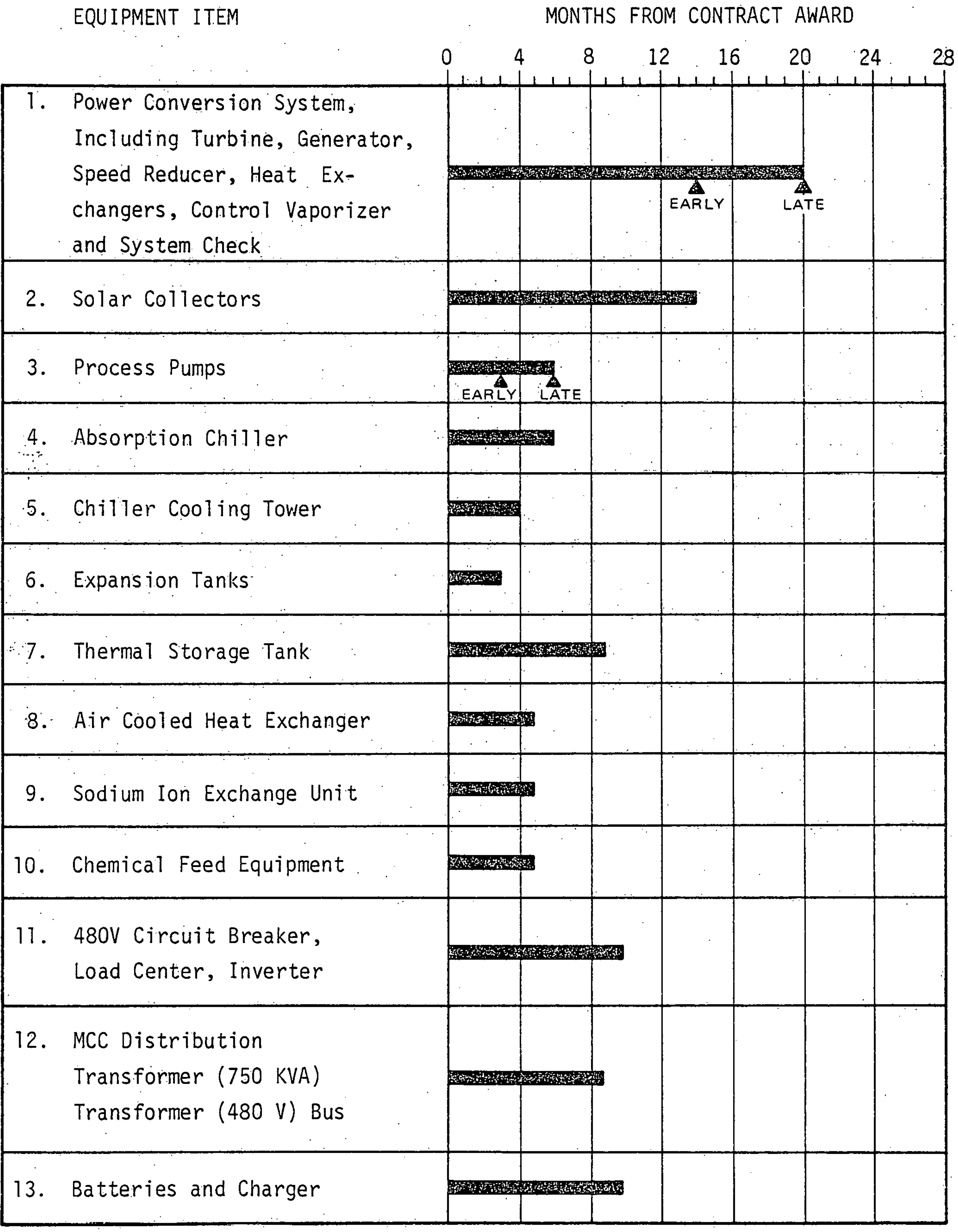


TABLE 3.6–1. MAJOR EQUIPMENT PURCHASE LEAD TIMES

SUBSECTION 3.7

3.7 SCHEDULING AND COST ESTIMATING

This subsection contains the anticipated program schedule and cost estimates, which may be expected for the base line concept presented within this report. Overall program schedule has been developed utilizing best effort time line approach, and includes manufacturers best estimate on delivery of long lead items of equipment. Cost estimates have been developed utilizing 1977 dollars, with a methodology as detailed herein.

3.7.1 SCHEDULING

The proposed STES NO. 2, program schedule for Phases III through VI, is presented as Figure 3.7–1. Details of methodology of schedule development are presented in the following:

3.7.1.1 ENGINEERING SCHEDULE (PHASES III AND IV)

Schedule for accomplishment of Phase III and IV was based on the utilization of engineering manpower loading, required for the preliminary and detailed design of the system and facility. Recognition of the need for early procurement of major long lead equipment items, dictates the concentration of effort on finalization of the concept design and development of procurement specifications, as well as timely procurement of the specific equipment items. A more detailed Schedule of Phases III and IV is presented in Subsection 3.8, Technical and Management Plans.

3.7.1.2 PROCUREMENT

Manufacturers of these long lead equipment items were contacted directly to obtain their best effort estimate of time required for bidding, preparing shop approval drawings, manufacturing and delivering the specific items. These estimates were used directly without allowance for possible long term test verification.

3.7.1.3 INSTALLATION SCHEDULE (PHASE V)

In order to establish a construction schedule, a group of Stearns-Roger specialists reviewed the proposed baseline concepts. This group consisted of STES project management and engineers, personnel from our construction department, cost estimators and schedulers. The cost estimate, craft labor requirements, methodology of construction sequencing, and equipment delivery schedules were analyzed to determine the resultant proposed construction schedule.

3.7.1.4 TEST AND OPERATIONS (PHASE VI)

A two-year test and operations (Phase VI) period is indicated following completion of construction. This phase of the operation was taken from the initial schedule established by ERDA.

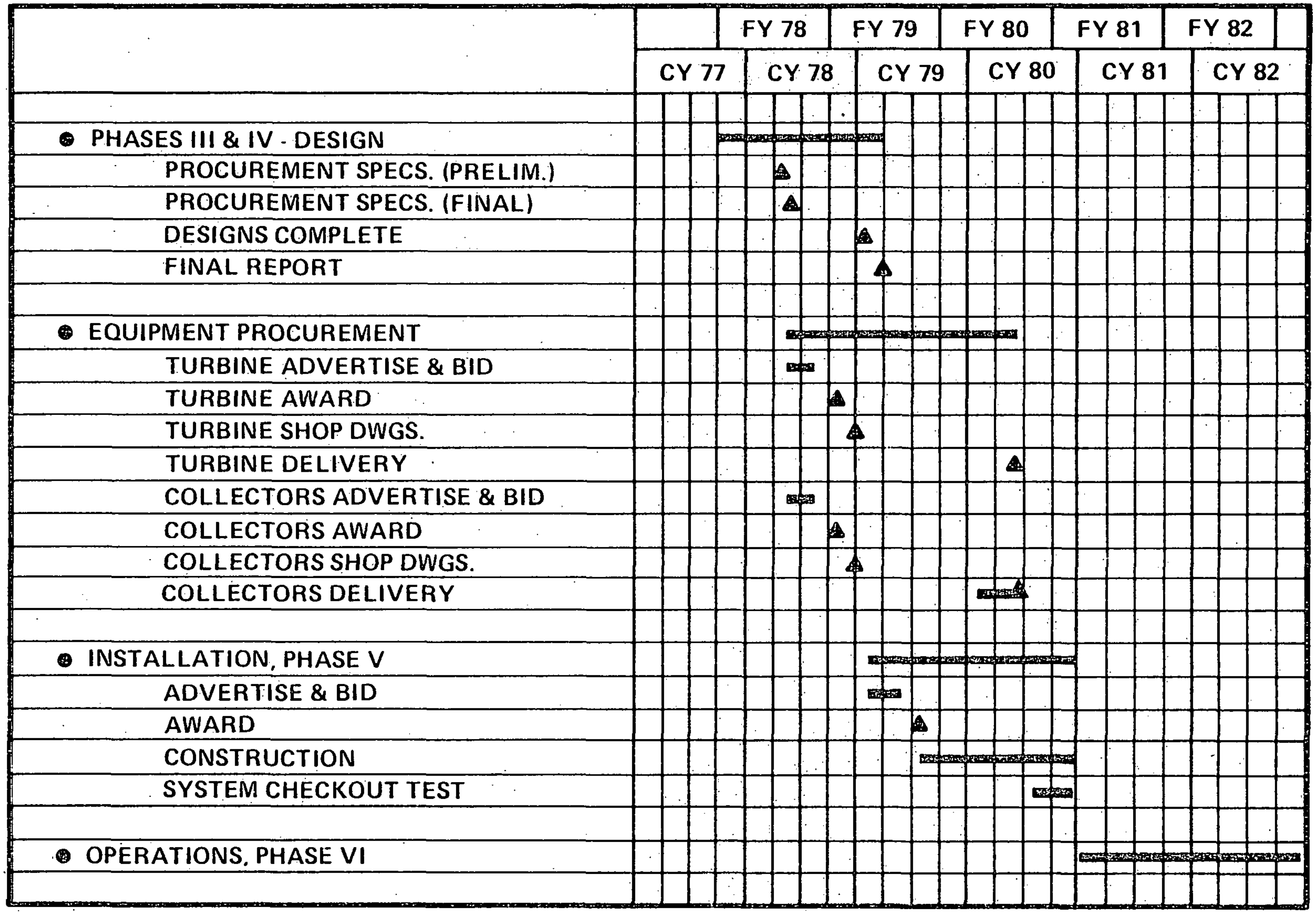


FIGURE 3.7–1. PROPOSED SCHEDULE - PHASE III THROUGH VI

3.7.1.5 CRITICAL PATH

The critical path of the proposed program schedule is probably:

Finalization of concept design
Finalization of procurement specifications
Award of long lead equipment items
Delivery of long lead equipment items

3.7.2 COST ESTIMATES

The estimates of cost for the proposed STES are presented herein. These include estimates for capital cost, maintenance and operating cost (including spare parts) and cost of the two-year test and operation phase (Phase VI). The methodology for cost estimating is also presented. The general ATU format has been utilized in the top level presentation of all cost items.

3.7.2.1 CAPITAL COST

Collector module cost is based on estimates obtained from the proposed trough manufacturers (Acurex Company). In compiling estimates for 10 and 100 systems, Acurex indicates no reduction for 10 systems, and only a slight reduction for 100 such systems.

Estimates for the thermal storage tank were developed from cost studies previously conducted for the proposed 10 MW pilot plant at Barstow, California.

Estimates for all other major items of equipment and materials, including the turbines, were made from manufacturers quotations. All other items of material and labor hours were derived from the historical data of the Stearns-Roger Estimating Department. This historical data is continually accumulated and updated, as projects proceed and are completed. Richardson Estimating Manual and Means Building Construction Cost Data were also used.

Indirect field costs were derived from the historical records maintained by Stearns-Roger, which indicate that for this size and type of project, indirects will be approximately 70 percent of total direct labor cost.

Labor rates of construction personnel are actual averages which are expected in the Shenandoah, Georgia, area. A Labor Rate Study survey for craft workers rates, was conducted for the area. Results of this survey are listed on Table 3.7–1.

Estimates of capital cost of this baselined STES, is presented in ATU format in Table 3.7–2. All backup estimates and further breakdown may be found in Appendix B.

In addition capital cost estimates for 10th and 100th plant are presented in Tables 3.7–3 and 3.7–4 respectively.

CRAFT	RATE EXP DATE	J M RATE	FOREMAN DIFF	HEALTH & WELFARE	VACATION	IND FUND	PENSION	APPT	SUBSIST	SUB-TOTAL	ESCAL	AVERAGE EST RATE
ASBESTOS WORKERS	6/30/77	9.35	--	.45	--	--	.50	.05	--	10.35	2%	10.56
BOILERMAKERS	10/31/77	9.50	1/3 .20	.75	--	--	1.00	.02	.75	12.22	--	12.22
BRICKLAYERS	6/30/78	9.25	1/4 .10	.55	(DEDUCT) --	.08	.50	.05	--	10.53	--	10.53
CARPENTERS	6/30/79	9.35	1/4 .15	.40	--	--	.45	.02	--	10.37	--	10.37
CEMENT MASONS	6/30/78	8.75	1/4 .10	.40	--	--	.55	--	--	9.80	--	9.80
ELECTRICIANS	7/31/77	10.10	1/4 .18	.91	(DEDUCT) --	--	.81	.05	--	12.05	--	12.05
IRONWORKERS	1/1/78	9.25	1/4 .15	.55	--	--	.57	.07	--	10.59	--	10.59
LABORERS (C)												
LABORERS (SS)		6.22	1/4 .17	.25	--	--	.33	.05	--	7.02	--	7.02
MILLWRIGHTS	1/1/78	9.20	1/2 .17	.45	--	--	.50	.05	--	10.37	--	10.37
OPERATING ENG (M)	6/30/78	7.15	--	.50	--	--	.75	.07	--	8.47	--	8.47
PAINTERS (S)	6/30/78	9.50	1/3 .07	.45	--	--	.65	.05	--	10.72	--	10.72
PIPEFITTERS	7/31/78	9.95	1/4 .12	.65	(DEDUCT) --	.08	.50	--	--	11.30	--	11.30
SHEET METAL	2/1/78	9.90	--	.50	--	.09	.81	.04	--	11.34	--	11.34
TEAMSTERS (M)	6/30/77	6.55	--	.15	--	--	--	--	--	--	2%	6.83

TABLE 3.7–1. LABOR RATE STUDY FOR SHENANDOAH, GEORGIA

ESTIMATE NO. CAPITAL COST (FOR ONE SYSTEM)
SHEET 1 OF 2
CUSTOMER ERDA/ALO
DATE 9-15-77
JOB STES NO. 2, SHENANDOAH, GEORGIA
JOB No. 19650
BY REW

	WEIGHT OR QUAN.	HOURS	LABOR ($000)	MATERIAL ($000)	OTHER ($000)	TOTAL ($000)
DIRECT COST - Collector Field						
Modules	6,983M^2		194	734	42	970
Piping, ET AL			32	594	41	667
Site Construction Materials			151	198	13	362
Packing, Shipping and Inspection			-	75	-	75
TOTAL COLLECTOR FIELD			377	1,601	96	2,074
Energy Plant						
Turbine and Turbine Generator System			102	677	-	779
Piping and Miscellaneous Equipment			65	180	-	245
Thermal Storage			2	19	515	536
Thermal Storage Piping and Miscellaneous Equipment			8	24	10	42
Buildings and Miscellaneous			108	165	-	273
Yard Work			34	9	66	109
Packing, Shipping and Inspection			-	50	-	50
TOTAL ENERGY PLANT			320	1,124	591	2,034
Interfacing Equipment Control and Display System						
Electrical Equipment			115	523	-	638
Instruments and Controls			90	210	-	300
TOTAL INTERFACING EQUIPMENT AND ETC			205	733	-	938
TOTAL DIRECT FIELD COST			901	3,458	687	5,046

TABLE 3.7–2. CAPITAL COSTS FOR ONE SYSTEM (Sheet 1 of 2)

ESTIMATE NO. CAPITAL COST (FOR ONE SYSTEM)
CUSTOMER ERDA/ALO
JOB STES NO. 2, SHENANDOAH, GEORGIA
JOB No. 19650
SHEET 2 OF 2
DATE 9-15-77
BY REW

	WEIGHT OR QUAN.	HOURS	LABOR	MATERIAL	OTHER ($000)	TOTAL ($000)
INDIRECT COSTS - Field Expense, Insurance, P.R. Tax, Bond, etc.					252	252
Construction Supplies					44	44
Startup					51	51
Temporary Facilities					95	95
Construction Equipment					189	189
TOTAL INDIRECT COST (70% of Labor)					631	631
TOTAL FIELD COST						5,677
Engineering						1,200
Sales Tax (5% of material)						173
Escalation						-0-
Contingency (10%)						705
Fee (10%)						775
TOTAL ESTIMATED COST (1 system)						8,530

TABLE 3.7–2. CAPITAL COSTS FOR ONE SYSTEM (Sheet 2 of 2)

ESTIMATE NO. CAPITAL COST (TENTH PLANT)
SHEET 1 OF 2
CUSTOMER ERDA/ALO
DATE 9-15-77
JOB STES NO. 2, SHENANDOAH, GEORGIA
JOB No. 10650
BY REW

	WEIGHT OR QUAN.	HOURS	LABOR ($000)	MATERIAL ($000)	OTHER ($000)	TOTAL ($000)
DIRECT COST - Collector Field						
Modules	$6.983M^2$		194	643	42	879
Piping, ET AL			32	570	41	643
Site Construction Materials			151	198	14	363
Packing, Shipping and Inspection			-0-	75	-0-	75
TOTAL COLLECTOR FIELD			377	1,486	97	1,960
Energy Plant						
Turbine and Turbine Generator System			102	643	-0-	745
Piping and MISC Equipment			66	173	-0-	239
Thermal Storage			2	19	438	459
Thermal Storage Piping and MISC Equipment			8	22	9	39
Buildings and Miscellaneous			108	165	-0-	273
Yard Work			34	9	66	109
Packing, Shipping and Inspection			-0-	50	-0-	50
TOTAL ENERGY PLANT			320	1,081	513	1,914
Interfacing Equipment, Control and Display System						
Electrical Equipment			115	523	-0-	638
Instruments and Controls			90	206	-0-	296
TOTAL INTERFACING EQUIPMENT ANC ETC.			205	729	-0-	934
TOTAL DIRECT FIELD COST			902	3,296	610	4,808

TABLE 3.7–3. CAPITAL COSTS FOR TENTH PLANT (Sheet 1 of 2)

ESTIMATE NO. CAPITAL COST (TENTH PLANT)
CUSTOMER ERDA/ALO
JOB STES NO. 2, SHENANDOAH, GEORGIA
JOB No. 19650
SHEET 2 OF 2
DATE 9-15-77
BY REW

	WEIGHT OR QUAN.	HOURS	LABOR	MATERIAL	OTHER ($000)	TOTAL ($000)
INDIRECT COSTS - Field Expense, Insurance, P.R. Tax, Bond, ETC					252	252
Construction Supplier					44	44
Startup					51	51
Temporary Facilities					95	95
Construction Equipment					189	189
TOTAL INDIRECT COST					631	631
TOTAL FIELD COST						5,612
Engineering						654
Sales Tax (5% of material)						170
Escalation						-0-
Contingency						644
Fee						708
TOTAL ESTIMATED COST (10 systems)						7,788

TABLE 3.7–3. CAPITAL COSTS FOR TENTH PLANT (Sheet 2 of 2)

ESTIMATE NO. CAPITAL COST (ONE-HUNDREDTH PLANT) SHEET 1 OF 2
CUSTOMER ERDA/ALO DATE 9-15-77
JOB STES NO. 2, SHENANDOAH, GEORGIA JOB No. 19650 BY REW

	WEIGHT OR QUAN.	HOURS	LABOR ($000)	MATERIAL ($000)	OTHER ($000)	TOTAL ($000)
DIRECT COST - Collector Field						
Modules	$6.983M^2$		194	733	42	969
Piping, ET AL			32	583	41	656
Site Construction Materials			151	198	14	363
Packing, Shipping and Inspection			-0-	75	-0-	75
TOTAL COLLECTOR FIELD			377	1,589	97	2,063
Energy Plant						
Turbine and Turbine Generator System			102	657	-0-	759
Piping and MISC Equipment			66	177	-0-	243
Thermal Storage			2	19	490	511
Thermal Storage Piping and MISC Equipment			8	22	9	39
Buildings and Miscellaneous			108	165	-0-	273
Yard Work			34	9	66	109
Packing, Shipping and Inspection			-0-	50	-0-	50
TOTAL ENERGY PLANT			320	1,099	565	1,984
Interfacing Equipment, Control and Display System						
Electrical Equipment			115	523	-0-	638
Instruments and Controls			90	206	-0-	296
TOTAL INTERFACING EQUIPMENT AND ETC.			205	729	-0-	934
TOTAL DIRECT FIELD COST			902	3,417	662	4,981

TABLE 3.7-4. CAPITAL COSTS FOR ONE-HUNDREDTH PLANT (Sheet 1 of 2)

ESTIMATE NO. CAPITAL COST (ONE-HUNDREDTH PLANT)
CUSTOMER ERDA/ALO
JOB STES NO. 2, SHENANDOAH, GEORGIA
JOB No. 19650
SHEET 2 OF 2
DATE 9-15-77
BY REW

	WEIGHT OR QUAN.	HOURS	LABOR	MATERIAL	OTHER ($000)	TOTAL ($000)
INDIRECT COSTS - Field Expense, Insurance, P.R. Tax, Bond, ETC					252	252
Construction Supplier					44	44
Startup					51	51
Temporary Facilities					95	95
Construction Equipment					189	189
TOTAL INDIRECT COST					631	631
TOTAL FIELD COST						5,439
Engineering						380
Sales Tax (5% of material)						165
Escalation						-0-
Contingency						560
Fee						616
TOTAL ESTIMATED COST (One hundredth system)						7,160

TABLE 3.7–4. CAPITAL COSTS FOR ONE-HUNDREDTH PLANT (Sheet 2 of 2)

All costs contained herein are presented in current (1977) dollars. No allowance has been made for escalation.

3.7.2.2 OPERATING AND MAINTENANCE COST

Operating and maintenance (O & M) cost has been developed from information contained in Subsection 2.7, Reliability Assessment, and Subsection 3.4, Operation Plan. In addition, Stearns-Roger historical data and experience in commercial plant operations, was utilized in determining additional labor and equipment requirements. The summary of these O & M costs are presented on Table 3.7–5.

3.7.2.3 TEST AND OPERATION COST (PHASE VI)

Cost estimates for the Phase VI, two year Test and Operation program, were developed utilizing similar Stearns-Roger experience on other R & D facilities. The labor requirements were based on the assumption of providing full time field engineers and technicians, and home office management, engineering, computer and technical publication support. Summary of Phase VI cost estimate is presented in Table 3.7–6.

ESTIMATE NO. YEARLY OPERATIONAL & MAINTENANCE COST
SHEET 1 OF 2
CUSTOMER ERDA/ALO
DATE 9-15-77
JOB STES NO. 2, SHENANDOAH, GEORGIA
JOB No. 19650
BY REW

	WEIGHT OR QUAN.	HOURS	LABOR ($000)	MATERIAL ($000)	OTHER ($000)	TOTAL ($000)
Labor						
Manager	1	2,080	28,000			28,000
Secretary	1	2,080	7,200			7,200
Operators	5	-	70,000			70,000
Maintenance Personnel	2	-	35,000			35,000
Janitorial & Cleanup	-	-			6,200	6,200
SUBTOTAL LABOR						146,400
Overhead (@20%)						29,200
G & A (@5%)						7,800
Fee (@8%)						15,600
TOTAL LABOR (PER YEAR)						199,000
O & M Equipment (Rental)						
Pickup Truck	1					3,300
Cleaning Rig	1					9,000
Cherry Picker (Hoist)	1					4,200
Electric Carts	2					3,300
Small Tools & Supplies	-					1,200
TOTAL EQUIPMENT						21,000

TABLE 3.7–5. YEARLY OPERATING AND MAINTENANCE COSTS (Sheet 1 of 2)

ESTIMATE NO. YEARLY OPERATIONAL & MAINTENANCE COST
SHEET 2 OF 2
CUSTOMER ERDA/ALO
DATE 9-15-77
JOB STES NO. 2, SHENANDOAH, GEORGIA
JOB No. 19650
BY REW

	WEIGHT OR QUAN.	HOURS	LABOR	MATERIAL	OTHER	TOTAL ($000)
<u>Spare Parts</u> (Yearly)						
Collector Field						6,380
Thermal Storage						4,640
Energy Plant & Controls						6,980
Fluid (replacement, 10%/YR)						40,000
						48,000
TOTAL O & M COST (PER YEAR)						$268,000

TABLE 3.7–5. YEARLY OPERATING AND MAINTENANCE COSTS (Sheet 2 of 2)

ESTIMATE NO. 2 YEAR TEST & OPERATIONS (PHASE VI)
SHEET 1 OF 2
CUSTOMER ERDA/ALO
DATE 9-15-77
JOB STES NO. 2, SHENANDOAH, GEORGIA
JOB No. 19650
BY REW

	WEIGHT OR QUAN.	HOURS	LABOR ($000)	MATERIAL	OTHER	TOTAL ($000)
LABOR						
Project Manager (½ time)	1	2,080	32,000			32,000
Field Engineer	1	4,160	44,000			44,000
Technicians (Field)	2	8,320	80,000			80,000
Project Engineer	1	4,160	52,000			52,000
Senior Engineers (½ time)	4	8,320	104,000			104,000
Data Reduction	1	4,080	36,000			36,000
Data Reporting	1	4,080	48,000			48,000
SUBTOTAL						396,000
Field Overhead (20% of 124 K)						25,000
Office Overhead (50% of 272 K)						136,000
TOTAL LABOR						557,000

TABLE 3.7–6. TWO-YEAR TEST AND OPERATIONS (PHASE VI) COSTS (Sheet 1 of 2)

ESTIMATE NO. 2 YEAR TEST & OPERATIONS (PHASE VI) SHEET 2 OF 2
CUSTOMER ERDA/ALO DATE 9-15-77
JOB STES NO. 2, SHENANDOAH, GEORGIA JOB No. 19650 BY REW

	WEIGHT OR QUAN.	HOURS	LABOR	MATERIAL	OTHER	TOTAL ($000)
OTHER COST						
Communications ($150/month)						3,600
Reproduction ($120/month)						2,880
Computer Time ($500/month)						12,000
Travel Per Diem ($1,000/month)						24,000
TOTAL OTHER COST						42,000
TOTAL LABOR & OTHER COST						599,480
G & A @5%						29,970
Fee						75,550
TOTAL						705,000
O & M						
(See Table 3.7-4) $268,000/YR x 2 YRS						536,000
TOTAL, PHASE VI						1,242,000

TABLE 3.7–6. TWO-YEAR TEST AND OPERATIONS (PHASE VI) COSTS (Sheet 2 of 2)

SUBSECTION 3.8

3.8 TECHNICAL AND MANAGEMENT PLAN

This subsection represents the Stearns-Roger Engineering Company proposed Technical and Management Plan to accomplish Phase III and IV of the STES, Shenandoah, Georgia project. The organizational chart, indicating the key personnel proposed to be used on this project, is presented on Figure 3.8–1. It is possible to compress the time initially scheduled for these two phases (10 months for Phase III and 12 months for Phase IV) to a total of 16 months, by combining both phases into one. To this end, the following is presented for the accomplishment of Phase III only, and for the combined Phases III and IV.

3.8.1 TECHNICAL PLAN FOR PHASE III

The following subparagraphs present the proposed Technical Plan for Phase III, Preliminary Design.

3.8.1.1 WORK BREAKDOWN STRUCTURE

Figure 3.8–2 is the proposed Work Breakdown Structure (WBS) for Phase III of the STES project. The five digit account numbers were developed as follows:

> The first digit (2xxxx) represents this project as being the second in a series of proposed STE/LSE projects.
>
> The second digit (x3xxx) represents Phase III of this STES.
>
> The third digit (xx2xx) identifies the major categories of work to be accomplished.
>
> The fourth digit (xxx4x) identifies the subtask. The combination of the third and fourth digits, identifies specific tasks as outlined in the Statement of Work (SOW).
>
> The fifth digit (xxxx0) is utilized where a further breakdown of the SOW is required to better definitize the effort and for better management control of the task effort.

3.8.1.2 PHASE III SCHEDULE

Figure 3.8–3 presents the proposed schedule for accomplishment of the Preliminary Design. This schedule assumes that the Phase II conceptual designs are relatively complete, and that a final discussion on the system process and major components will be made within the time schedule indicated.

3.8.1.3 MANPOWER LOADING

Each task of the SOW has been reviewed by a team of individuals who will be assigned to this project; they are familiar with and have experience in, the fields

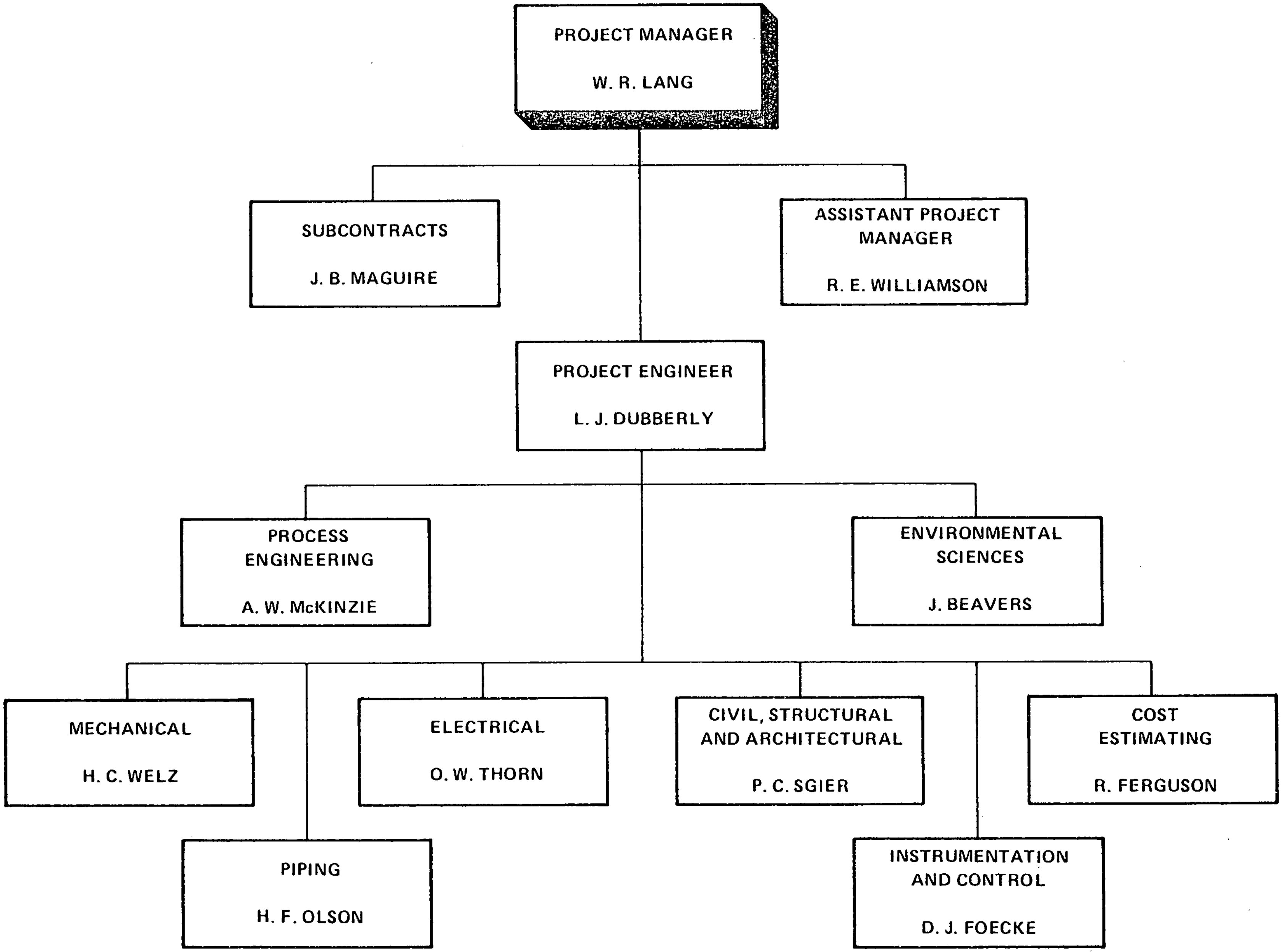


FIGURE 3.8–1. PROPOSED ORGANIZATION CHART - STES PHASE III

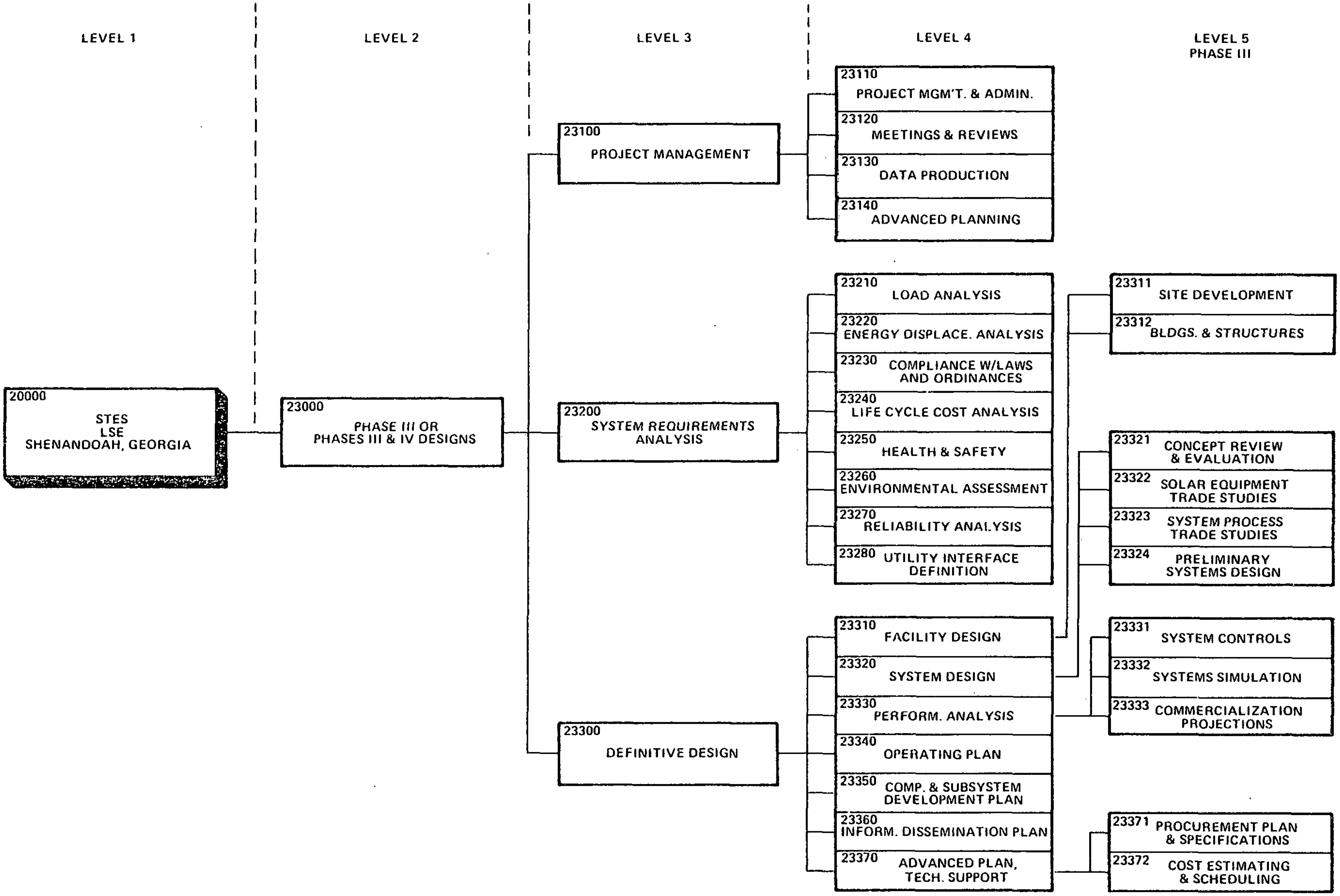
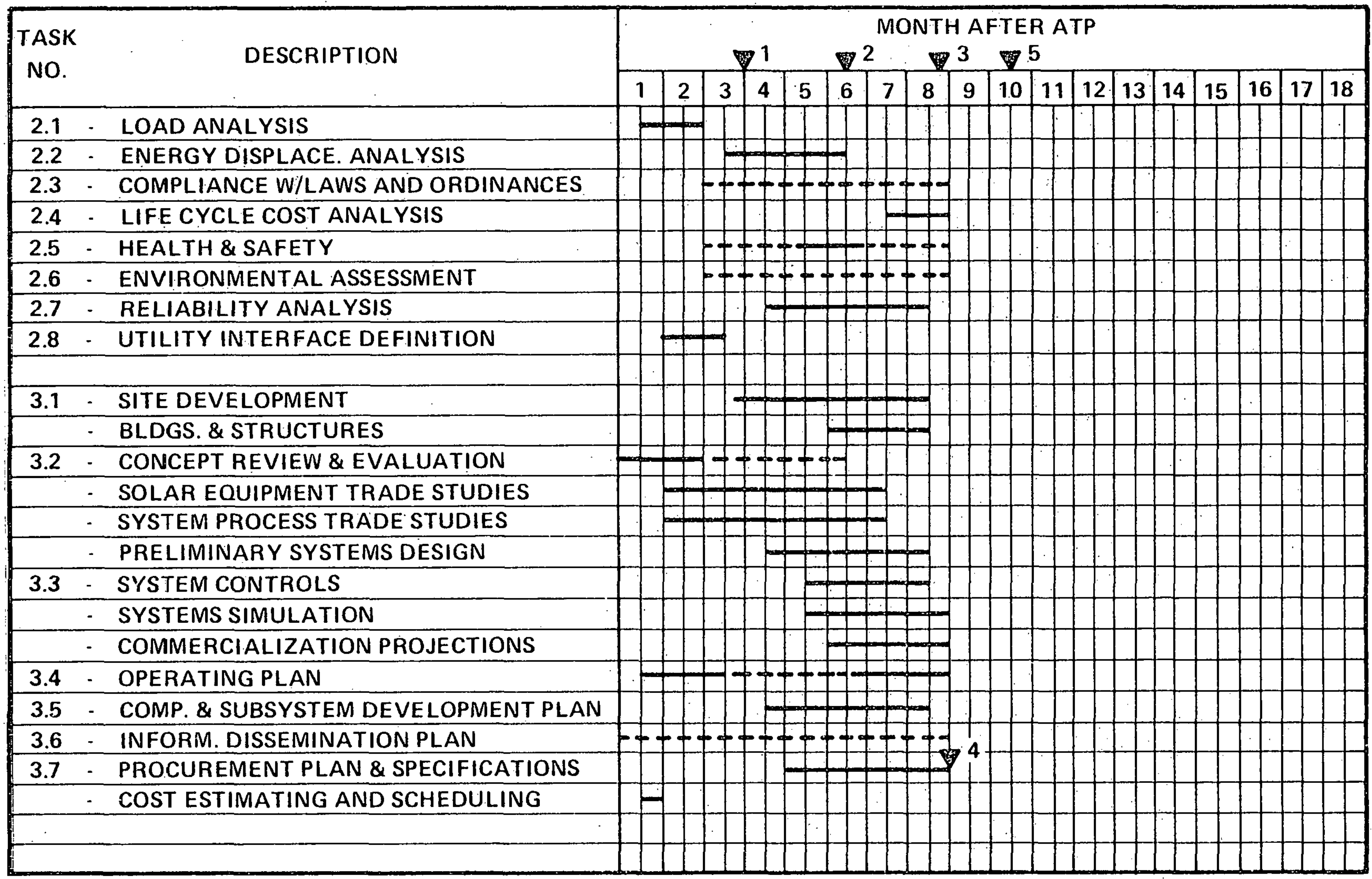


FIGURE 3.8–2. WORK BREAKDOWN STRUCTURE - PHASE III



▼ MAJOR MILESTONE DESCRIPTIONS

1. 30% REVIEWS
2. 65% REVIEWS
3. 95% REVIEWS
4. PROCUREMENT SPECS. COMPLETE
5. FINAL REPORT

▼ MAJOR MILESTONE

——— PRIMARY TIME ELEMENT

-·-·- INTERMITTENT EFFORT TIME ELEMENT

FIGURE 3.8–3. PROPOSED SCHEDULE - PRELIMINARY DESIGN of solar energy, power conversion and conceptual development. Based on their historical experience and the established schedule for Phase III, an estimate of manpower requirements has been developed.

The estimated manpower for each subtask, the type of manpower to be used, and the scheduling of such manpower, was then reviewed by Stearns-Roger management with the Project Manager and compared to historical records for similar type projects. Management experience was then applied to resolve any apparent variances between the historical data and the engineering estimate. Any adjustments to the manpower loading estimates, were made with concurrence of all involved parties. The results of these estimates are presented in Table 3.8–1.

3.8.1.4 SYSTEM REQUIREMENTS ANALYSIS

The purpose of this task is to update the systems requirements analysis which were developed during Phase II of this STES/LSE. The components chosen to be used in this STES, in support of the knitwear manufacturing facility in Shenandoah, Georgia may require further systems analysis. Descriptions of subtask for Phase III and Phases III and IV combined, will be the same. In some cases, the amount of effort will be greater for the combined phases than for Phase III alone (refer to Manpower Loading Charts, Tables 3.8–1 and 3.8–2). A detailed description of these subtasks follows.

3.8.1.4.1 Load Analysis (Task 2.1, Figure 3.8–3)

The load analysis performed under Phase II, was based on preliminary electric, heating, cooling, mechanical and other energy needs. The actual design loads for the Shenandoah knitwear facility will be utilized to update and finalize the requirements for electrical and thermal power to be displaced by solar thermal energy.

The computer program utilized to determine seasonal building heating and cooling loads, is NASA's Energy Cost Analysis Program (NECAP). This program utilizes local weather data in a format as obtained from the National Climatic Center, ASHRAE, and other sources. The representative year weather data for the Atlanta, Georgia area, was obtained during Phase II from the Aerospace Corporation, using an Aerospace format. Our program has not been expanded to utilize the data as supplied in the Aerospace form.

Based upon the new user's load requirements and the previously determined applicable energy costs, a trade study will be performed to establish the most economical and technically feasible split between electric power generation and thermal utilization to be accomplished by the solar thermal energy conversion system.

3.8.1.4.2 Energy Displacement Analysis (Task 2.2, Figure 3.8–3)

The energy displacement analysis conducted during Phase II, will be updated, utilizing the results of the revised load analysis. The results of this analysis will

LEVEL III TASK	MONTHS AFTER ATP										TOTAL
	1	2	3	4	5	6	7	8	9	10	
1.0 PROJECT MANAGEMENT	38	35	42	22	29	34	38	73	93	40	444
2.0 SYSTEMS REQUIREMENTS ANALYSIS	15	22	22	22	33	38	38	38	30	10	268
3.0 DESIGN	42	60	115	172	178	178	195	195	205	100	1440
TOTAL	95	117	179	216	240	250	271	306	329	150	2152

TABLE 3.8–1. PHASE III MANPOWER LOADING BY TASK AND MONTH (IN MANDAYS)

LEVEL III TASK	MONTHS AFTER ATP																	TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1.0 PROJECT MANAGEMENT	42	36	36	32	63	21	18	7	15	44	19	33	34	34	81	91	18	624
2.0 SYSTEMS REQUIREMENTS ANALYSIS	8	40	15	17	27	33	37	38	2	2	3	3	18	22	35	30	-	330
3.0 DESIGN	20	40	82	130	135	133	103	75	40	78	110	256	365	355	129	110	22	2183
TOTAL	70	116	133	179	225	187	158	120	57	124	132	292	417	411	245	231	40	3137

TABLE 3.8–2. PHASE III AND IV MANPOWER LOADING BY TASK AND MONTH (IN MANDAYS)

determine the economic impact of the STES on energy consumption and the conservation of vital energy resources. An annual estimate of cost of energy displaced will be estimated.

3.8.1.4.3 Compliance with Laws and Ordinances (Task 2.3, Figure 3.8–3)

Federal, State and local laws were assessed during Phase II to determine the design and operating restrictions for the system as well as any compliance, improvement, relief, modification, or other action that might effect the STES on the Shenandoah Site. As equipment and processes to be utilized are finalized, building codes and standards, site architecture, zoning codes, building restrictions, OSHA regulations and other Government requirements, will be reviewed to assure compliance. As operational plans are developed, surveillance will be maintained to evaluate if they will have an impact on Safety and Health compliance. The magnitude of any constraints will be assessed and the proper Government level (local, State, Federal) will be identified.

3.8.1.4.4 Life Cycle Cost Analysis (Task 2.4, Figure 3.8–3)

The life cycle cost for the STES at Shenandoah, Georgia will be updated, based on final system and equipment selection. Life cycle cost based on installation of one (1), ten (10) and one hundred (100) such facilities will be determined. The cost for further design, test, production planning, fabrication, assembly, installation, checkout and operations and maintenance will be determined and reported under this task.

Methodology of cost estimating of fabrication, construction, assembly, installation and checkout is detailed under the paragraph "Cost Estimating and Scheduling", herein.

Estimates for operations and maintenance will be developed based on preliminary scenarios for accomplishment of these activities. Equipment, manpower, materials and other resources will be identified and loaded and costed at levels necessary to support the examined installation ratio.

Preliminary estimates of failure rates provided by standard NASA and Army handbooks will be employed to estimate spares cost and to estimate failure replacement maintenance cost for important failure items.

3.8.1.4.5 Health and Safety Analysis (Task 2.5, Figure 3.8–3)

The health and safety analysis of Phase II will be utilized as a guideline during the design phases.

Design, Operational Plans and the safety requirements of OSHA and other pertinent local laws will be reassessed and followed. Of particular concern will be the environmental consequences of accidents, spills, etc. and how they will affect the safety requirements of the STES. Our health and safety personnel will work closely with technical design personnel to ensure compliance with all safety ordinances.

3.8.1.4.6 Environmental Assessment (Task 2.6, Figure 3.8–3)

The environmental assessment completed during Phase II will be updated as it may be affected by the final selection of materials and equipment.

Those additional and supplemental studies, outlined in the Phase II document, should be completed during the design phase in order to finalize the impact assessment document. Those studies in which Stearns-Roger will provide assistance, are listed as follows:

Calculations showing that the fugitive losses of toluene for comparison to the acceptable EPA limits.

Determination of emissions from the NO. 2 fuel oil-fired turbine in respect to the Georgia emission standards (assuming design capacity in excess of 7.5 million BTU per hour).

On-site survey of the second growth mixed pine-hardwood forest and understory vegetation.

On-site survey of possible endangered or threatened species of plants for the state of Georgia.

Assist ERDA in providing information on the faunal components of the environment: small and large mammals, birds, amphibians and reptiles.

3.8.1.4.7 Reliability Analysis (Task 2.7, Figure 3.8–3)

It is expected that the reliability analysis accomplished during Phase II will require modifications, based on final component and subsystem selection.

The objective of a reliability analysis on the STES is to provide a prediction of the portion of the required operating time that the system will be available. This prediction is in terms of individual components and functions. This prediction is then used to detail where reliability improvement techniques (redundance, hi-rel parts, etc.) should be applied and to provide an estimate of the expected energy displacement.

The actual analysis conducted is an availability prediction where availability is defined as the percentage of time that a system is available for service. In such a prediction, the availability calculation will be a function of the number of component failures that will occur in a specified time, the amount of time required to correct the failure, the availability of the sun, the availability of alternate fuels, the amount of downtime for scheduled maintenance and the required operating scenario for each part of the STES.

A Failure Mode and Effects Analysis (FMEA) will be conducted for the final selected configuration. This FMEA determines the failure modes of each component and the effect of that failure. For those component failures that will affect system availability by causing a portion of the STES to be shut down, a calculation of the failure rate or Mean Time Between Failure (MTBF) is made. This calculation uses a five factor formula which includes the basic component failure rate, an adjustment for the specific environment that the component will experience (temperature, pressure, shock, vibration, etc.), the fraction of the basic failure rate attributable to a specific failure mode, the probability of system failure given that the component fails and the operating time (or cycles). The result is the number of system failures per unit time or the MTBF.

The downtime for preventive maintenance (turbine overhaul, heat exchanger tube cleaning, etc.), or scheduled outage is also estimated based on historical data.

The overall forced outage and scheduled outage rates and times are compared with power plant historical data, provided by the Edison Electric Institute, to assure conformity with past experience.

The STE/LSE availability will also be a function of outside influences. The output of the solar portion is a function of the availability of the sun determined by the normal sun cycles and the presence of clouds. This data is provided by meteorological agencies and by the Aerospace Corporation Weather Tapes.

The above factors must be compared with the STES operational plan to determine the actual availability characteristics. The unique operation of the STES where different sections are required at different periods of the 24-hour cycle and where functional redundance is provided, means that there will be no simple value of availability. The fact that a thermal storage unit is available when the sun energy is lost for short periods (cloud passage) must be considered. The fact that fossil fuel may be available for long periods of loss of sun energy or for some component failures will increase the system availability but will decrease the energy displacement. The probability of multiple functional failures (loss of sun and loss of thermal storage) will be a factor in the calculations. The fact that all systems are not required for the full 24-hour period (or for a full 7-day period) will be a factor and will allow time for component repair and scheduled maintenance without a charge against availability.

The output of this task will be a description of the availability characteristics of the STES including the availability of each subsystem, the component failure and repair characteristics and the effects of external forces on the availability.

3.8.1.4.8 Utility Interface Definition (Task 2.8, Figure 3.8–3)

The utility interface of Phase II will be updated based on the new load analysis. A detailed description of interface control and operation, will be coordinated with Georgia Power, to assure compliance with their requirements, prior to definitive design.

3.8.1.5 PRELIMINARY DESIGN

The purpose of this general task is to develop the preliminary design of the STES for the Shenandoah facility. This preliminary design shall define the total process to be utilized, and shall include complete procurement specification for major long lead components and equipment items. A detailed description of scope of work to be accomplished is represented in the following subparagraphs.

3.8.1.5.1 Facility Design (Task 3.1, Figure 3.8–3)

The facility design shall include all preliminary design associated with the site development, grading, drainage, roadways, utilities, buildings and structures. Specifically, this task will encompass the following:

A. Site Development

Site development shall include preliminary general arrangements as well as the preliminary design of site utilities and facilities.

General arrangements of plant equipment will be developed giving proper consideration to the economical utilization of space relative importance of equipment, process requirements, and structural necessities, while recognizing the requirements for sufficient access, ease of operation, maintenance, cleanliness and safety.

Preliminary site development will include site survey and geotechnical investigation from which the competency of the soil to sustain the required loadings, compaction, and so on will be determined. Preliminary design layouts will be made for grading, drainage, fencing, roadways and utilities.

B. Buildings and Structures

Preliminary design of structures will include investigation to determine the most economical and efficient structures (particularly foundations) for each type of equipment and its functions. Preliminary architectural design will be carried out with complete attention being given to compliance with the Developments' Covenants and other applicable codes. Structural steel framing studies will be made as required.

3.8.1.5.2 System Design (Task 3.2, Figure 3.8–3)

The system design shall include the review of conceptual designs under Phase II, solar equipment and system process trade studies, and the work associated with the system preliminary design. Specifically, this task will include the following:

A. Concept Review and Evaluation

On receipt of the updated facility loads and prior to preliminary design, the baseline conceptual design (including ERDA's recommended modifications) will be reviewed to validate performance predictions. Those subsystems to be reviewed include the collector selection and performance, collection fluid and the fluid transfer loop, thermal storage, the power conversion cycle (including working fluid), and instrumentation and controls.

The collector performance will be analyzed, utilizing the McDonnell Douglas Astronautics Corp. (MDAC) Distributed Collector Program (DISCOL), which accounts for shading and thermal losses from the interconnecting piping. The program determines the net energy which can be collected throughout the day with the results integrated over the day to obtain a daily energy collection total. Collector field sizing is also performed by the program. The collector efficiencies (as a function of temperature) are combined with the power conversion performance to ensure operation at maximum possible system efficiency.

DISCOL will utilize Aerospace tapes to determine typical week per seasons (for concept review purposes). The weeks are synthesized with the weeks being selected by randomly picking seven days in each season such that the average daily total direct insolation and interquartile range of the seven days is within a specified percentage of the long-term monthly average insolation and interquartile range, respectively. (For the preliminary design, hourly performance calculations for every day of the typical year will be performed.)

The fluid loop will be reviewed to ensure that 1) the collector locations do not compromise system performance, 2) the collection fluid is compatible with the long life goals of the system, 3) the collection fluid is compatible with the baseline thermal storage concept, 4) the line lengths, diameters, and insulation thickness have been optimized, and 5) that proper consideration has been given to controls and instrumentation.

The thermal storage loop will be reviewed to ensure overall system compatibility and the overall storage philosophy will be revisited. The purpose of the latter investigation is related to the weekend collection operating mode. This approach, although yielding maximum collector utilization and displacement, also yields large thermal storage tank and hence fluid requirements. For the preliminary, final sizing, instrumentation and controls, and subsystem operation and status monitoring will be defined.

The power conversion cycle will be reviewed with the updated knitwear plant energy requirements and collector field performance. The load matching capability will be determined. Special attention will be given to interaction of Rankine cycle efficiency and the collector efficiency, again with the requirement to maximize overall system performance without compromising facility loads or reliability. The instrumentation and controls will be further refined. This is especially important for the supercritical toluene cycle where wet vapor or liquid in the lines could cause turbine damage.

B. Solar Equipment Trade Studies

With the conceptual design generated in Phase II (and reviewed in Task 3.2) as the baseline, trade studies will be conducted (e.g., cost versus performance) where other components are available. As an example, with a parabolic trough as a baseline collector, cost and performance data will be solicited from trough manufacturers. Overall efficiencies, capital costs, operating costs and life cycle costs can then be compared to ensure that the preliminary design reflects components which are the most economical. Each component on the solar side of the heat exchanger will be similarly evaluated yielding the most efficient, economical, and technically feasible design.

C. System Process Trade Studies

Based upon the system process selected under Phase II, additional work will be performed using current information available since the concept selection. Specifically, this work will include but not be limited to the following:

> Evaluation of the system concept in relation to practical equipment design and operational considerations.
>
> Equipment availability and development risks will be analyzed in relation to the conceptual design. For example, a decision must be made early in Phase III as to whether the organic Rankine cycle power conversion system should be supplied by a single supplier (through competitive bidding) as an integrated package or whether specifications should be written for each component in the system with the Rankine cycle system integration performed by the constructor. There are advantages and disadvantages to each method of power system procurement.
>
> Potential equipment suppliers will be contacted and will be evaluated as to their qualifications for supplying the equipment as specified, for reasonable costs and in the time allowed. A qualified bidders list will be completed subject to ERDA approval.

In addition, the system process will be evaluated for interface with the solar system and application load requirements. Overall system efficiencies, capital costs, operating costs and life cycle costs and complexity will be compared and analyzed to determine the most feasible and economic process for interface with the solar system as well as supplying the maximum load to the site.

D. Preliminary Design of Solar and Process Systems

After completion of the concept review and trade studies included under Task 3.2, the preliminary design of the collector, thermal storage and power conversion subsystems will be initiated. This work will involve the preparation of flow schematics, outline specifications for major equipment and/or systems, component sizing, pipe sizing, preliminary layouts, control system definition, electrical one-line diagrams, and determination of auxiliary power requirements. Also the functional interfaces between the various STES subsystems, utilities and knitwear facility will be defined. This preliminary design will be coordinated with the Plant General Arrangement previously discussed.

3.8.1.5.3 Performance Analysis (Task 3.3, Figure 3.8–3)

A. System Controls

The performance analysis will be performed utilizing the system controls developed under the preliminary design. Major control loops such as thermal fluid flow and temperature control, toluene pressure and temperature control, in addition to electrical power generation level and thermal load requirements will be simulated to obtain a realistic performance analysis during steady state and transitional operating modes.

B. System Simulation

This analysis will be performed utilizing the MDAC Energy Conversion and System Analysis computer program (P5595). The system will be modeled from the outputs of subsystem definition and analysis. The program also allows for parametric definition of the subsystem which then allows the sensitivities of the overall solar total energy system to be determined (e.g., degradation of collector performance).

The P5595 is an extremely versatile tool for support of thermal control and heat transfer loop systems development work, beginning with preliminary design and proceeding through definitive design, system integration and test, and system startup. Typical performance results are transient and steady state operating characteristics, fluid and component temperatures, rates of heat transfer, fluid loop pressure drops, and pressure drop/flow balance for parallel branch flow.

The program will be exercised for anticipated system design and off-design conditions. Anticipated off-design conditions will be obtained from the Reliability Analysis (Task 2.7). The results of this portion of the task will produce overall system efficiencies as well as indicating those subsystems where additional controls are required.

C. Operational Projections

The analysis of the failure characteristics of a system to determine its reliability level and maintenance requirements must consider several types of component failures. These failures are usually represented by the "bathtub" curve as a function of time. Initially, there is a high failure rate due to "infant mortality" which decreases with operating time. These failures can be eliminated by using "burn-in" techniques. The center portion of the lifetime curve is the region of chance or random failures characterized by a constant failure rate and is described by the exponential failure distribution. This is the failure rate used in most reliability calculations. At the end of the life of a component, the failure rate increases with time and is called the wear-out region. If the required system lifetime approaches or exceeds the operational lifetime of the several components, then this latter wear-out failure rate must be considered.

The magnitude of the wear-out failure rate is a function of time and is controlled by the wear phenomenon of the specific component and thus the operational life. It is usually described by the normal or Gaussian distribution. The actual values for a specific component must be obtained from test data or physics of failure analysis. The specific components in the STE/LSE that should be analyzed from a wear-out or limited lifetime consideration would include surface coatings, seal materials (valves, tanks), bearings (motors, actuators, turbine, generator, etc.) and insulations (motors, solenoid valves, etc.). Completion of these analyses gives the operational life of the solar total energy system.

The commercialization plans and projections will be addressed by first determining the versatility of the preliminary design. This will be accomplished via the previously discussed simulations in the off-design mode. The entire industrial sector will then be reviewed to determine industries which operate in the same ration of thermal-to-electric loads as the Shenandoah knitting mill with a selected reduction in electric load. (The process load will be held constant in that any reduction in that requirement produces an adverse thermal-to-electric load. Since the existing load ratio is marginal, increasing the electric load would also result in an adverse ratio.) This will give the total amount of energy which can be displaced with the SRE/MDAC solar total energy system design. This value will then be extrapolated to year 2010, utilizing the methodology described in Reference 1. The projected sector will then be reviewed and the portion available for market penetration determined (the major consideration being historical annual capital outlays versus that required for the solar total energy system). With appropriate market diffusion assumptions, the predicted energy displacement (and thus the number of LSE designs) as a function of time will be determined.

3.8.1.5.4 Operational Plan (Task 3.4, Figure 3.8–3)

Using the operational modes from the baseline conceptual design as a guide, the STES preliminary design will be investigated to determine operational procedures at both the component and overall system levels. Operational variations due to changes in load profile, insolation availability, component degradation or failure,

1. Industrial Applications of Solar Total Energy, SAN-1132-2, April 1977.

and utility activities will be addressed and alternate procedures described. Using this operational procedure as a guide, the test plan will be updated and the data to be gathered and evaluation procedures will be identified.

The major operating modes to be addressed include, but are not necessarily limited to, steady-state at design point, steady-state off-design, startup and shutdown transients, nonsolar operation both out of storage and hybrid modes, and emergency response modes.

3.8.1.5.5 Component and Subsystem Development Plan (Task 3.5, Figure 3.8–3)

During the preliminary design, components and subsystems requiring development and/or test data will be identified along with any program risks as they affect system design, performance, procurement or schedule. Those subsystems and components having a development status that minimizes project technical and schedule risks will be selected for the STE/LSE where possible.

3.8.1.5.6 Information Dissemination Plan (Task 3.6, Figure 3.8–3)

Stearns-Roger controls the release of information relative to various projects, fields of endeavor, and interests of the company and our customer by requiring all external dissemination be coordinated by the Manager of Advertising and Public Relations, Mr. L.B. Fisher.

Prior to any submittal to the Manager, the Project Manager of the cognizant project obtains the required coordination and approval of the customer to whom the project applies (i.e., ERDA). Each release, paper, brochure, or other means of dissemination of information is thoroughly checked for accuracy, applicability, recognition as appropriate, and compliance with company standards by the Project Manager/Project Engineer prior to submittal. Appropriate scheduling is also reviewed to insure sufficient time to accomplish the tenets of Stearns-Roger's policy of accuracy and conforming to the public relations programs of the customer.

ERDA's Solar Energy Program objectives of developing an industry will be encouraged by Stearns-Roger's active participation in the STES program by incorporation of this program into Stearns-Roger's Public Relations Plan. This is further enhanced by our continual day-by-day contact with the utilities, process industries, our multi-million dollar purchasing program, the eye-to-eye contact with environmental organization through our Environmental Sciences group and the encouragement we give our technical and professional people to participate in technical and civic organizations. Greater interfacing with the solar community will now occur with the location of the Solar Energy Research Institute at Golden, Colorado, a suburb of Denver.

Stearns-Roger Dissemination Plan has been formulated as an integral part of our overall policy of the interchange of technical information within the policies and procedures established by our customer. While the emphasis is on technological development and information exchange, it also includes the "good citizen policy" concerning the local and regional civic, service and related organizations.

The dissemination plan will incorporate the following goals:

Preparation of the technical reports, briefings and manuals as necessary for proper execution of the contract.

Preparation of related papers, presentations and pertinent technical information at various technical societies, meetings and conferences; such as ISES, ASME, etc.

Incorporation of the Solar Program into Stearns-Roger's presentation to Educational, Minority and Small Business groups as part of our on-going recruiting and educational program.

Participation in local civic, service and related organizations to the extent of giving presentations. This would include such groups as League of Women Voters, Kiwanis, Lions, etc.

Assistance to the media, in providing technical information relative to current news release and topical announcement by others. To provide local interest that would increase the opportunity for publication in Denver.

Description of our business and the products and services we purchase by our Purchasing Department in flyers and brochures to maintain a complete source list for Stearns-Roger's needs.

Advertising in technical and business publications.

Press release to local media outlets.

Stearns-Roger maintains control by inserting in all subcontracts a clause to the effect that all external press releases and dissemination of information relative to the subcontract must be approved by Stearns-Roger. However, in accordance with the individual project requirements and the customers policy, local coverage and visibility is encouraged.

3.8.1.5.7 Advanced Planning Technical Support (Task 3.7, Figure 3.8–3)

This task is established to provide the technical support in the areas of Specifications and Cost Estimating, to accomplish the Advanced Planning task listed a management item in the Statement of Work. The type of technical support and methodology is detailed in the following subparagraphs:

A. Procurement Plan and Specifications

Phase II procurement plan will be utilized and updated as new information on delivery times of equipment and components are gathered. The result of this portion of the task is a more reliable updated Procurement Plan.

For each of the major components identified as having a procurement lead time which may affect the proposed construction schedule, a procurement specification will be developed. These specifications shall be a complete package, prepared in such a manner that ERDA may then proceed with the advertisement for bid, in preparation for advanced procurement. Where warranted, performance type specifications will be developed, requiring manufacturers to certify and provide test data proving that the equipment will meet the design conditions of the specification.

Detailed specifications will be prepared by the technical staff responsible for the design. The Stearns-Roger Purchasing Department will combine these specifications with Terms and Conditions and other items required to produce a complete bid package. These bid packages will be delivered to ERDA for their disposition.

B. Cost Estimating and Scheduling

Stearns-Roger proposes utilization of their computer program called "Optimum Program and Integrated Schedule (OPIS)" to accurately determine the cause and effect relationship between the schedule and the project costs. OPIS has the capability to evaluate the effects of changes in funding, work scheduling and resource availability. It utilizes the "Project Cost System" computer program to:

Determine manpower and material costs for a given schedule.

Optimize schedules to spread costs in accordance with funding limitations.

Determine unrestrained schedules based on the activities and the availability of trade skills and materials.

Identify the Critical Path of the Project Schedule.

The master schedule is updated in response to expanded planning definitions and includes program milestones and activities associated with funding dates, criteria development, conceptual design, preliminary design, design development, contract document preparation, procurement and construction phases. Detailed schedules reflect the network flow for each major activity on the master schedule. Included in the detail schedules are design start and complete dates, design review periods, release dates for procurement of long lead items, and allocations of time for the construction phases.

Stearns-Roger has extensive data from existing contracts that provides a current data base on the costs of labor, equipment and materials. The data is compiled and used in the computer program called "Project Cost System (PCS)" mentioned above, to develop credible cost estimates. Information is collected in accounts by area, type of work, trade skills and appropriation code. Construction cost elements include quantity and units of measurement. Labor hours and costs, material costs and other costs are compiled and totals of each element are defined. The budget estimate which was prepared during Phase II will be input to the computer and will be the baseline estimate. As the design is expanded and definitized, the baseline estimate will be revised to reflect the more accurate anticipated costs.

3.8.2 TECHNICAL PLAN FOR PHASES III AND IV

The following subparagraphs present the proposed Technical Plan for the combined Phase III, Preliminary Design, and Phase IV, Definitive Design.

In many cases, the efforts expended in accomplishment of an individual task under the combined Phases III and IV, are the same as previously detailed for Phase III only. In such cases, the detailed task description will reference the appropriate paragraph.

3.8.2.1 WORK BREAKDOWN STRUCTURE

The proposed WBS for the combined Phases III and IV, will be similar to that presented for Phase III. This proposed WBS is presented as Figure 3.8–4.

3.8.2.2 PHASES III AND IV SCHEDULE

Figure 3.8–5 presents the proposed schedule for accomplishment of the combined Phases III and IV. The most critical items which may affect this schedule, would be the advanced procurement of major items of equipment, and the receipt and approval of shop drawings for these equipment items.

3.8.2.3 MANPOWER LOADING

The methodology for estimating manpower requirements for the combined Phases III and IV, are as previously described under paragraph 3.8.1.3. The results of these estimates are presented in Table 3.8–2.

3.8.2.4 SYSTEMS REQUIREMENTS ANALYSIS

The purpose and general requirements for the systems requirements analysis for the combined Phases III and IV, are the same as previously presented for Phase III, paragraph 3.8.1.4.

3.8.2.4.1 Load Analysis (Task 2.1, Figure 3.8–5)

Reference paragraph 3.8.1.4.1.

3.8.2.4.2 Energy Displacement Analysis (Task 2.2, Figure 3.8–5)

Reference paragraph 3.8.1.4.2. In addition, this analysis will be reviewed and updated prior to completion of the definitive design, utilizing new technology developed during this design phase.

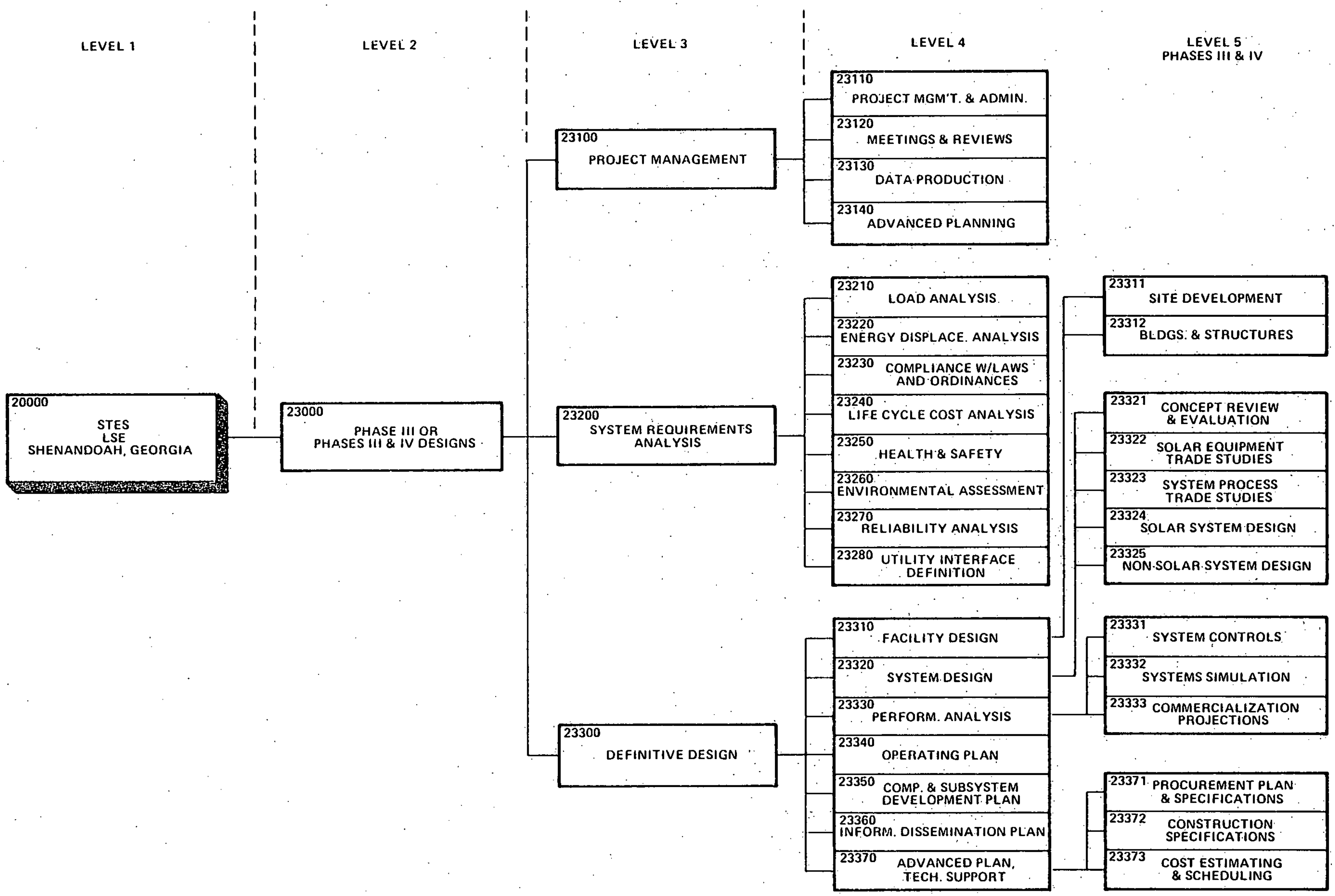
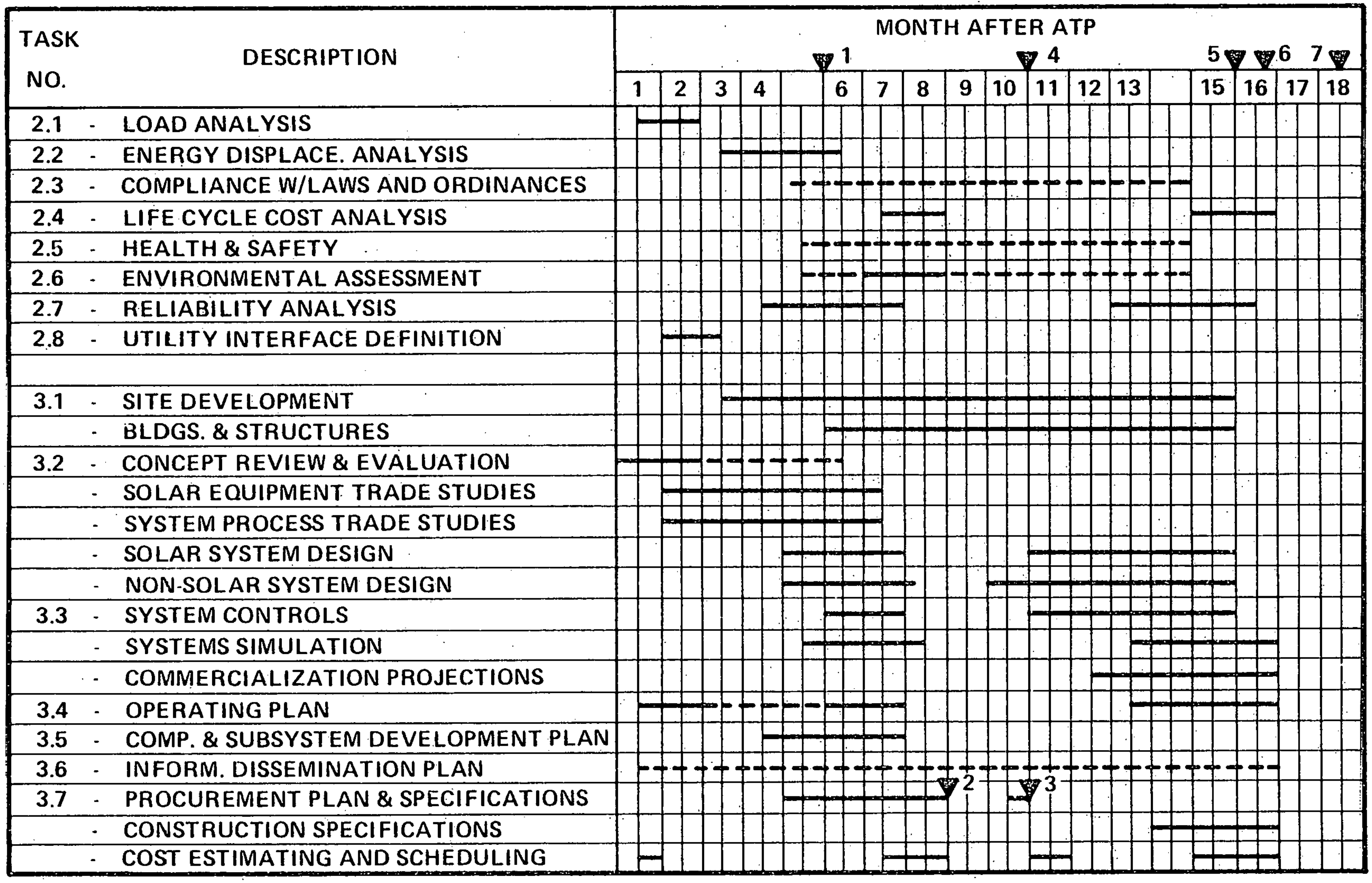


FIGURE 3.8—4. WORK BREAKDOWN STRUCTURE - PHASES III AND IV



▼ MAJOR MILESTONE DESCRIPTIONS

1. 30% REVIEW
2. PROCUREMENT SPEC. COMPLETE
3. PROCUREMENT ITEMS SELECTED
4. 65% REVIEW
5. ALL DESIGNS COMPLETED
6. 95% REVIEW
7. FINAL REPORT

▼ MAJOR MILESTONE
—— PRIMARY TIME ELEMENT
- - - - INTERMITTENT EFFORT TIME ELEMENT

FIGURE 3.8–5. PROPOSED SCHEDULE - PHASES III AND IV

3.8.2.4.3 Compliance with Laws and Ordinances (Task 2.3, Figure 3.8–5)

Reference paragraph 3.8.1.4.3.

3.8.2.4.4 Life Cycle Cost Analysis (Task 2.4, Figure 3.8–5)

Reference paragraph 3.8.1.4.4. In addition, this cost analysis will be updated utilizing the more definitive estimate of construction cost developed along with the definitive design phase.

3.8.2.4.5 Health and Safety (Task 2.5, Figure 3.8–5)

Reference paragraph 3.8.1.4.5.

3.8.2.4.6 Environmental Assessment (Task 2.6, Figure 3.8–5)

Reference paragraph 3.8.1.4.6.

3.8.2.4.7 Reliability Analysis (Task 2.7, Figure 3.8–5)

Reference paragraph 3.8.1.4.7. With the combined Phases III and IV, this reliability analysis will utilize information obtained from the actual vendors of the major equipment items (long lead procured items).

3.8.2.4.8 Utility Interface Analysis (Task 2.8, Figure 3.8–5)

Reference paragraph 3.8.1.4.8.

3.8.2.5 DEFINITIVE DESIGN

The purpose of this task is to develop the final definitive designs for the Shenandoah facility. Complete detailed design drawings and construction specifications for the total facility will be developed, as the primary end item of this general task. A detailed description of scope of work to be accomplished is presented in the following subparagraphs.

3.8.2.5.1 Facility Design (Task 3.1, Figure 3.8–5)

Facility design shall include all preliminary complete definitive design and detailing associated with overall facility arrangement, site development, buildings, structures, roadways, and all other facility items not covered under other tasks. Complete construction specifications and detailed cost estimates will be prepared under Task 3.7.

A. Site Development

Reference paragraph 3.8.1.5.1A. In addition, the complete definitive design of the items discussed will be completed under this task.

B. Buildings and Structures

Reference paragraph 3.8.1.5.1B. In addition, the complete definitive design of all buildings and structures will be completed under this task.

3.8.2.5.2 System Design (Task 3.2, Figure 3.8–5)

The system design to be carried out under combined Phases III and IV includes the concept review and evaluation, solar equipment trade studies, system process trade studies, solar system design and the non-solar system design, as defined as follows:

A. Concept Review and Evaluation

Reference paragraph 3.8.1.5.2A.

B. Solar Equipment Trade Studies

Reference paragraph 3.8.1.5.2B.

C. System Process Trade Studies

Reference paragraph 3.8.1.5.2C.

D. Solar System Design

In addition to the solar system preliminary design activities in paragraph 3.8.1.5.2D for Phase III, Phase IV will include the definitive design of the solar system, including solar collector and thermal storage final configurations, design drawings, process flow diagrams, piping and instrument diagrams, final electrical one-line diagrams and complete detailed design for the auxiliary power requirements. Construction and performance specifications for equipment and/or subsystem procurement, and control system specifications, will be identified under the task and completed under Task 3.7.

E. Non-Solar System Design

Preliminary design of the non-solar systems, i.e. thermal power conversion and thermal loop subsystems, will be carried out under Phase III as described in paragraph 3.8.1.5.2D. Phase IV will entail the continuation of the preliminary design through the definitive design phase. The system requirements and configurations will be finalized, design drawings prepared, process flow and piping and instrument diagrams finalized, design and performance specifications for equipment and/or subsystem procurement prepared (under Task 3.7), control system specifications prepared, electrical one-line and auxiliary power requirements finalized, and the physical and functional interfaces between the STES subsystems, utilities and knitwear factory finalized.

3.8.2.5.3 Performance Analysis (Task 3.3, Figure 3.8–5)

The performance analysis carried out under preliminary design will be redefined as required in Phase III definitive design to reflect any design changes that would affect system performance.

A. System Controls

Reference paragraph 3.8.1.5.3A.

B. System Simulation

Reference paragraph 3.8.1.5.3B.

C. Operational Projections

Reference paragraph 3.8.1.5.3C.

3.8.2.5.4 Operational Plan (Task 3.4, Figure 3.8–5)

Reference paragraph 3.8.1.5.4.

3.8.2.5.5 Component and Subsystem Development Plan (Task 3.5, Figure 3.8–5)

Reference paragraph 3.8.1.5.5.

3.8.2.5.6 Information Dissemination Plan (Task 3.6, Figure 3.8–5)

Reference paragraph 3.8.1.5.6.

3.8.2.5.7 Advanced Planning Technical Support (Task 3.7, Figure 3.8–5)

This task is established to provide the technical support in the areas of Specifications and Cost Estimating, to accomplish the Advanced Planning task listed a management item in the Statement of Work. The type of technical support and methodology is detailed in the following subparagraphs:

A. Procurement Plan and Specifications

Reference paragraph 3.8.1.5.7A. All items described for Phase III will be accomplished in the same manner for the combined Phases III and IV. In addition, Stearns-Roger will assist ERDA in the analysis and evaluation of bids for each of the component and equipment proposals received for advanced procurement.

B. Construction Specifications

Specifications for construction of the complete STES will be developed during this phase of the project. Through our many years of experience in A/E design and facility construction, Stearns-Roger has developed standard construction specifications. These specifications are on tape, are continually upgraded, and are in such a form that they may be modified to fit the specific application.

Specific technical specifications for the STES will be developed by the engineers responsible for the detailed design. These specifics will be incorporated with our standard specifications, to produce a set of completed technical specifications applicable to the detailed design and requirements of this STES.

3.8.3 MANAGEMENT PLAN

Our management plan is structured to assure ERDA and ourselves that the STE/LSE Project is thoroughly defined, logically planned and scheduled, staffed with the proper personnel, and implemented with effective management controls for achieving the objectives of the ERDA National Solar Energy Research and Development Program.

The management techniques we will use on this STES Phase III and IV Project(s) are based upon proven experience in other similar work. We will work closely with ERDA to assure that our management techniques provide the controls necessary to successfully achieve the technical objectives of the project, deliverables are made on schedule, and specified funding limits are not exceeded.

The management plan for Phase III or for Phases III and IV combined, will be essentially the same. The primary difference will be in the allocation of manpower resources and the descriptions and budgets established on the task work packages.

Within one (1) week of the contract award, the contractor shall meet with the appropriate government representatives for review and revision to technical and management plans. Agreements reached at this meeting will be incorporated into the plans. Within two (2) weeks after contract award, the complete Project Procedures and Management Plan shall be submitted.

3.8.3.1 PROJECT MANAGEMENT CONTROL SYSTEM

The Stearns-Roger Project Management Control System (PMCS) will be implemented to manage this project. The system is a complete management program that includes an effective technique to assign responsibility and authority; and to organize, plan, and schedule the work. It is also used to produce a time-phased budget baseline. The PMCS provides the capability to collect and organize data for preparation of an objective job performance measurement on cost and schedule.

The Stearns-Roger PMCS is organized to be consistent with the format guideline for the Cost/Schedule Control System as established in the criteria document AFSC/AFCP 173-5. However, the Stearns-Roger PMCS has been modified to provide the level of control and reporting specifically required for this project.

The PMCS maintains traceability of all change orders and modifications to the contract. The PMCS also establishes the line of authority as shown on Figure 3.8–6 for accomplishment of each task or work package.

CONTRACT

AUTHORIZED: By Client
DIRECTS: S/R through Project Manager to deliver product and/or services

COST ACCOUNT/PLANNING PACKAGE
BUDGET BASLINE

AUTHORIZED: By Project Manager
DIRECTS: Project Engineer to proceed with definitive integration and assignment of the work to organizational performers

WORK PACKAGE

AUTHORIZED: By Project Engineer
DIRECTS: Organizational performers to proceed with the discrete work as defined, scheduled and budgeted by the work package

FIGURE 3.8–6. WORK AUTHORIZATION

3.8.3.2 COST BREAKDOWN STRUCTURE AND PERT NETWORK

The first step in the preparation for efficient management and control of any multi-organizational project is the development of a clear and logical plan. The Work Breakdown Structure (WBS), previously discussed, and the Cost Breakdown Structure (CBS), Figure 3.8–7, are the key elements in the plan where work has been divided into progressively smaller packages as it is defined level by level.

These breakdown structures are the framework for the preparation of both Stearns-Roger and subcontractor project plans and schedules, cost estimates, budgets, work authorization, collection of costs and evaluation of project performance. Work definition is keyed to the WBS and is reflected in the project plan, Stearns-Roger internal operating work statements, and subcontract work statements. The project plan and subsidiary work statements will be maintained throughout the life of the contract and will be updated to reflect any contract changes.

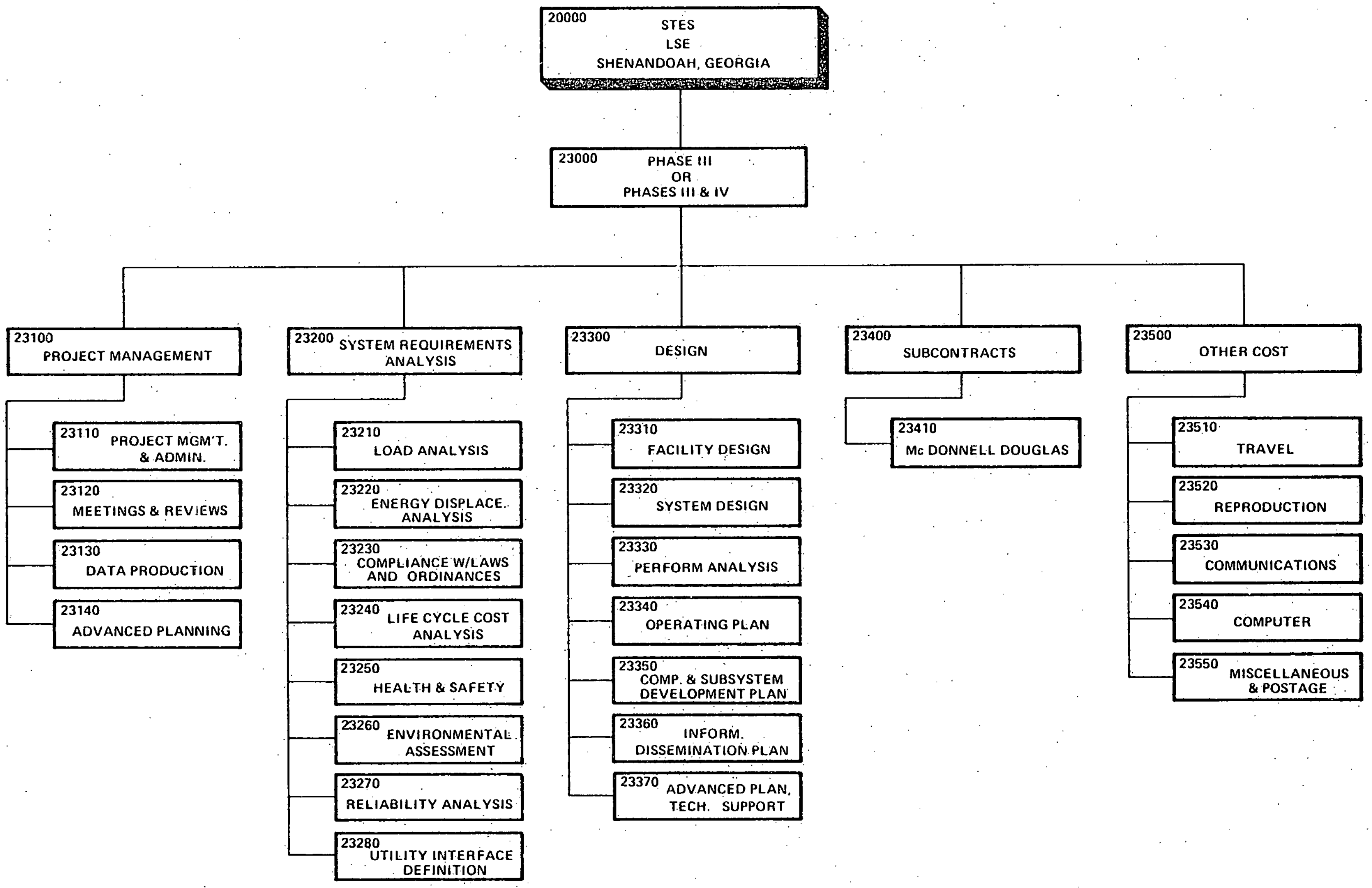


FIGURE 3.8–7. COST BREAKDOWN STRUCTURE

Data for monthly progress and cost reports will be collected on the fourth and fifth level for reporting on the third level.

A PERT Network chart is to be developed for this project and will be submitted as a portion of the Project Procedures and Management Plan. This PERT Network will be developed after ERDA has reviewed and approved the WBS. Development of this chart will utilize the Level 4 and 5 items of the Contract Work Breakdown Structure (CWBS), the statement of work from the Technical Plan, overall established schedule requirements, and our estimate of manpower requirements to accomplish each individual task.

Utilization of this PERT Network provides the key to proper management, and the visibility required to maintain the project schedule.

The PERT Network will be prepared as a time phased schedule to show the sequence of each planned task. This PERT Network will indicate scheduled meetings and reviews, major and minor milestones, slacktime and interrelation between the tasks. It is the planning schedule which we will utilize to accomplish each individual task, and to complete the overall project within the established schedule. The PERT Network will be maintained and reviewed inhouse on a weekly basis, and updated or modified as may be required to indicate actual progress and any change in scope.

3.8.3.3 DESIGN REVIEWS AND CONFERENCES

Design reviews will be conducted at periods representing approximately 30 percent, 65 percent, and 95 percent completion of design, the first and second review to be held at Stearns-Roger, Denver, Colorado. Schedules and agendas for these reviews will be prepared and submitted to the Technical Project Manager (TPM) for approval. The 30 percent review will be an informal "on-board" type review on the design status and will be presented orally by the personnel involved. For the 65 percent and 95 percent reviews, copies of all design drawings will be submitted to the TPM not less than 10 days prior to the review date. Accomplishments, problem areas, schedules, cost, and programmatic responses to problem areas will be emphasized. Design review reports will be maintained by the contractor, and distributed to all attendees, within two (2) weeks after each review meeting.

Stearns-Roger will plan on attending five (5) additional conferences covering areas of importance in the execution of design. These conferences may cover technical reviews of individual design items, reviews of procurement specifications, technical information dissemination, etc.

3.8.3.4 MANAGEMENT TOOLS

The Stearns-Roger PMCS provides many tools for use in effective project management. These tools provide methods of control and forecasting of both cost and schedule, while providing for complete traceability. A number of these tools, which will be utilized on this project, are as follows:

Work Packages – A work package is provided for each of the Level 4 or 5 items which falls under account number 23200 and 23300 of the CWBS. These Work Packages are prepared from the PERT Network, and contain manhour estimates, semi-monthly budgeted cost of work scheduled (BCWS), milestones, inputs, outputs and authorization to proceed with the discrete work. Once a task has started, progress will be recorded on a bi-weekly basis. Actual Cost of Work Performed (ACWP) and Budgeted Cost of Work Performed (BCWP) will be compared to the BCWS, to obtain the Estimated Actual Cost (EAC) at completion. Variance in EAC over 15 percent and pertinent comments are to be recorded. A sample work package form is presented as Figure 3.8–8.

Tabulation of Cost – To provide record and control of all Level 4 items not covered by work packages, Tabulation of Cost forms will be utilized. These forms show the scheduled expenditures, actual cost, and remaining funds available for each reporting period. These forms will be used for the following items:

CBS NO. 23110 - Project Management & Administration
CBS NO. 23120 - Meetings and Reviews
CBS NO. 23130 - Data Production
CBS NO. 23140 - Advanced Planning
CBS NO. 23400 - Subcontracts
CBS NO. 23500 - Other Costs

These forms are utilized for internal management control and are not intended for distribution to ERDA, unless specifically requested.

Management Reserve Fund – A manhour reserve is established by pulling a small percentage of manhours from the proposed time required for each of the various work packages. This reserve is then available for new work packages, for unforeseen tradeoff studies and changes in scope not covered in an existing work package. In order to provide traceability and control of these funds, a LOG-MANAGEMENT RESERVE is established (Figure 3.8–9). This reserve may receive additional funds from change in contract or from left over funds from a work package which is completed under budget.

The Project Manager has sole responsibility for these funds, and only he may authorize the use of such funds.

Base Line Change Traceability – The Project Manager will maintain a log for the purpose of providing traceability of any or all baseline changes to the original contract, or changes which may be covered by funds available in the Management Reserve (Figure 3.8–10).

Allocation of Resources – PERT diagrams emphasize the development of a workable plan and schedule for accomplishing the tasks making up a project. By the use of time-phase scheduling of activities, manpower allocation for the project can be analyzed with respect to the utilization of key personnel

WORK PACKAGE - C-19650

TITLE: TASK 3.2 - System Concept Design

BUDGET: 304 M.H.	AUTHORIZATION: PE PM 6/9/77	DESCRIPTION: Provide a system description of the STE/LSE, including flow diagrams and application interface definition, Electrical One-Lines and Equipment Lists.	START: 9 June 1977 FINISH: 22 September 1977

WORK EFFORT	NO.	MANHOUR ESTIMATE					
		PE	ET	PR			
Develop Prel. Non-Solar Sys Req'ts	1.			40			
Prepare Prelim. Flow Diagrams	2.	80	24	8			
Update Flow Diagrams	3.		24	16			
Finalize System Concept Design	4.		32	8			
Final Review Preparation	5.		16	16			
Final Report	6.		16				
TOTAL HRS.		80	112	112			

MILESTONES:

1.	Develop Prelim. Non-Solar System requiements	23 June	40
2.	Prepare Prelim. Flow Diagrams	15 July	112
3.	Update Flow Diagrams	29 July	40
4.	Finalize System Concept Design	26 August	40
5.	Final Review Preparation	9 September	32
6.	Final Report	22 September	40
	TOTAL		304 M.H

MONTH	BCWS (HRS.)	ACWP (HRS.)	BCWP (HRS.)	EAC (HRS.)
2nd 1/2 Jun	60			304
1st 1/2 Jul	92			
2nd 1/2 Jul	40			
1st 1/2 Aug	20			
2nd 1/2 Aug	32			
1st 1/2 Sep	32			
2nd 1/2 Sep	28			

ANCES & COMMENTS:

ACCOUNT NO.
X01320

FIGURE 3.8–8. SAMPLE WORK PACKAGE FORM

LOG
MANAGEMENT RESERVE

JOB NO.

PROJECT:

DATE	DESCRIPTION	WORK PACKAGE NUMBER	AUTHORIZED BY	HOURS		BALANCE IN RESERVE
				DR	CR	

FIGURE 3.8–9. LOG MANAGEMENT RESERVE FORM

LOG FOR
BASE LINE CHANGE TRACEABILITY

JOB NO. C-19650

PROJECT: STE/LSE

CHANGE ORDER OR M.R. LOG NO.	DATE	START BUDGET	CHANGES		CURRENT BUDGET	WORK PACKAGES DESCRIPTION
			CHANGE ORDER	MGMT. RESERVE		

FIGURE 3.8–10. LOG FORM FOR BASELINE CHANGE TRACEABILITY

or other resources. Once defined, critical path methods and adjustments in resource allocation can be simulated to determine an acceptable way of eliminating undesirable peak demands on key resources.

Through the use of the PERT diagram and resource requirements, Stearns-Roger will prepare a time phase resource allocation curve showing percent of project time versus percent of completion (by manhours) for the project. This data will be evaluated and updated as the project proceeds to reflect both a current and expected future status of the project. This method will also form the basis for variance analysis performed based on initial budgetary resource allocation. Continual update of the schedule and resource allocation will be performed and reported to the customer in the Milestone and Management Plan.

3.8.3.5 REPORTING REQUIREMENTS

All reporting requirements for this project were established from the requirements of the RFP for Phase II. A summary of requirements indicating distribution, is presented as Table 3.8–3. Report distribution listed on this summary, shall be sent to the following:

Contracting Officer (CON. OFF.)

U.S. Energy Research and Development Administration, Albuquerque Operations Office, Attn: G.E. Cordova, Contracts and Procurement Division, P.O. Box 5400, Albuquerque, New Mexico 87115.

Government Technical Representative (GTR)

U.S. Energy Research and Development Administration, Albuquerque Operations Office, Attn: G.W. Rhodes, Special Programs Division, P.O. Box 5400, Albuquerque, New Mexico 87115.

USERDA Headquarters (HDQRS)

U.S. Energy Research and Development Administration, Division of Solar Energy, Attn: James E. Rannels, Washington, D.C. 20545.

Technical Project Manager (TPM)

Sandia Laboratories, Attn: R.W. Hunke, Division 5711, Albuquerque, New Mexico 87115.

National Technical Information Service (NTIS)

Release through USERDA-ALO.

REPORT TITLE	FREQ	DUE DATE	REPORT DISTRIBUTION				
			GTR	CON OFF	TPM	HDQRS	NITS
Design Review	3	DR + 2 weeks	1	1	1	1	
Management Plan	1	With proposal					
Hot Line Reports	A	A	1		1		
Conference Reports	A	A	1		1		
Technical Status Reports	M	15th of each month	1		1	1	
Energy RD & D Report	1	A	1	1	1	1	
Technical Progress	1	*	1	1	2	2	27
Cost Plan	1	With Proposal					
Cost Management Report	M	15th each month	1	1	1		
Funds Reconciliation Report	A	A	1	1	1		
Milestone Plan and Management Report	M	15th each month	1	1	1		
Contract Management Summary Report	M	15th each month	1	1	1		

* 41 Weeks after ATP, for Phase III
78 Weeks after ATP, for Phases III & IV

TABLE 3.8–3. SUMMARY OF REPORTING REQUIREMENTS

A brief description of reports, both required and not required, which will be submitted, are as follows:

Design Review

Not later than two (2) weeks following each of the scheduled design reviews, a narrative summary of the review shall be submitted. This report shall document the actions at the review including all decisions, directions, redirections and action items.

Hot Line Report (Required)

Will be prepared and submitted to convey important research or development breakthrough, when important technical objectives are either achieved or not achieved. When a cost/schedule is such that we will be able to foresee significant schedule slippage or cost overruns in sufficient time that Hot Line reporting should not be required; such slippage or overruns will be reported on a Variance Report. Hot Line reports will be submitted as required by fastest means (i.e. Telex, TWX, etc.).

Conference Report (Required)

Will be prepared for all formal meetings with ERDA representatives. This report shall document our understanding of significant decisions, direction or redirection. These reports shall be submitted within five (5) working days following the meeting.

Record of Telephone Conversation (Not Required)

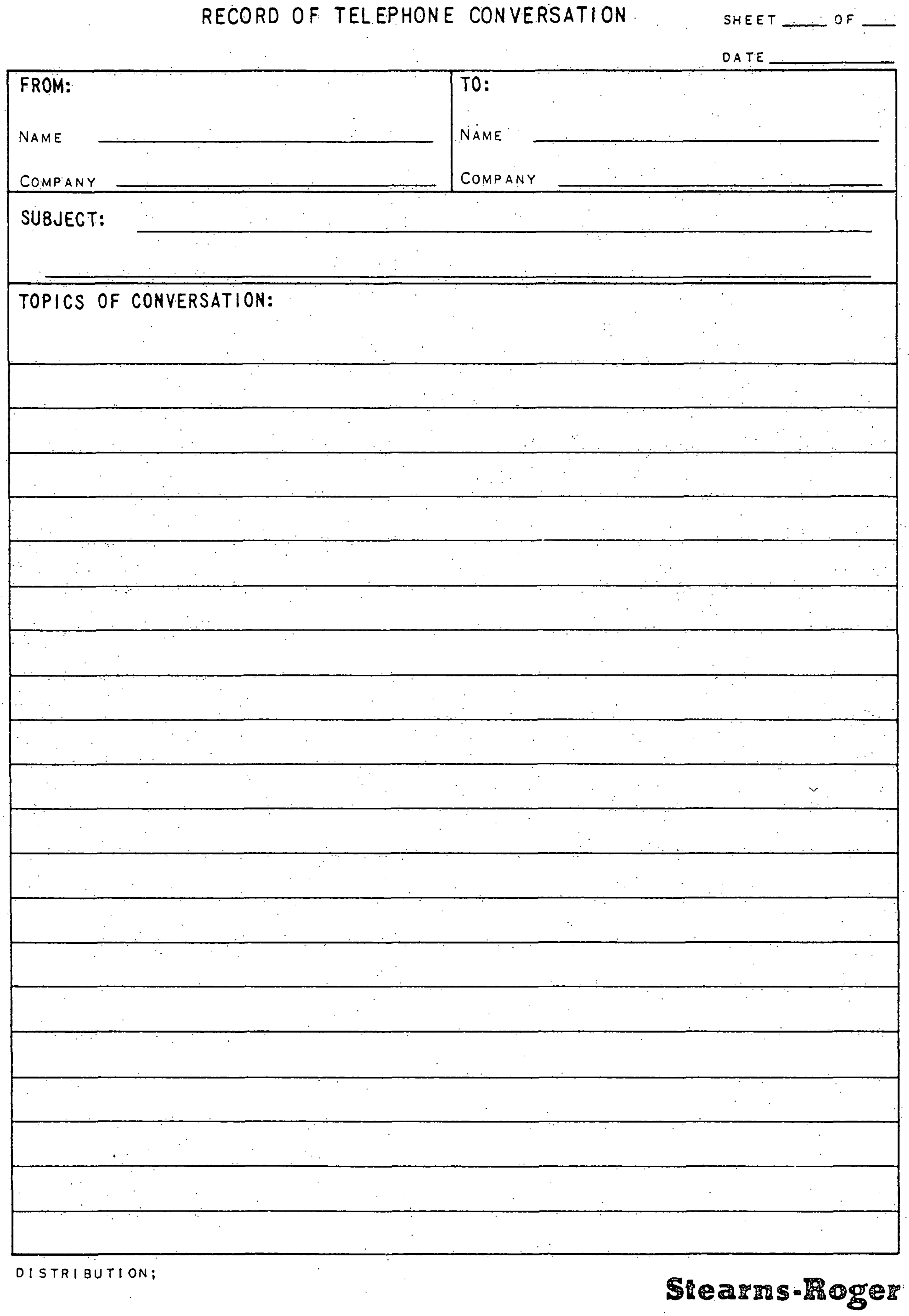
Shall be prepared for telecons between ERDA, their representatives, and Stearns-Roger, which have a direct and significant bearing on the project. These memos will be submitted on a monthly basis along with the monthly Technical Status Reports. (Standard Form attached, see Figure 3.8–11).

Confirmation Notice (Not Required)

Will be prepared to document any verbal schedule, cost, or design affecting verbal direction which may be received from ERDA or an ERDA representative. These notices will be submitted within three (3) days from receiving such direction. (Standard Form attached, see Figure 3.8–12). Copies of these Confirmation Notices will be submitted along with the monthly Technical Status Report.

Technical Status Report (Required)

Will be submitted to ERDA on a monthly basis. This letter report will summarize the progress achievement for the reporting period ending the last day of each month. Each in-progress work package will be reviewed for milestone accomplishment and status. Problem areas, changes in work plan,



RECORD OF TELEPHONE CONVERSATION

SHEET ____ OF ____

DATE __________

FROM: NAME __________ COMPANY __________	TO: NAME __________ COMPANY __________

SUBJECT: __________

TOPICS OF CONVERSATION:

DISTRIBUTION;

Stearns-Roger

FIGURE 3.8–11. RECORD OF TELEPHONE CONVERSATION FORM

Stearns-Roger
P.O. BOX 5888
DENVER, COLORADO 80217

CONFIRMATION NOTICE

DATE:
NUMBER:
CONTRACT:
JOB NUMBER:
WORK ORDER NO:

TO:

PROJECT:
CONFIRMS:

PARTIES TO
DISCUSSION:

FIGURE 3.8–12. CONFIRMATION NOTICE FORM

contractual items and any other open items requiring ERDA action will be identified. Copies of supplemental data (Hot Line items, Confirmation Notices, Conference Reports, etc.) generated during the reporting month, will be included.

Cost Management Report (Required)

Shall be submitted on a monthly basis in a format similar to that presented on Figure 3.8–13. The reporting categories shall be the Level 3 of the CBS. Cost will be collected inhouse on Level 4 of the CBS. Change in scope or newly added and approved tasks will be indicated on the report. All costs will be reported as of the end of the calendar month preceeding the reporting date.

Technical Progress Report

Shall be the final report issued upon completion of the task. This report shall consist of all drawings, specifications, cost estimates and schedules. Engineering calculations and other supporting data shall be submitted as a backup to the completed plans and specifications.

Variance Reports (Not Required)

Will be submitted as required. These reports will present justifications for significant changes in cost of any individual CBS Level 4 item, which will affect Level 3 cost or overall performance schedule by more than ±15 percent.

Funds Reconciliation Report (Required)

Will be submitted as may be required in support of changes in scope or direction, or recommended changes which will affect the contract cost. Funds Reconciliation Reports will be submitted on forms similar to that presented in Figure 3.8–14.

Milestone Plan and Management Report (Required)

Shall be submitted monthly. This report shall graphically show the planned schedule, progress to date, milestones, slippage, schedule changes, and contract changes. The reporting form shall be as presented in Figure 3.8–15.

Contract Management Summary Report (Required)

Shall be submitted on a monthly basis. Purpose of this report will be to present a comparison between actual and planned expenditures, both in cost and manpower. The reporting form shall be as presented in Figure 3.8–16.

FORM ERDA ________
(9-76)

Page _____ of _____

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

COST MANAGEMENT REPORT

1. Contract Title STE/LSE Phase II	2. Reporting Period Jul 1 thru Jul 31	3. Contract Number EG-77-C-04-3987
4. Contractor (name and address) Stearns-Roger Engineering P.O. Box 5888 Denver, Colorado 80217	5. Cost Plan Date 23 Aug 1977	6. Contract Start Date 24 May '77 7. Contract Complete Date 21 OCT '77

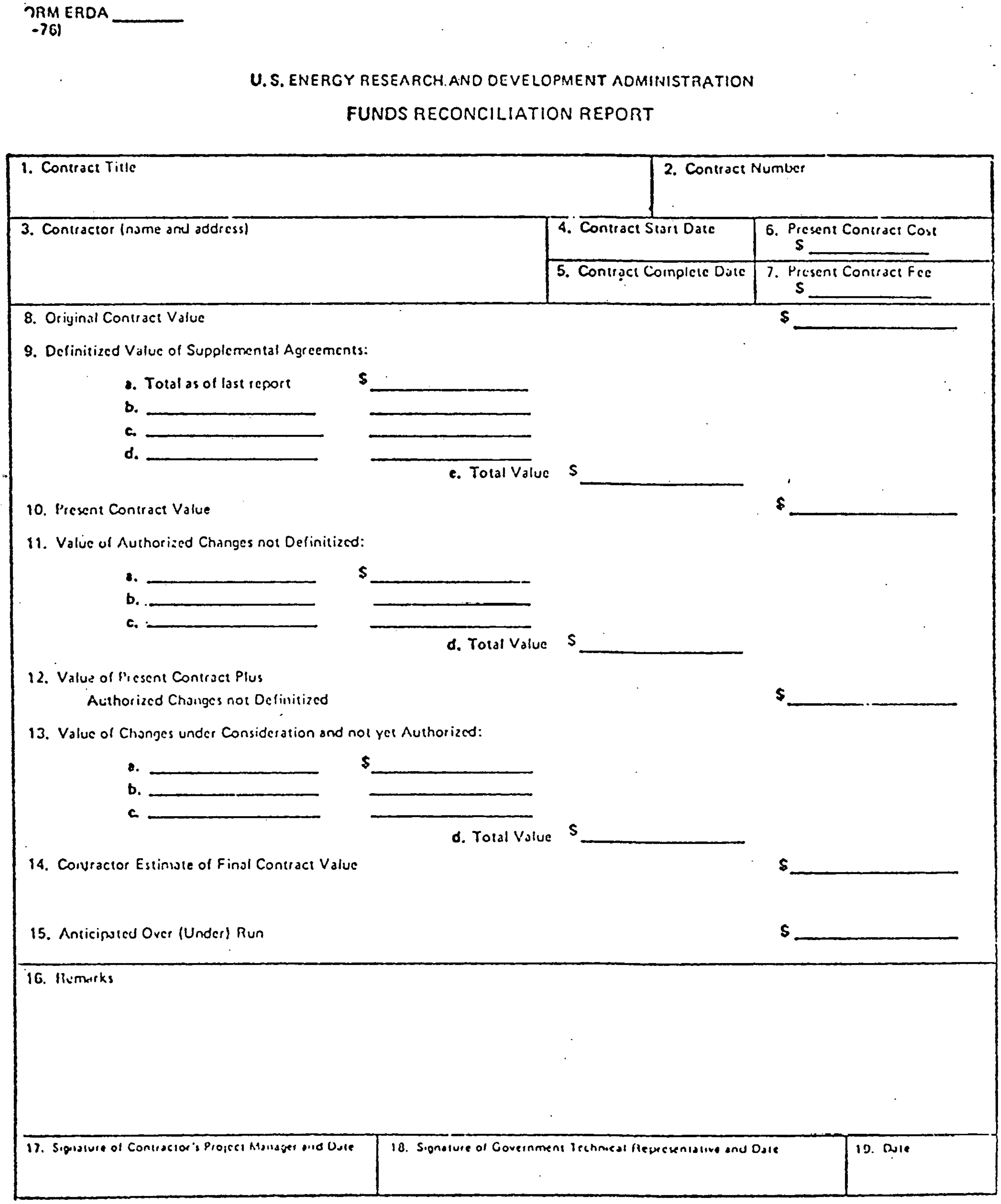
8. Government Funding 100%	9. Contractor Funding -0-	10. Number of Invoices Billed 1	11. Frequency	12. Number of Invoices Paid -0-	13. Total Invoice Amounts Billed 38.1	14. Total Payment Received -0-

15. Identification Number	16. Reporting Category (e.g., contract line item or work breakdown structure element)	17. Costs Accrued				18. Projected Accrued Costs			19. Negotiated Contract Cost	20. Variance	21. Outstanding Commitments
		During Reporting Period		Cumulative to Date							
	WBS No.	Actual a	Planned b	Actual c	Planned d	Subsequent Reporting Period a	Balance of Fiscal Year b	Total Contract c			
	01100	5.7	4.5	14.4	11.6	3.0	6.9	24.3	20.3	+4.0	
	01200	5.7	3.5	10.9	[illegible]	6.0	3.6	20.5	24.3	-3.8	
	01300	10.2	16.0	24.9	[illegible]	22.0	9.2	56.1	56.3	-0.2	
	01400	3.0	4.3	6.9	[illegible]	2.8	6.6	16.3	16.3	-0-	
	Subcontract	25.4	35.2	62.1	[illegible]	[illegible]	36.4	146.9	146.9	-0-	
	Management Reserve						5.5	5.5	5.5	-0-	
22.	Total	50.0	63.5	119.2	140.0	79.4	68.2	269.6	269.6	-0-	

23. Remarks	24. Dollars Expressed In: 1000
25. Signature of Contractor's Project Manager and Date 8/25/77	26. Signature of Government Technical Representative and Date

SAMPLE

FIGURE 3.8–13. COST MANAGEMENT REPORT FORM



ORM ERDA ______
-76)

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

FUNDS RECONCILIATION REPORT

1. Contract Title		2. Contract Number
3. Contractor (name and address)	4. Contract Start Date	6. Present Contract Cost $ ______
	5. Contract Complete Date	7. Present Contract Fee $ ______

8. Original Contract Value $ ______

9. Definitized Value of Supplemental Agreements:

a. Total as of last report $ ______
b. ______ ______
c. ______ ______
d. ______ ______
e. Total Value $ ______

10. Present Contract Value $ ______

11. Value of Authorized Changes not Definitized:

a. ______ $ ______
b. ______ ______
c. ______ ______
d. Total Value $ ______

12. Value of Present Contract Plus Authorized Changes not Definitized $ ______

13. Value of Changes under Consideration and not yet Authorized:

a. ______ $ ______
b. ______ ______
c. ______ ______
d. Total Value $ ______

14. Contractor Estimate of Final Contract Value $ ______

15. Anticipated Over (Under) Run $ ______

16. Remarks

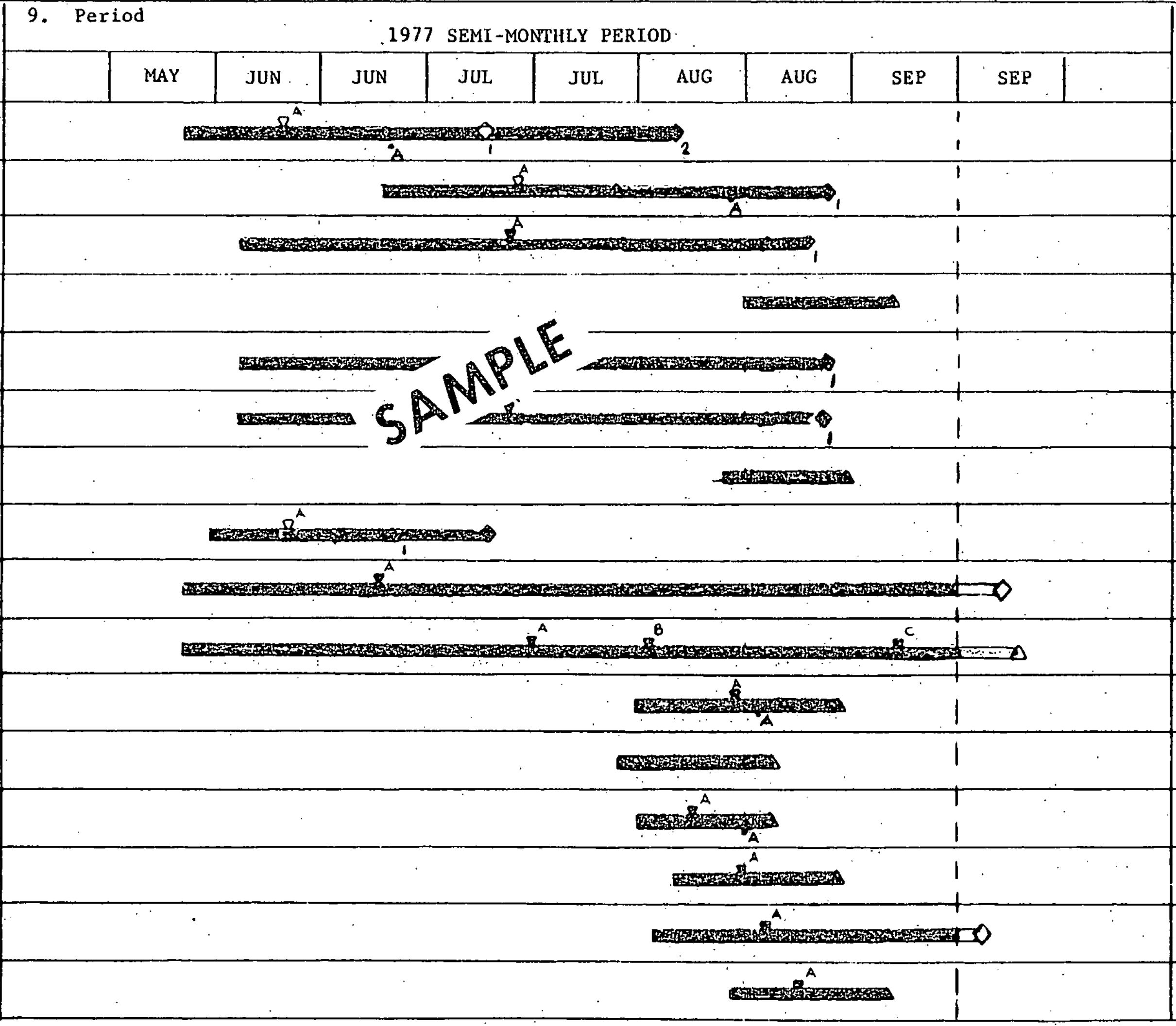
17. Signature of Contractor's Project Manager and Date	18. Signature of Government Technical Representative and Date	19. Date

FIGURE 3.8–14. FUNDS RECONCILIATION REPORT FORM

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

MILESTONE PLAN AND MANAGEMENT REPORT

1. Contract SOLAR TOTAL ENERGY/LARGE SCALE EXPERIMENT	2. Period Aug. 16 thru Sept. 15	3. Contract No. EG-77-C-04-3987
4. Contractor STEARNS-ROGER ENGINEERING CO. P.O. BOX 5888 DENVER, COLORADO 80217		5. Start Date 24 MAY 1977 6. Completion Date 21 Oct '77



7. Ident. No. TASK NO.	8. Reporting Category WORK BREAKDOWN STRUCTURE ELEMENT	10. Percent Complete
2.1	01210	98
2.2	01220	98
2.3	01230	98
2.4	01240	98
2.5	01250	98
2.6	01260	98
2.7	01270	98
2.8	01280	98
3.1	01310	90
3.2	01320	88
3.3	01330	98
3.4	01340	98
3.5	01350	98
3.6	01360	98
3.7	01370	70
3.8	01380	98

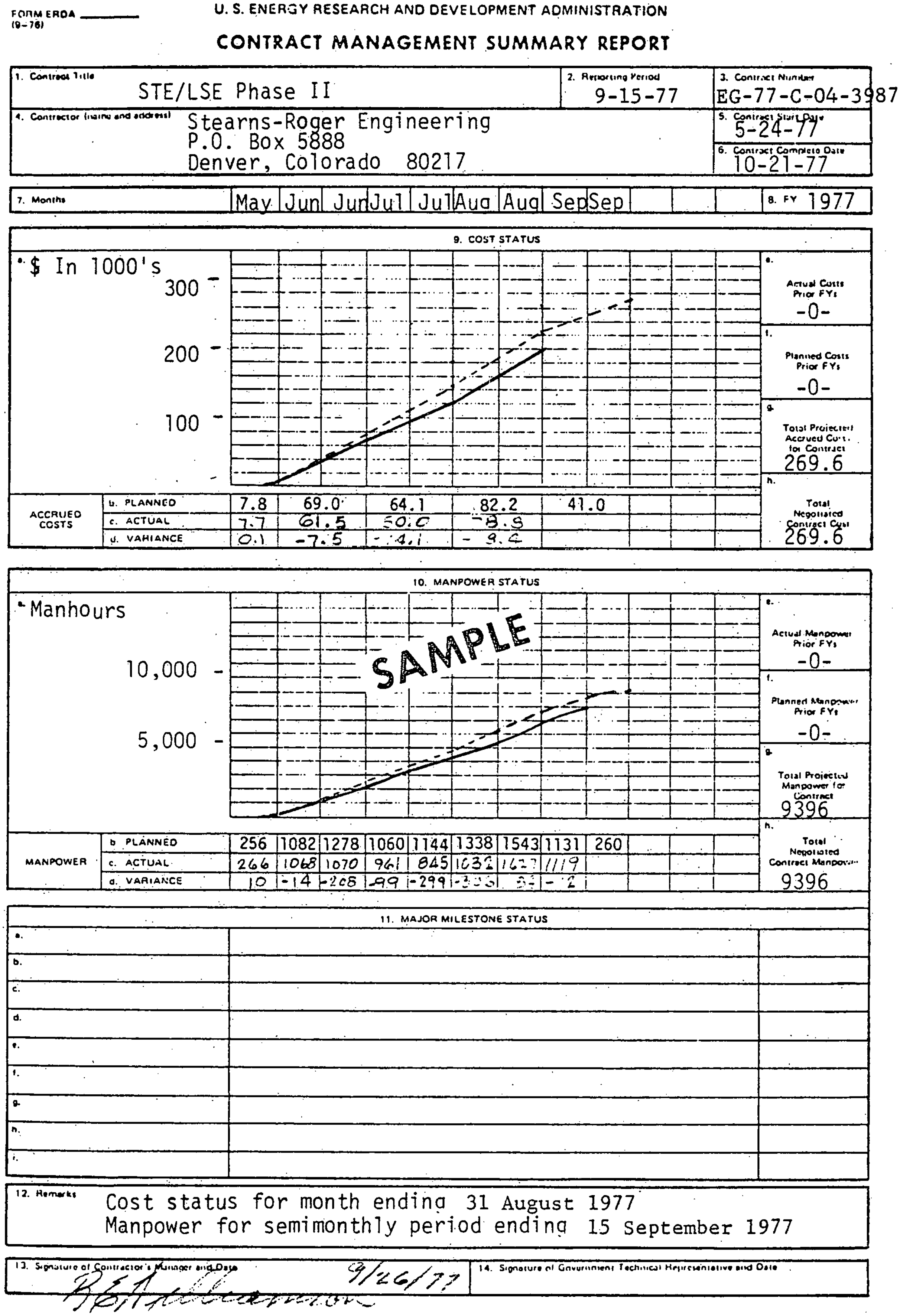
Page 1 of 2

11. Remarks
Remaining milestones are: Sept. 22, Draft of Final Tech.
Progress Report & Oct. 17, Final Tech. Progress Report.

12. Contractor's Project Manager, Signature and Date
R E Williamson 9/26/77

13. Government Technical Representative, Signature and Date

FIGURE 3.8–15. SAMPLE OF MILESTONE PLAN AND MANAGEMENT REPORT



FORM ERDA ________
(9-76)

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

CONTRACT MANAGEMENT SUMMARY REPORT

1. Contract Title STE/LSE Phase II

2. Reporting Period 9-15-77

3. Contract Number EG-77-C-04-3987

4. Contractor (name and address)
Stearns-Roger Engineering
P.O. Box 5888
Denver, Colorado 80217

5. Contract Start Date 5-24-77

6. Contract Complete Date 10-21-77

7. Months May Jun Jun Jul Jul Aug Aug Sep Sep

8. FY 1977

9. COST STATUS

		May	Jun	Jun	Jul	Jul	Aug	Aug	Sep	Sep			
ACCRUED COSTS	b. PLANNED	7.8	69.0		64.1		82.2		41.0				
	c. ACTUAL	7.7	61.5		50.0		78.9						
	d. VARIANCE	0.1	-7.5		-14.1		- 9.4						

e. Actual Costs Prior FYs -0-

f. Planned Costs Prior FYs -0-

g. Total Projected Accrued Cost for Contract 269.6

h. Total Negotiated Contract Cost 269.6

10. MANPOWER STATUS

		May	Jun	Jun	Jul	Jul	Aug	Aug	Sep	Sep			
MANPOWER	b. PLANNED	256	1082	1278	1060	1144	1338	1543	1131	260			
	c. ACTUAL	266	1068	1070	961	845	1032	1627	1119				
	d. VARIANCE	10	-14	-208	-99	-299	-306	84	-12				

e. Actual Manpower Prior FYs -0-

f. Planned Manpower Prior FYs -0-

g. Total Projected Manpower for Contract 9396

h. Total Negotiated Contract Manpower 9396

11. MAJOR MILESTONE STATUS

a.		
b.		
c.		
d.		
e.		
f.		
g.		
h.		
i.		

12. Remarks
Cost status for month ending 31 August 1977
Manpower for semimonthly period ending 15 September 1977

13. Signature of Contractor's Manager and Date 9/26/77

14. Signature of Government Technical Representative and Date

FIGURE 3.8–16. SAMPLE OF CONTRACT MANAGEMENT SUMMARY REPORT

3.8.4 ADDITIONAL CAPABILITIES

The Stearns-Roger organization has the experience and personnel to provide full services for all phases of this proposed STES project. The support departments of the Stearns-Roger organization, which are available for use as may be required on any project, are:

- Accounting Department
- Advertising and Public Relations Department
- Architectural Services Department
- Auditing Department
- Construction Department
- Data Processing Department
- Environmental Sciences Department
- Estimating, Cost Control and Planning and Scheduling Department
- Equipment Department
- Insurance Department
- Labor Relations Department
- Legal Department
- Library
- Personnel Department
- Publications (Technical)
- Purchasing Department
- Quality Assurance Department
- Safety Department
- Specifications Department
- Traffic Department

The support departments of Stearns-Roger which will be utilized in the performance of Phases III and IV, or that may be utilized for the additional tasks included in Phases V and VI, are briefly described in the following subparagraphs:

3.8.4.1 ACCOUNTING DEPARTMENT

Our Cost Accounting procedure, developed during years of experience in engineering and/or construction projects, is efficient and in accordance with modern methods. It is, of necessity, very flexible and is adaptable to customer requirements for capital evaluation and tax computation. This procedure meets our own rigid requirements for proper project management and cost records.

Field Accounting

On large contracts, on-the-job accounting may be supplemented with IBM equipment in our home office in Denver. Our traveling field auditors ensure that correct accounting procedures are being followed, and that construction offices are properly staffed and equipped. The Denver office retains completed job files as reference for a period of ten years.

3.8.4.2 ADVERTISING DEPARTMENT

The department originates all public relations, advertising and sales promotion material and is responsible for the review of any material for publication.

Photographic coverage of projects engineered or constructed by the company is made by the department which maintains physical control of all negatives relating to project photographs. The department is also responsible for the production of slide materials and film strips.

3.8.4.3 ARCHITECTURAL SERVICES DEPARTMENT

Architectural design of commercial and industrial buildings is performed by a wholly-owned Stearns-Roger subsidiary, Stearns-Roger Architects, Ltd. This group represents a fully integrated design organization having the capability to perform the complete structural, mechanical and electrical design in addition to the architectural design of any type of building. The Client is assured of a single design responsibility, as all design and engineering services required are provided.

3.8.4.4 AUDITING DEPARTMENT

The Auditing Department provides the review of financial and accounting procedures independent of the project organization. It ensures that correct accounting procedures are being followed in our field offices, and retains all job files for a period of ten years.

3.8.4.5 CONSTRUCTION DEPARTMENT

Stearns-Roger has long recognized the importance to our Clients that a reliable and proficient construction organization is available. Our construction staff, headed by a vice president, is eminently competent and suitably equipped for efficient supervision and construction of complex projects under close scheduling control. This group bridges the expanse between engineering and operation as it translates plans and specifications into concrete, steel and equipment assembled and constructed to produce the desired end result. This department's composition, capabilities and flexibility enables Stearns-Roger to contract for a wide variety of work regardless of location.

Continuity and diversification of Stearns-Roger construction activities are accomplished by training and advancement programs, and have enabled us to attract and maintain a loyal group of construction specialists with an impressive experience background.

Our construction superintendents are experienced in working with organized labor. Denver-based construction managers working with our Labor Relations Department, conduct research and surveys of labor conditions prior to starting field activity. These efforts have enabled us to minimize difficulties in labor supply and jurisdictional problems.

3.8.4.6 ENVIRONMENTAL SCIENCES DEPARTMENT

The Environmental Sciences Department is concerned with all aspects of environmental protection. Air and water pollution control, sewage and waste treatment, solid wastes systems, and noise control are all within the scope of the department's work.

Emphasis is placed on industrial problems, including process and plant design, to reduce pollution at the source as well as control discharge of contaminants. Systems studies include monitoring, modeling, ecological analysis, and evaluation of interacting events. Preparation of environmental reports for Federal and State agencies is a specialty.

3.8.4.7 ESTIMATING, COST CONTROL, AND PLANNING AND SCHEDULING DEPARTMENT

The Estimating, Cost Control, and Planning and Scheduling Department was established to develop a Corporate approach rather than a Division approach for maximum efficiency and coordination of these functions.

Procedures and standards of performance have been established for application in preparing feasibility, preliminary and definitive estimates. Current "state-of-the-art" techniques are applied. The department has also established methods to measure progress and subsequently trend-forecast probable cost. Programs are used to make comparisons and to point out abnormal situations. Project Management Systems (PMS) are utilized to increase the effectiveness planning and scheduling for optimum correlation between related activities. Capabilities include preparation of a master plan expanded into detailed engineering and construction schedules which are continuously monitored. Significant milestones are summarized for management appraisal of project status. Optimizing manpower and/or resources on a priority basis is another capability.

3.8.4.8 CONSTRUCTION EQUIPMENT

Stearns-Roger Equipment Company is a wholly-owned subsidiary whose principal function is managing mechanical construction equipment for maximum efficiency. The decision controlling assignment of equipment and tools for a construction project is reached when the Critical Path Schedule is developed. Such decision vitally affects the quantity and type of labor force required for any given operation within the scope of the total project. Our inventory of construction tools and equipment is maintained at a level consistent with the requirement to meet construction commitments. At our warehouses and storage depots we store, repair, recondition, and modernize our construction equipment on a continuing basis.

3.8.4.9 QUALITY ASSURANCE DEPARTMENT

The Stearns-Roger Quality Assurance Department is responsible for quality assurance of work performed by or for Stearns-Roger on facility design and/or construction. The Quality Assurance Department utilizes and follows the established Stearns-Roger "Quality Assurance Program" document. This document is in accordance with the Energy Research and Development Administration, Quality Assurance/Quality Control Requirements, and available for inspection upon request.

3.8.4.10 LABOR RELATIONS DEPARTMENT

Stearns-Roger, as a member of the National Constructors Association, operates as a national contractor and enjoys most satisfactory working arrangements with all unions at national and local levels.

Stearns-Roger maintains a qualified Labor Relations Department that is responsible for labor relations on all field construction work and contract maintenance projects. Staff members have an outstanding accumulation of experience. Department policy is to be concerned actively and directly with project planning, preconstruction negotiations with labor, and with a harmonious, efficient prosecution of the work.

The department works closely with our project management and supervision in policy guidance and interpretation pertaining to the various labor agreements, jurisdictional matters, etc. in an effort to maintain project schedules without lost time due to labor-management disputes, strikes, or work stoppages of any nature.

Because of the close working relationships within our own corporate structure and our long-standing excellent working relationships with the various Building Trades Unions, Stearns-Roger Incorporated has one of the finest records in the industry with respect to quality and quantity of union productivity, and minimal amount of lost-time hours due to labor-management disputes.

3.8.4.11 PUBLICATIONS DEPARTMENT

A Technical Publications Department is staffed with qualified personnel that compile, prepare, illustrate and publish a complete scope of technical documents including studies, reports, operation, maintenance, safety and quality control manuals. Additionally, the department is equipped with the latest typesetting and IBM equipment.

3.8.4.12 PURCHASING DEPARTMENT

The Purchasing Department is managed by competent and experienced managers whose main objective is to provide quality equipment and materials.

The department is staffed by purchasing agents and buyers, several of whom specialize in specific commodities, expediters, material control personnel and inspectors. Extensive services on many foreign projects have been provided. A branch in Calgary, Alberta, supplements our Denver office.

Operation and Maintenance Data Books for our Client's use are produced under the supervision of this department. The documents include certified dimension prints, wiring diagrams, descriptive bulletins, installation and operation instructions, and recommended spare parts lists.

3.8.4.13 SAFETY DEPARTMENT

Stearns-Roger recognizes that construction is a hazardous industry and regards the safety of their employees to be of utmost importance. Our Safety Program is managed by a Safety Director and staff in Denver, with field safety and first aid personnel on each major project. The Safety Program has resulted in low accident frequency and severity and favorable insurance rates. Work stoppages and damage to equipment and materials are minimized through our accident prevention policies.

All work is performed in accordance with the Occupational Safety and Health Act of 1970. Extensive orientation on OSHA is given all supervisors on a periodic basis.