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ATU/FORT HOOD SOLAR TOTAL ENERGY MILITARY LARGE-SCALE EXPERIMENT (LSE-1)

Final Report for the Period
November 23, 1976 - November 30, 1977

MASTER

SYSTEM DESIGN AND SUPPORT ACTIVITIES

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United States Department of Energy
Division of Solar Energy
Under Contract No. EG-77-C-04-3878

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ABSTRACT

The work performed by American Technological University (ATU) under Department of Energy (formerly ERDA) Contract No. EG-77-C-04-3878 on the ATU/Fort Hood Solar Total Energy Military Large-Scale Experiment-(LSE-I) during the period November 23, 1976 - November 30, 1977 is described by this report. A baseline conceptual design was completed by ATU in 1976, and further conceptual design studies were performed by other contractors in 1977.

The ATU/Fort Hood Solar Total Energy System will include a concentrating solar collector field of several acres. During periods of direct insolation, a heat-transfer fluid will be circulated through the collector field and thus heated to 500 - 600°F. Some of the fluid will be circulated through a steam generator to drive a turbine-generator set; additional fluid will be stored in insulated tanks for use when solar energy is not available. The electrical output will satisfy a portion of the electrical load at Fort Hood's 87000 Troop Housing Complex. Heat extracted from the turbine exhaust in the form of hot water will be used for space heating, absorption air conditioning, and domestic water heating at the 87000 Complex. Storage tanks for the hot water are also included.

During the contract period covered by this report, ATU performed systems analysis and technical studies; conducted an engineering test program on concentrating solar collectors; and provided direct support in the form of site coordination, site specific input data, and cost modeling for the additional conceptual design studies. These design studies were performed under competitive ERDA contracts by Westinghouse Electric Corporation and TRW, Inc. to reflect new ERDA guidelines and design philosophy. The successful contractor (Westinghouse Electric Corporation) will complete the preliminary design under subcontract to ATU during the next contract period.

FOREWORD

The Department of Energy (DOE) is sponsoring the development of the ATU/Fort Hood Solar Total Energy Military Large-Scale Experiment (LSE-I), to be installed at Fort Hood, Texas. The project originated in 1974 under National Science Foundation funding and was transferred to the Energy Research and Development Administration (ERDA) in 1975. American Technological University (ATU) has been the principal contractor on the project since its inception and completed the original conceptual design for LSE-I in 1976. During 1977 ERDA sponsored the development of two new conceptual designs by competing industrial contractors; these reflected new ERDA guidance and design philosophy. In addition to providing site coordination and input data for the design competition, ATU continued systems analysis, engineering testing, and other support activities for LSE-I during the period November 23, 1976 - November 30, 1977, reported herein. On the basis of the design competition, Westinghouse Electric Corporation has been selected by ERDA (now DOE) for further design work under subcontract to ATU.

Recognition and special acknowledgement are due Headquarters, III Corps and Fort Hood; the Directorate of Facilities Engineering; Headquarters, Training and Doctrine Command Combined Arms Test Activity; the Office of Scientific Advisor (TCATA); the Central Texas Area Office, Fort Worth Engineer District; the Fort Worth Engineer District; and Headquarters, 6th Cavalry Brigade (Air Combat) for their time and unstinting cooperation during this period.

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1. INTRODUCTION

I. INTRODUCTION AND SUMMARY

This is the final report on work performed by American Technological University (ATU) during the period November 23, 1976 - November 30, 1977 on the ATU/Fort Hood Solar Total Energy Military Large-Scale Experiment, also known as LSE-I. The work reported herein was performed under Department of Energy (formerly ERDA) Contract No. EG-77-C-04-3878 in compliance with the original and modified contract statements of work given in Appendix A.

Work on the project started in 1974 with Phase I, which was sponsored by the National Science Foundation (NSF). During Phase I solar energy availability and energy requirements at Fort Hood, Texas were studied, and alternate system approaches for utilizing solar energy at military installations were investigated. Phase II, funded by the Energy Research and Development Administration (ERDA), involved the development of the original conceptual design for a solar total energy system for Fort Hood's 87000 Troop Housing Complex and included the initial steps toward implementing a supporting engineering test program. The project background through Phase II is reviewed in Section I.I.

The objectives of the project and the system design criteria have been through a number of revisions since the project administration was shifted from NSF to ERDA. Table I-I summarizes the initial objectives and criteria and the subsequent revisions. The early revisions accompanied several changes in ERDA program management whereas the later revisions resulted largely from the evolution of plans for the national Solar Total Energy Program (STEP).

The original objectives for this contract period were to perform the preliminary design for LSE-I, to carry out a supporting engineering test program, and to conduct a variety of related support activities as described in Part I of Appendix A. However, the ATU/Fort Hood project originated (Phase I) prior to formation of ERDA (now superceded by DOE), and the LSE-I conceptual design (Phase II) had taken on specific directions based on early ERDA guidance before firm guidelines were established for the STEP. Thus, ERDA in the spring of 1977 decided to redirect the project to comply with its new guidelines.

Table 1-1. Summary of Objectives

	INITIAL	REVISED
	1973 (Military Applications)*	1976
NATIONAL SOLAR TOTAL ENERGY PROGRAM (STEP)	o Determine feasibility of military solar applications o Develop solar system to experimentally demonstrate applications * STEP Program not yet in existence	o Demonstrate the technological, economic, and industrial feasibility of the solar total energy concept o Promote a technology which offers the prospects of being economically competitive with other energy sources o By end of FY1982, have an installed capacity of 30 megawatts (5 MW electric, 25 MW thermal)
	1975	1976
LSE-1 DESIGN CRITERIA	o Provide all electricity required by 87000 Complex at solar noon on clear days o High-temperature storage capable of operating the system at full electrical output for one hour	o Base overall system size on load and solar availability profiles o Size system as a supplementary source of energy
	o Use exhaust heat to supply a substantial portion of the thermal energy requirements (space heating and domestic hot water), day and night, year round, of 87000 Complex o Minimize wasted exhaust heat o Use existing air conditioning system	1977 o Provide 60 to 100% of thermal load of 5 selected buildings in 87000 Complex o Provide electricity to 87000 Complex as possible o High-temperature storage for several hours of operation o Use absorption air conditioning o Provide fossil fuel backup

The major impact of the redirection was that, instead of developing a preliminary design based upon the original conceptual design, updated conceptual designs reflecting the new ERDA guidelines and design philosophy were developed as a competitive effort under concurrent ERDA contracts by Westinghouse Electric Corporation and TRW, Inc. ATU's contract was modified as indicated in Part 2 of Appendix A to provide close support to the design contractors during the competition. The preliminary design tasks, which were being performed by Brown and Root Development, Inc. under subcontract to ATU, were eliminated. However, many of ATU's original systems analysis, engineering test, and program support tasks not closely associated with a specific design approach were continued with some reduction in scope for the balance of the contract period.

Most of the systems analysis and program support activities are reported in Section II. These include further studies of solar availability and energy requirements at Fort Hood, investigation of interfacing LSE-I with existing energy systems at the 87000 Complex, and preliminary studies of environmental, health, and safety considerations. An extensive survey of available concentrating solar collectors and modifications to a computerized system simulation model for LSE-I use are also reported. Important program support activities included in Section II are military liaison and information dissemination.

The engineering test program reported in Section III involved completion of the Solar Engineering Test Module (SETM) and extensive performance testing of a single module of the Suntec Systems, Inc. SLATS^{TM} collector. The data obtained for this particular linear-focusing collector will facilitate verification of models for predicting the performance of concentrating collectors in the Fort Hood environment. Plans to test a larger array of the collector selected for LSE-I were deferred until the next contract period because of the impact of the project redirection on the schedule for collector selection.

The system design activities are reported in Section IV. These include the review and refinement of the original conceptual design prior to the project redirection and a description of the site coordination, input data, and other support provided by ATU in connection with the conceptual design competition. Also included is a brief review of the competitive conceptual designs.

The remaining activities for this contract period were the development of detailed plans for the tasks defined in Appendix A; planning the next project phase (during which a preliminary system design will be developed by ATU, with Westinghouse Electric Corporation as the major subcontractor); and broad planning for the balance of the project through construction and testing. These activities are described in Section V.

1.1 Background

The ATU/Fort Hood Solar Total Energy Military Large-Scale Experiment originated in 1973, when the Solar Energy Program Manager of the National Science Foundation (NSF) and general officers from Fort Hood met at ATU to discuss and plan the program. The U.S. Army Corps of Engineers took an active role in the program by assigning a representative to work at NSF to lay the groundwork for military involvement in the Solar Energy Programs. With NSF funding and Fort Hood cooperation, ATU initiated Phase I studies in 1974: to assess the energy requirements of Fort Hood; to set up a station for measuring solar intensity; to examine the applicability of available technology; and to assess the feasibility of solar energy system applications at Fort Hood. This study effort was concluded in March, 1975 and is reported in References 1 through 4.

Phase II, the original conceptual design phase, was planned under the auspices of NSF but was initiated under ERDA when the NSF Solar Energy Programs were transferred to the newly-created ERDA organization. This phase, which had the development of the conceptual design for the ATU/Fort Hood Solar Total Energy System as its primary goal, began in April, 1975 and concluded on November 30, 1976. It included further investigations of solar energy availability and energy requirements at Fort Hood. In addition, an engineering test program was planned and a computerized simulation model was formulated during Phase II. The Phase II activities and results are reported in Reference 5.

The Phase II conceptual design is reviewed here since it serves as the point of departure for subsequent designs. This initial design was based on the definition of a solar total energy system as illustrated in Figure 1-1. The system uses a solar collector field as a source of energy to heat a working fluid which powers a heat engine. The resulting shaft power drives an electrical generator, and the exhaust heat is recovered at a lower temperature for thermal applications such as space heating and domestic hot water.

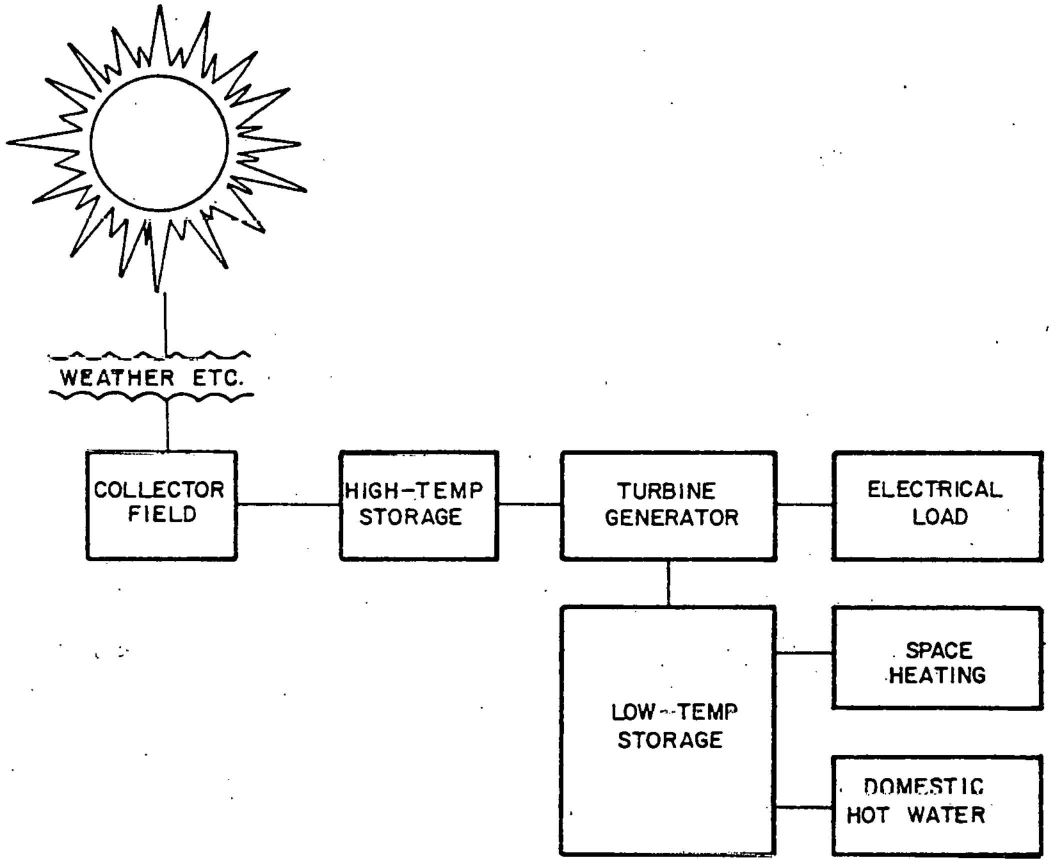


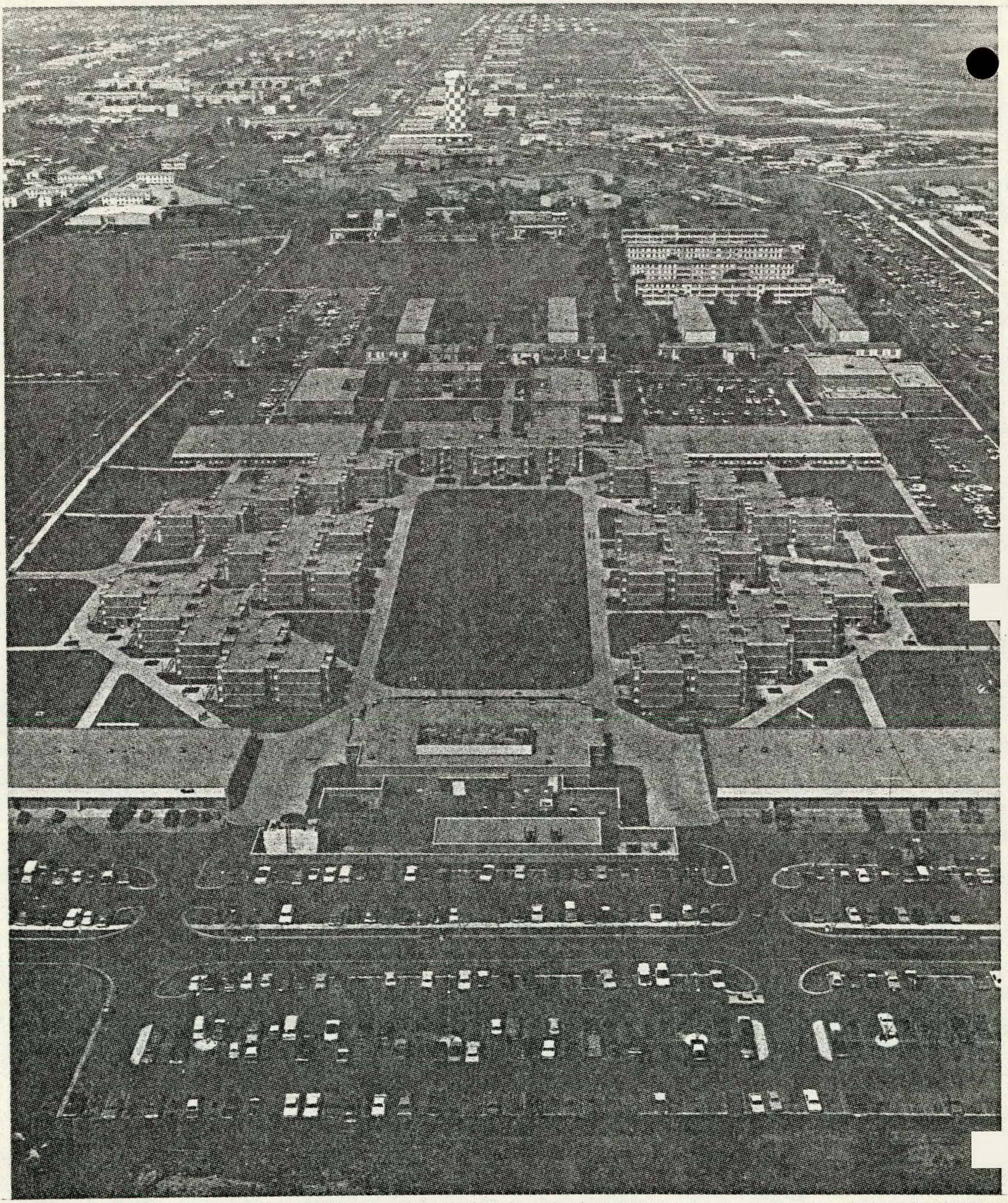
Figure 1-1. Solar Total Energy System Simplified Block Diagram

The 87000 Troop Housing Complex at Fort Hood was selected (with the concurrence of ERDA Program Management) as the basis for the Phase II conceptual design. The 87000 Complex, an aerial view of which is shown in Figure 1-2, is a group of twenty buildings of contemporary Army design located at the eastern extremity of the main post at Fort Hood. This set of buildings provides housing, food services, administration, storage, and recreation for a brigade-size complement of troops.

Consistent with early ERDA direction (see Table 1-1), the solar total energy system was designed as a retrofit system, leaving in place and making use of existing equipment, such as the centrifugal air conditioners and the steam boilers already installed at the 87000 Complex. The effect of this approach was to establish system size requirements based largely upon the high electrical load imposed by summertime operation of the air conditioning. A turbine with variable exhaust temperature was proposed to permit maximum electrical output in the summer and maximum utilization of the thermal output in winter to meet the average daily thermal energy requirments.

Development of the initial conceptual design for the ATU/Fort Hood Solar Total Energy System involved a number of important design decisions, such as the selection of water as the heat-transfer and working fluid throughout the system and setting a maximum water temperature of 530°F at the collector field outlet. The initial conceptual design was presented to ERDA at a September 12-13, 1975 project review meeting and was accepted as the baseline conceptual design. Subsequent Phase II design studies were directed toward refinement of this initial design concept.

The major elements of the conceptual system design and their functional interrelationships as of the end of Phase II are shown in Figure 1-3. The collector field consists of single-axis tracking reflectors that focus direct solar radiation onto receiver tubes to heat the water circulating through them to approximately 530°F. The receivers form part of a heat-transfer loop for transferring the collected heat to an insulated high-temperature primary storage tank, as depicted in Figure 1-3. High-temperature pressurized water is circulated from the primary tank to a steam generator for driving the turbine/generator. Water from the low-temperature secondary storage tank is



77-1021 Figure 1-2. Aerial View of 87000 Troop Housing Complex

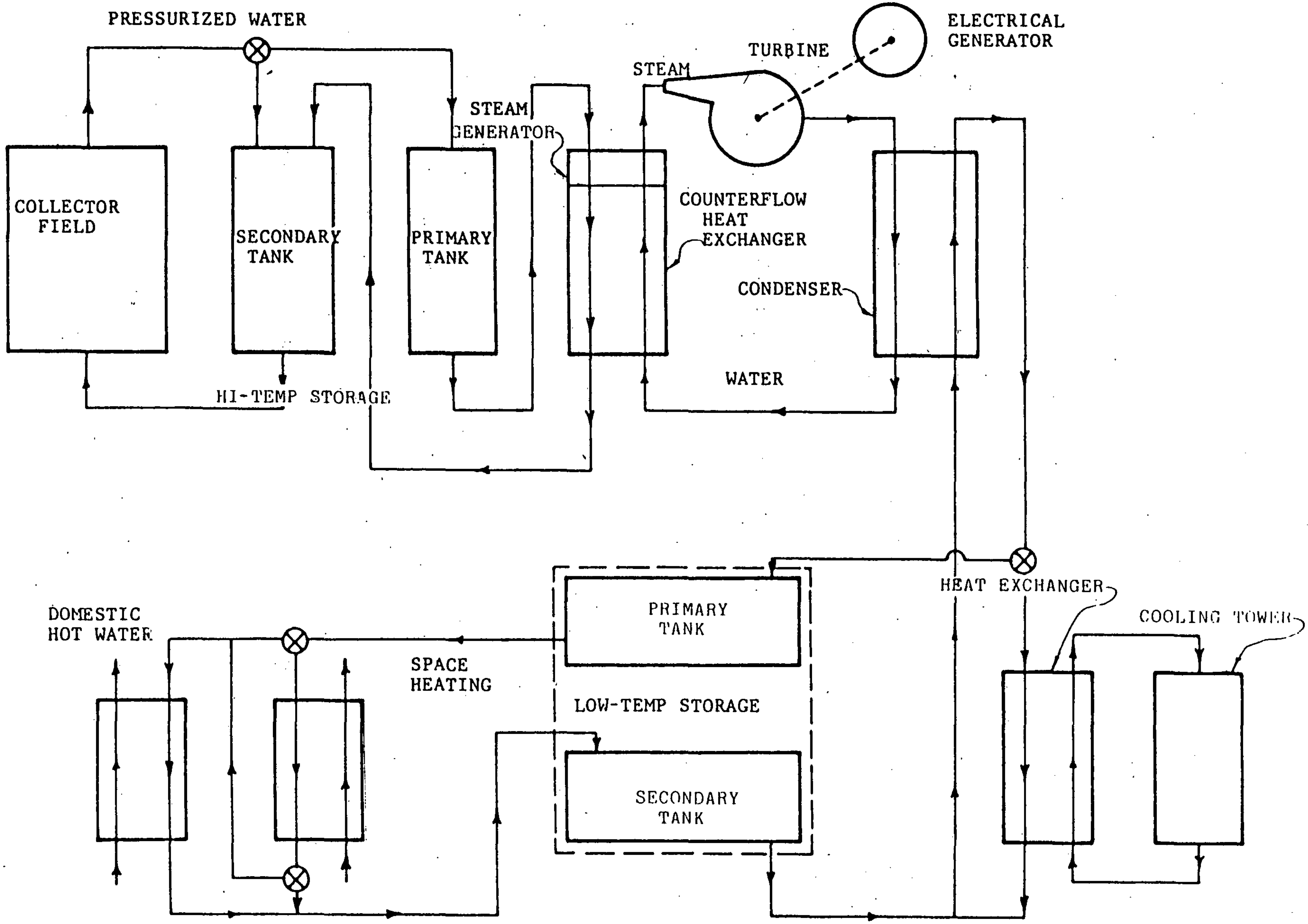


Figure 1-3. Conceptual Solar Total Energy System for the 87000 Troop Housing Complex at Fort Hood

circulated through the turbine condenser to extract exhaust heat for space heating and domestic hot water heating. During the summer, when thermal energy is required only for domestic hot water, the exhaust heat is removed by circulating condenser water to the cooling tower after the low-temperature primary storage tank is fully charged.

It is necessary that total energy systems be decentralized to make effective use of exhaust heat; cost, line losses, and other considerations preclude distribution of thermal energy over wide areas. Therefore, the capacity of a total energy system should be carefully scaled to the loads that are to be satisfied. Accordingly, a significant task of the conceptual design effort was to define the energy requirements of the 87000 Troop Housing Complex at Fort Hood. An average summer peak electrical load of approximately 1.33MW$_e$ and an average winter thermal energy load of approximately 185,000,000 BTU/day were estimated by processes described in detail in Reference 5.

The overall annual performance of the Phase II conceptual system design is summarized in Figure 1-4. Approximately 42 percent of the 79 x 10^9 BTU/year (based on solar intensity measurements for 1974-75) available to an east-west aligned, 220,000 square-foot collector field at Fort Hood is collected. Thermal losses from the manifold pipes, storage tanks, etc., account for approximately 4.2 percent of the 32.9 x 10^9 BTU collected during a year. An average of 14 percent of the remaining thermal energy is converted to electricity, thus supplying 1193 of the 5396 MWH required annually by the 87000 Complex. An additional 99 MWH are generated but are offset by parasitic losses (i.e., the electricity required to operate the solar system).

Although 22 percent of the electricity required by the 87000 Complex is supplied by the system on an annualized basis, all required electricity is supplied during the peak load periods on clear days. No electricity is produced at night, but thermal energy for the 87000 Complex is supplied 24 hours per day, all year, depending upon availability and the requirements. Approximately 27.1 x 10^9 BTU is extracted from the turbine exhaust, and of this, 22.59 x 10^9 BTU is applied toward the estimated 32.75 x 10^9 BTU of thermal energy required annually by the 87000 Complex. Thus, the Phase II conceptual design would

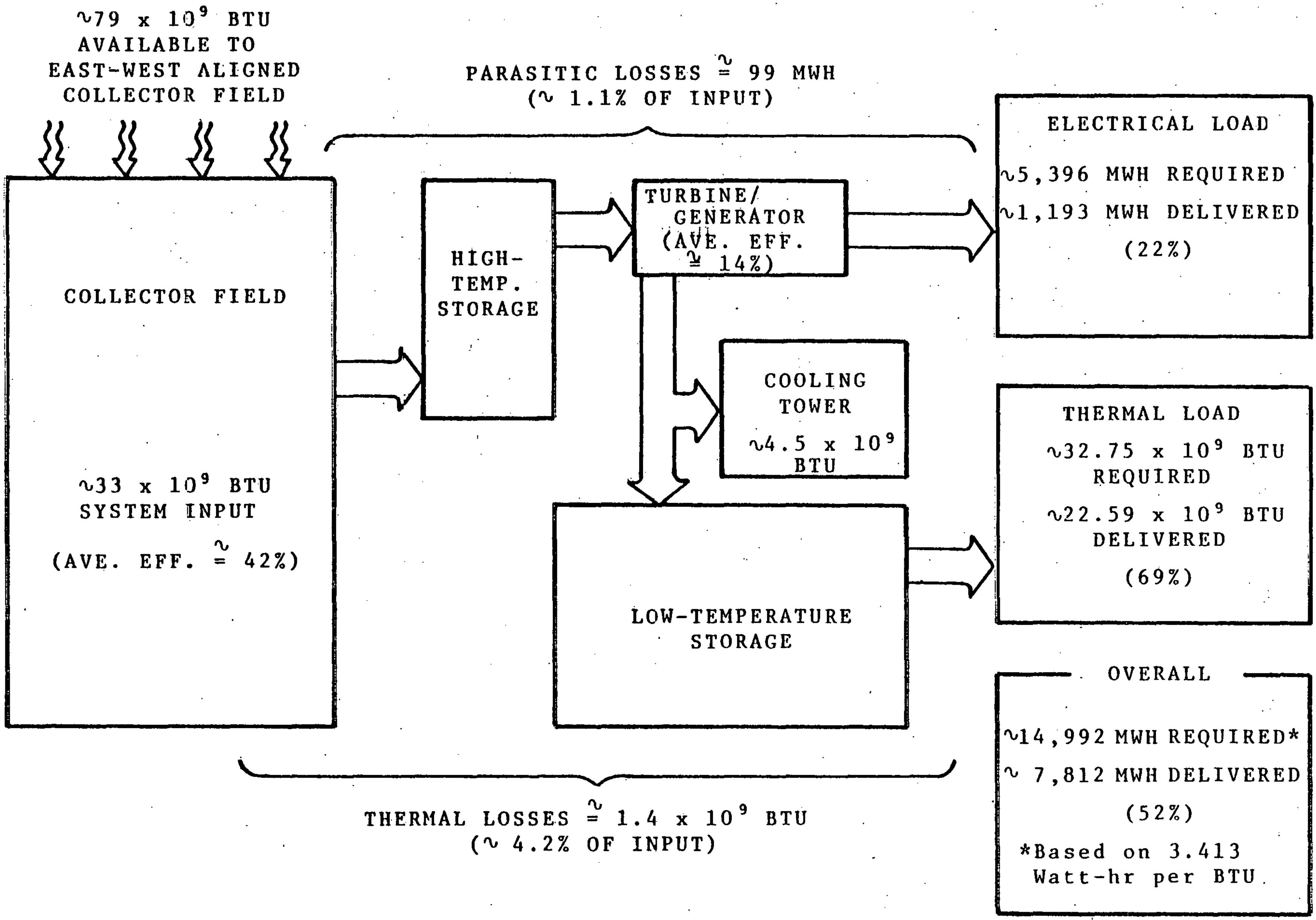


Figure 1-4. Overall Annual Performance Based on Solar Availability Data for 1974-75

supply 69 percent of the annual thermal energy requirements of the 87000 Complex, and 52 percent of the overall annual energy requirements.

Subsequent engineering analyses and performance calculations support the early design approach described above (see Section 4.1). In addition, the conceptual design was reviewed by a panel of experts convened by ERDA on June 29 - July 1, 1976 and was found to be well-conceived and effective within the ERDA guidelines applicable at that time.

1.2 Summary

During the period covered by this report (November 23, 1976 - November 30, 1977) further progress toward realization of the ATU/Fort Hood Solar Total Energy Military Large-Scale Experiment (LSE-1) was made. Major highlights for the period are:

1. Refinement of the original ATU conceptual design for the system with assistance from Brown and Root Development, Inc., and finalization of the 87000 Troop Housing Complex as the installation site.
2. Major redirection of the project effort to reflect new ERDA design philosophy which evolved toward the end of and subsequent to the original conceptual design period.
3. Development of two alternate conceptual designs based on the new ERDA guidelines by other contractors (with ATU site coordination and input data) and ERDA's selection of Westinghouse Electric Corporation for further design work under subcontract to ATU.
4. Completion of the Solar Engineering Test Module installation and extensive testing of the SLATS^{TM} collector.

In addition to the above results, numerous supporting and auxiliary activities are described in this report.

Because of the project redirection, the overall results for this contract period are different from those planned and expected on the basis of the original contract statement of work included in Appendix A. In particular, the original principle objective was to develop the preliminary design for LSE-1; that task was deferred to the next contract period. However, as a consequence of the project redirection, more design alternatives have been studied more thoroughly than could have been done otherwise. Between this advantage and the anticipation that the ERDA objectives and design philosophy have stabilized, it should be possible to approach the preliminary design with more confidence during the next contract period.

Among the various activities that merit specific attention in this summary is the military liaison conducted by ATU. This liaison is the focal point of all coordination between ERDA, ATU, and the other ERDA contractors, and the

U.S. Army. On the military side, several Army organizations at Fort Hood and the Corps of Engineers are involved. This liaison effort has been effective during the contract period reported herein, as is evidenced by continuing strong Army support and cooperation despite the uncertainties caused by the project redirection.

A detailed comparative survey of the characteristics, state of development, and advantages/disadvantages of various generic types of concentrating solar collectors was performed during this period. Although there are other strong contenders, it was concluded that, all factors considered, a parabolic trough collector was the preferred type for LSE-1.

Two supporting activities initiated during Phase I of the project were continued through the present period: solar availability and energy requirements studies. The solar availability at Fort Hood is critical to system design since it is a determinant of collector field size and influences the potential operating patterns of the solar total energy system. Through a cooperative effort with the U.S. Army ASL Fort Hood Meteorological Team, routine measurements of direct, total, and various other insolation values were continued and the results added to the computerized data files at ATU. In addition, compilations of concurrent weather data have been obtained. The more recent data will be used to update the insolation model developed during Phase II in the following contract period.

Energy requirements studies during this period were centered around the detailed energy loads at Fort Hood's 87000 Troop Housing Complex, the installation site selected for LSE-1. Emphasis was placed on resolving the total 87000 Complex electrical and thermal loads into the loads for individual buildings. In addition to utilizing predictive techniques developed during Phase II, a comprehensive metering program was initiated to provide more definitive data.

Although final assessments and plans must await resolution of the solar total energy system design and operation, preliminary studies of LSE-1 environmental, health, and safety aspects were performed; these studies identified those aspects which could be resolved immediately and those which require expanded treatment. A preliminary environmental impact assessment examining the potential effects on air quality, water quality, area biota, etc.

II. ANALYSIS

II. SYSTEMS ANALYSIS AND PROGRAM SUPPORT

Both the original and the modified statements of work (Appendix A) for this contract period provide for a number of analysis and support activities which are more or less independent of a specific design for the ATU/Fort Hood Solar Total Energy Military Large-Scale Experiment. These activities, except for the engineering test program, are reported in this section.

Of particular importance is military liaison, described in Section 2.1 It is necessary to keep the appropriate U.S. Army organizations apprised of current system design directions and alternatives and to determine Army views and policies which must be considered in the LSE-I design. In addition, many of the supporting activities require Army coordination and/or participation.

Two supporting activities that the Army has been deeply involved in from the beginning of the project are the solar availability studies (Section 2.2) and the energy requirements studies (Section 2.3). Solar intensity measurements are made by the U.S. Army ASL Fort Hood Meteorological Team, and the Fort Hood Directorate of Facilities Engineering provides data and close support for the energy requirements studies.

The energy requirements studies encompass Fort Hood as a whole, but the requirements of the 87000 Troop Housing Complex, the LSE-I installation site, are emphasized. Other studies concerning the 87000 Complex (Section 2.4) deal with soil characteristics which are required to determine the future design of collector field and major components foundations and with interfacing considerations for the LSE-I electrical and thermal systems. The environmental, health, and safety studies (Section 2.5) also assume the 87000 Complex as the LSE-I installation site.

Solar total energy systems involve new technology primarily in the solar collector area. Numerous vendors are exploring new approaches to the design and fabrication of concentrating collectors to improve performance and/or reduce cost. It is essential to stay abreast of these developments to provide a better basis for the selection of a particular collector for use in LSE-I. To this end, a survey of concentrating collectors was made and is reported in Section 2.6.

An important tool in designing a solar total energy system and in evaluating its performance is a computerized system simulation model. Modeling requirements and approaches established during Phase II were updated during this contract period, and existing models were evaluated. As described in Section 2.7, this resulted in the selection and modification of an existing model for future use with LSE-1.

The increased public awareness of the necessity to develop alternate energy sources has focused much attention on major solar energy projects such as the ATU/Fort Hood Solar Total Energy Military Large-Scale Experiment. In response to this interest, and to foster support for solar energy development, ATU has been actively involved in information dissemination, including briefings and tours for visitors, technology transfer, and training planning. These activities are described in Section 2.8.

2.1 Military Liaison

From the inception of the ATU/Fort Hood Solar Total Energy Project through Phase II (November, 1976), the Deputy Science Advisor of TCATA* (Training and Doctrine Command Combined Arms Test Activity)was designated as the single point of contact for coordinating project activities with the U.S. Army. Occasionally, Fort Hood, Corps of Engineers, or other U.S. Army representatives were involved in specific activities but requirements were coordinated and arrangements were made through TCATA. This liaison approach worked effectively, but by the beginning of this contract period, it was apparent that increased Army input, especially at Fort Hood, would be required to:

1. Insure that as the preliminary and final design phases progress, the design will remain acceptable to the U.S. Army.
2. Assure that the design meets or exceeds applicable codes and specifications.
3. Provide necessary orientation and coordination with the cognizant Army organizations.
4. Establish definitive roles and interactions for the remainder of the program.

To provide this increased Army participation, the Chief of the Engineering Divison of the Directorate of Facilities Engineering (DFE) at Fort Hood was designated Installation Point of Contact for Solar Energy. The Directorate of Facilities Engineering, although under the command of Headquarters, III Corps and Fort Hood, works directly with the Corps of Engineers including the Fort Hood Resident Engineer Office, the Fort Worth District Engineer Office, and the Southwestern Division Engineer Office. This coordination with the Corps of Engineers is vital to the project since the Corps of Engineers is responsible for all U.S. Army fixed facilities and thus will ultimately be responsible for the ATU/Fort Hood Solar Total Energy System.

Figure 2-1 shows the current relationships between various U.S. Army organizational elements and ATU as they relate to the coordination of the ATU/Fort Hood project. During this contract period TCATA was the prime

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* Formerly MASSTER (Modern Army Selected Systems, Test, Evaluation and Review).

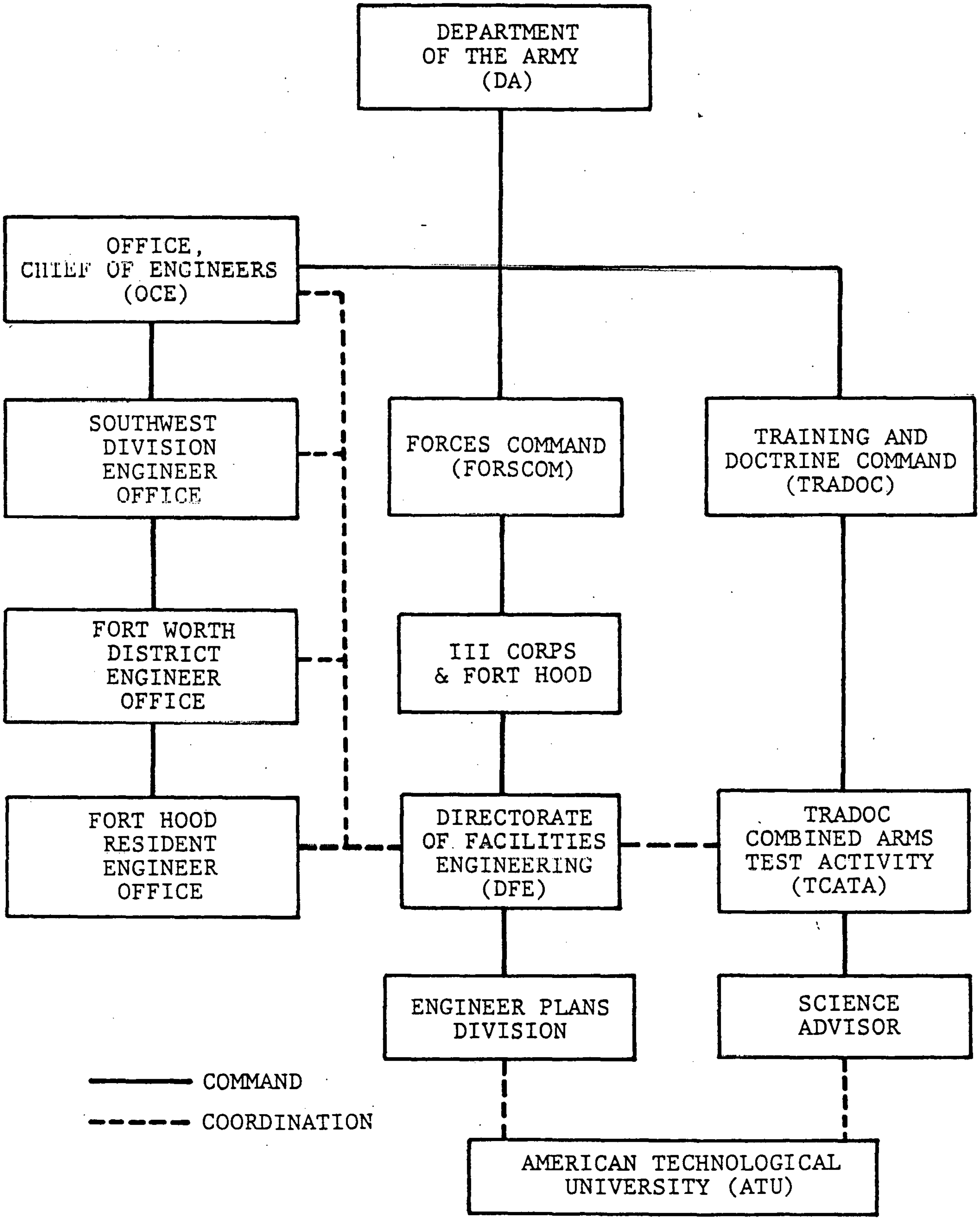


Figure 2-1. ATU/Army Coordination Chart

contact, but DFE will be the main point of contact for subsequent phases. Table 2-1 summarizes ATU, DFE, and TCATA responsibilities requiring coordination.

ATU

- o Obtain Army Clearances & Approvals for SETM
- o Obtain DOD/Corps of Engineers Approval
  - o Troop Housing Complex Selection
  - o Site Layout Selection
- o Hold Joint Reviews of Interface Requirements
- o Coordinate Preliminary Site Preparation Requirements
- o Coordinate & Assist Army in Establishing Future Roles & Missions
- o Coordinate Decisions with Army for Design Acceptance
- o Assist to Training Development Program
- o Coordinate Daily with DFE & TCATA

TCATA

- o Review Design as it progresses
- o Coordinate Logistical Support
- o Provide Reports to DFE
- o Coordinate ASL Met Team Effort
- o Provide Military Interface and Advice to ATU
- o Assist ATU in Briefings & Visitor Arrangements for Military & Civilian Dignitaries
- o Coordinate Daily with ATU and DFE

DFE

- o Review Design as it Progresses
- o Provide Logistical Support
- o Provide Progress Reports CG, III Corps & Fort Hood
- o Facilitate DOE/OCE Support Agreement
- o Provide Ft. Hood/COE Interface and Advice to ATU
- o Ensure Compliance with Applicable Statutes & Regulations
- o Coordinate Construction Codes & Specifications
- o Coordinate Daily with ATU & TCATA

Table 2-1. Coordination Responsibilities

2.2 Solar Availability Studies

System design studies require knowledge of the direct solar intensity available to a field of concentrating collectors located at Fort Hood. The solar intensity must be known not only to determine the amount of solar energy available per unit collector aperture area but also to determine an optimum system size and collector field layout.

In defining the availability of solar energy for the purposes of designing solar energy systems, it is desirable to have long-term data so that average expected solar availability can be determined. The yearly fluctuations in available solar energy can be quite large and it would be improper to design a solar system based on the solar availability for a given year. The solar availability studies are aimed at providing the required data and at supplying a format that is suitable for direct application in the system design studies.

At the start of this project in 1974, no measured solar intensity data were available for the Fort Hood area and no measurements were being made. To remedy this situation, ATU coordinated with the U.S. Army to establish a solar observatory at West Fort Hood. The observatory, which began operation on September 6, 1974, is operated by the U.S. Army Atmospheric Sciences Laboratory (ASL) Fort Hood Meteorological Team. Measured solar intensity and weather data for Fort Hood are now available from September, 1974 through the present time. ATU presently has these data in a magnetic tape data file which is extended every six months to include the most recent measurements. A complete description of the solar radiation and climatological measurements is given in Appendix B of the Phase II Final Report (Reference 5).

Because no long-term solar intensity data were available for Fort Hood, analytical expressions for estimating long-term trends in solar availability were developed during Phase II. These expressions, which relate solar intensity to cloud cover and visibility, were based on the following data:

1. Measured hourly normal incidence and total insolation data for Fort Hood for the period September, 1974 to May, 1976.

2. Hourly cloud cover and visibility at Fort Hood for the period September, 1974 - May, 1975.

It was found that the solar intensity at any hour of any day under various weather conditions could be predicted with these expressions.

Climatological data for the years 1961 - 1969 were used to estimate solar availability at Fort Hood for the same period. These data were then used to develop a model average year of solar availability. This model average year is described in detail in Reference 5. The model average year data were used for the conceptual design and will be used at the start of preliminary system design. During preliminary design, both the methods for estimating the solar intensity and the model average year will be updated using the expanded measured solar intensity data base and climatological data for the years 1961 - 1977.

The Lawrence Berkeley Laboratory (LBL) Circumsolar Telescope Program placed a circumsolar telescope at Fort Hood from July, 1976 through September, 1977. The circumsolar telescope consists of a highly collimated detector (resolution of approximately 1.5 minutes) to measure relative intensities across the sun and within ± 3 degrees of the sun (Reference 6). Measurements were made for the above period and the data sent to LBL for reduction.

ATU's interest in these data stems from the fact that the concentrating solar collectors that may be used for LSE-1 typically have an aperture of approximately 1.5 degrees. The solar intensity data defined in the model average year are based on data taken with normal incidence pyrehilometer (NIP) which has an aperture of approximately 5.7 degrees. Use of this data implicitly assumes that the diffuse component between 1.5 degrees and 5.7 degrees is negligible. Examination of limited data from measurements and analyses indicates that this assumption is reasonable under ideal, clear day conditions. However, under other atmospheric conditions, this assumption could lead to overestimating the energy that may be collected. Whether the net overestimate over an extended period of time (i.e., one year) is significant is unknown at the present time (see Section 3.3.2 for related discussion).

To help resolve this issue, ATU requested that LBL analyze the Fort Hood circumsolar data for a representative variety of atmospheric conditions. The following mode of analysis was suggested:

1. Let $f(\phi)$ represent the circumsolar telescope clear filter data as a function of angle ϕ relative to the center of the sun.
2. Integrate

   $$F(\phi) = 2\pi\int_0^{\phi'} f(\phi) \sin \phi d\phi$$

   for $\phi' = 0.25$ (solar rim angle), 0.5, 1.0, 1.5, 2.0 and 3.0 degrees
3. Plot or tabulate $F(\phi')$.

It is anticipated that the results of this analysis will be received from LBL early during the preliminary design. They will provide a basis for adjustments which should be included in the preliminary design studies.

Collector field layout and control studies also require some knowledge of the spatial variation of the solar intensity over the collector field during partly cloudy periods. Such measurements have been planned for the next contract period.

2.3 Energy Requirements Studies

Considerable emphasis has been placed on defining the energy requirements of the fixed facilities at Fort Hood. During Phase I, the energy requirements studies were concentrated upon the monthly, daily, and hourly usage patterns of the post as a whole and upon resolving the total energy consumption into components according to type of load (i.e., space heating, domestic hot water heating, lighting, etc.). These studies, described in Reference 1, were based upon data developed primarily from utility company metering records for Fort Hood during the period October, 1973 through September, 1974.

Detailed gas and electricity consumption data for the period October, 1974 through September, 1975 were prepared as part of the Phase II conceptual design effort (see Reference 5). However, the emphasis of the Phase II energy requirements studies was on estimating and verifying the monthly energy requirements at the 87000 Troop Housing Complex.

Energy studies performed under the present contract emphasized energy load profiles for the 87000 Complex and the loads of individual buildings within the complex. The load profiles were required for the evaluation and refinement of the original conceptual design (see Section 4.1). The data for individual buildings were used in the conceptual design competition (see Section 4.3). An extensive metering program was also initiated at the 87000 Complex.

2.3.1 87000 Complex Load Profiles

Profiles defining both the thermal and electrical energy load requirements for the 87000 Complex were developed at two levels of detail:

1. The hourly thermal and electrical energy requirements for an average winter and summer day; and
2. The daily and hourly thermal and electrical energy requirements consistent with the Phase II model average year.

These profiles were based on the estimated gas and electricity consumption at the 87000 Complex during the years 1974 - 1975. Predictive techniques developed in Reference 5 and the overall measured gas and electricity consumption for Fort Hood were used to determine the consumption data for the 87000 Complex.

The hourly thermal loads for an average winter and summer day were based on the gas consumption, assuming 985 BTU per cubic foot of gas and an efficiency of 81.2 percent for the steam boilers. The gas requirements for the 87000 Complex were determined by multiplying the Fort Hood usage by the ratio of the number of square feet in the buildings at the 87000 Complex to the total number of square feet in all buildings at Fort Hood.

These different thermal components, domestic hot water, space heating, and absorption air conditioning, were used to define the three hourly thermal load profiles shown in Table 2-2. The one thermal load profile for an average winter day contains only the domestic hot water and space heating components. The hourly thermal loads were required for the average summer day. One included domestic hot water and an estimated load assuming absorption air conditioning was added at the 87000 Complex. The second average summer day thermal load included the domestic hot water load only, as is presently the case using centrifugal air conditioning.

The estimated domestic hot water load was based on 40 gallons of 130°F water per occupant per day. The absorption chiller thermal load was estimated from the electrical load for centrifugal chillers given in Reference 5. A coefficient of performance (COP) of 4.22 and 0.665 was assumed for the centrifugal and absorption chillers, respectively. The absorption chiller thermal load was calculated as the centrifugal chiller electrical load multiplied by the conversion factor 3.413×10^3 BTU/KWH and the ratio of the COP (centrifugal) to COP (absorption).

Table 2-2. Hourly Thermal and Electrical Energy Loads at the 87000 Complex for an Average Winter and Summer Day

	Thermal Load (BTU/hr)			Electrical Load (KW)	
Hour	Average Winter Day*	Average* Summer Day (centrifugal A/C)	Average Summer Day (absorption A/C)	Average Winter Day	Average Summer Day
1	6,598,837	1,129,031	11,921,961	295.2	793.2
2	6,597,863	1,088,708	11,881,638	270.6	768.6
3	6,675,595	1,048,386	10,941,902	270.6	727.1
4	6,832,030	1,008,063	10,002,171	246.0	661.0
5	7,108,944	1,068,547	10,062,655	246.0	661.0
6	7,564,879	1,209,676	10,203,784	270.6	685.6
7	8,522,423	1,754,031	9,848,732	295.2	668.7
8	8,798,368	1,774,192	9,868,300	344.4	717.9
9	8,741,282	1,854,837	10,848,945	369.0	784.0
10	8,507,122	1,935,483	12,728,413	369.0	867.0
11	8,156,358	2,076,612	14,668,364	369.0	950.0
12	7,761,874	2,036,289	15,527,455	369.0	991.5
13	7,230,693	2,036,289	17,326,276	369.0	1,074.5
14	6,717,131	1,955,644	18,145,039	369.0	1,116.0
15	6,221,356	1,794,354	18,883,163	369.0	1,157.5
16	6,003,468	1,733,870	18,822,679	344.4	1,132.9
17	5,884,442	1,693,547	18,782,356	319.8	1,108.3
18	6,142,654	1,794,354	17,983,746	344.4	1,091.4
19	6,377.789	1,754,031	17,044,018	344.4	1,049.9
20	6,432,444	1,572,579	15,063,745	369.0	991.5
21	6,508,718	1,471,773	14,962,939	369.0	991.5
22	6,646,932	1,491,934	14,983,100	344.4	966.9
23	6,764,500	1,471,773	14,063,525	319.8	900.8
24	6,662,237	1,310,483	13,902,235	295.2	876.2
TOTAL	169,457,885	38,064,486	338,446,029	7,871.4	21,731.4

* Includes both space heating and domestic hot water.

The 24-hour electrical loads for the 87000 Complex were estimated in two components, the base load and the air conditioning load. The base load was estimated by assuming that the energy use of the 87000 Complex was directly comparable to the percentage of the total Fort Hood floor area represented by the 87000 Complex. This percentage, 2.46, was then applied to the hourly Fort Hood electrical load for an average day in June, July, and August of 1975. The air conditioning electricity requirements were estimated by prorating on the basis of the total air conditioning tonnage installed at Fort Hood rather than by floor area, since not all the floor area is air conditioned.

To estimate the 87000 Complex daily and hourly loads corresponding to the model average year, expressions were derived from the relationships between degree days and energy consumption at Fort Hood, as described in Reference 1.

The thermal energy load, T_J, in BTU per day is given by the expression:

$$T_J = 10^7 \left[SH_J (0.443 H_J + 6.116) + 3.806\right]$$

where SH_J = space heating option for day J

= 1.0 when space heating is on

= 0 when space heating is off

and H_J = number of heating degree-days for day J

$= 65^{\circ}F - \overline{T}$

where $\overline{T}$ = average temperature for day J.

The constant 3.806 represents the load for domestic hot water heating.

The electrical energy load, E_J, in MWH per day is given by the expression:

$$E_J = AC_J (0.404 C_J + 6.342) + 8.284$$

where AC_J = air conditioning option for day J

= 1.0 when air conditioning is on

= 0.0 when air conditioning is off

and C_J = number of cooling degrees for day J

$= \overline{T} - 70^{\circ}F$

The constant 8.284 represents the electrical base load.

The terms SH_J and AC_J in the above equations were included to account for the energy conservation program employed at Fort Hood. Under this program, air conditioning is provided only from May 1 through September 30 and space heating is provided from October 1 through April 30. Using the above equations and the average daily temperature, $\bar{T}$, calculated from the hourly temperatures given in the model average year (see Section 2.2), daily thermal and electrical energy loads were estimated for use in annual system performance calculations.

The daily loads were also extended to provide hourly load profiles for each day of the year. Based on the hourly gas and electricity consumption profiles for Fort Hood, an hourly profile was developed for an average day in each month. These profiles were normalized to unit and then weighted by the daily load as calculated above. Hourly loads were thus calculated for each hour of each day of the year.

2.3.2 Individual Building Loads

Individual heating and cooling loads were also calculated for the five buildings within the 87000 Complex selected as a basis for the thermal load for the conceptual design competition (see Section 4.2). The buildings included: a three-module barracks (87013), two four-module barracks (87012 and 87015), a three-company administration and storage building (87014), and a five-company administration and storage building (87016). The methods used for the calculations are those developed in the ASHRAE Handbook (Reference 7). The assumed building characteristics, number of people per building, and rate of air infiltration were the same as those used in the original design of the complex.

Inside temperatures of 68°F and 78°F were assumed for heating and cooling days, respectively. The assumed outside dry-bulb temperatures were as follows:

Hour	Cooling Day	Heating Day
2	79°F	38°F
4	77	34
6	75	36
8	76	38
10	83	40
12	89	46
14	93	50
16	96	52
18	95	51
20	92	47
22	86	44
24	82	40

Linear interpolation was used to obtain the temperature for the hours not listed.

The calculated hourly heating and cooling loads for the design day are given in Table 2-3 for each of the five selected buildings. The total daily heating load was 48.0×10^6 BTU and the cooling load was 50.5×10^6 BTU. A daily domestic hot water load of 20×10^6 BTU was assumed and must be added to the space heating and cooling loads to obtain the total daily thermal load for the five buildings.

Table 2-3. Calculated Hourly Heating and Cooling Loads for Five Select Buildings within the 87000 Complex

Building No. and Type	(BTU/hr) x 10^3																								
	Hour																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
												Heating Load													
BARRACKS																									
3 Module 87013	516	533	567	600	583	567	550	533	516	500	449	399	365	332	314	298	306	315	348	382	411	440	470	500	10,800
4 Module 87012	698	721	765	812	789	766	744	721	698	676	607	540	494	449	426	404	415	426	471	517	550	585	630	676	14,600
4 Module 87015	698	721	765	812	789	766	744	721	698	676	607	540	494	449	426	404	415	426	471	517	550	585	630	676	14,600
ADM. & STOR.																									
3 Co. 87014	155	159	166	173	170	166	162	159	155	152	141	130	122	115	112	108	110	111	119	126	131	137	144	152	3,370
5 Co. 87016	210	214	222	231	227	222	218	214	210	206	193	180	192	163	159	155	157	159	167	176	182	187	197	206	4,630
TOTAL	2,280	2,350	2,490	2,630	2,560	2,490	2,420	2,350	2,280	2,210	2,000	1,790	1,670	1,510	1,440	1,370	1,400	1,440	1,580	1,720	1,850	1,930	2,070	2,210	48,000
												Cooling Load													
BARRACKS																									
3 Module 87013	425	396	336	336	411	435	500	515	523	532	544	557	579	602	634	666	647	627	585	543	518	494	474	453	12,400
4 Module 87012	557	513	486	445	611	633	653	673	688	702	681	692	741	792	846	900	870	841	781	722	674	627	607	588	16,300
4 Module 87015	557	513	486	445	611	633	653	673	688	702	681	692	741	792	846	900	870	841	781	722	674	627	607	588	16,300
ADM. & STOR.																									
3 Co. 87014	63	58	53	48	51	54	79	103	107	110	107	104	106	107	115	123	101	79	78	78	75	72	69	67	2,010
5 Co. 87016	99	91	81	72	91	110	166	222	223	223	198	173	178	183	197	212	173	134	132	129	123	116	112	108	3.550
TOTAL	1,700	1,600	1,470	1,350	1,630	1,920	2,050	2,190	2,230	2,270	2.210	2,220	2,350	2,480	2,640	2,800	2,660	2,520	2,360	2,190	2,060	1,940	1,870	1,800	50,500

2.3.3 87000 Complex Metering

Another important aspect of the Phase II energy requirements studies was the planning and initiation of individual metering for a number of buildings at Fort Hood. The "Facilities Engineering Support Agency Fixed Facility Energy Consumption Investigation", described in Reference 5, resulted in electricity and/or gas meters being installed in approximately 70 individual Fort Hood buildings. ATU project personnel worked closely with both the Fort Hood Directorate of Facilities Engineering (DFE) and the Facilities Engineering Support Agency (FESA), Fort Belvoir, Virginia, in selecting installation sites and installation priorities for these meters. Unfortunately, reassignments of key FESA personnel directly involved in the instrumentation program resulted in installation schedule slippage. Moreover, much data recorded by the instrumentation already installed contained erroneous multipliers and lacked positive instrument connections, rendering the data collected too questionable for use.

Because of the problems with the FESA metering and the importance of accurate load data to the LSE-I design, ATU recommended and ERDA agreed that meters to directly record the consumption of the entire 87000 Troop Housing Complex, and of the twenty individual buildings within, be installed as part of the project effort. Amprobe recording ammeters and a kilowatt/kilovolt ampere reactive (KW/KVAR) recorder were procured. The recording ammeters were installed on individual building electric circuits to provide minute-by-minute ampere demands for one phase of the three phase circuits. The recording KW/KVAR meter was used in analyses of individual building circuits (i.e., KW/KVAR, power factor, three phase power, and reactive power) such as 87017 (Food Service) and 87018 (Central Energy).

Ampere load profiles have been recorded continuously since July, 1977, when the air conditioning in the 87000 Troop Housing Complex was turned on. Maximum hourly demands are recorded on worksheets by building number, Julian date, and duty or non-duty day. Data were acquired for half of the buildings; then the recorders were removed and installed on circuits to the other half of the buildings. Three phase apparent power in KVA was calculated for each hour of each day during the recording periods.

The next step involved manually entering the three phase maximum KVA calculations onto coding forms and key punching these for storage in a computer data file. A computer program was prepared to record and store the hourly maximum KVA demands, the hourly minimum KVA demands, and the average hourly KVA demands. The program provides for updating this data base as additional data are acquired. Periodic computer printouts show maximum, minimum, and average hourly KVA demands for each building by duty and non-duty day. Appendix B contains printouts of the data collected during the 1977 air conditioning season.

Metering of the monthly electricity consumption of the entire 87000 Troop Housing Complex was initiated by DFE in October, 1975 (Reference 5). Beginning on May 8, 1977, meter readings were taken daily and hourly on some days. Figure 2-2 shows the hourly electricity consumption in KWH for the entire 87000 Complex for Wednesday, May 11, 1977. These hourly consumption values were obtained from KWH meter readings. Shown in Figure 2-3 is the hourly consumption for the 87000 Complex for fifteen duty days. Consumption is greater on duty days than on non-duty days.

Figure 2-4 shows the recently measured and the earlier estimated monthly electricity consumption for the entire 87000 Complex. The estimated electrical consumption was based on the application of proration techniques to the base-wide consumption for the period October, 1973 through September, 1974 (see Reference 5). The estimated and measured consumption for the months of June, July, August, and October agree closely. During May, 1977, the 87000 Complex air conditioning was not operated, resulting in a much lower monthly consumption than estimated based on May, 1973 data. The large difference noted for September is due to the unusually low temperatures recorded during September, 1973 and the unusually high temperatures recorded in September, 1977. The present measurements will continue into 1978, completing at least a full year of daily data.

In addition to the electrical measurements presently underway, instrumentation has been procured for measuring and recording the heating and cooling loads of the five selected buildings. This instrumentation consists of flow meters and temperature sensors for chilled water supply and chilled water

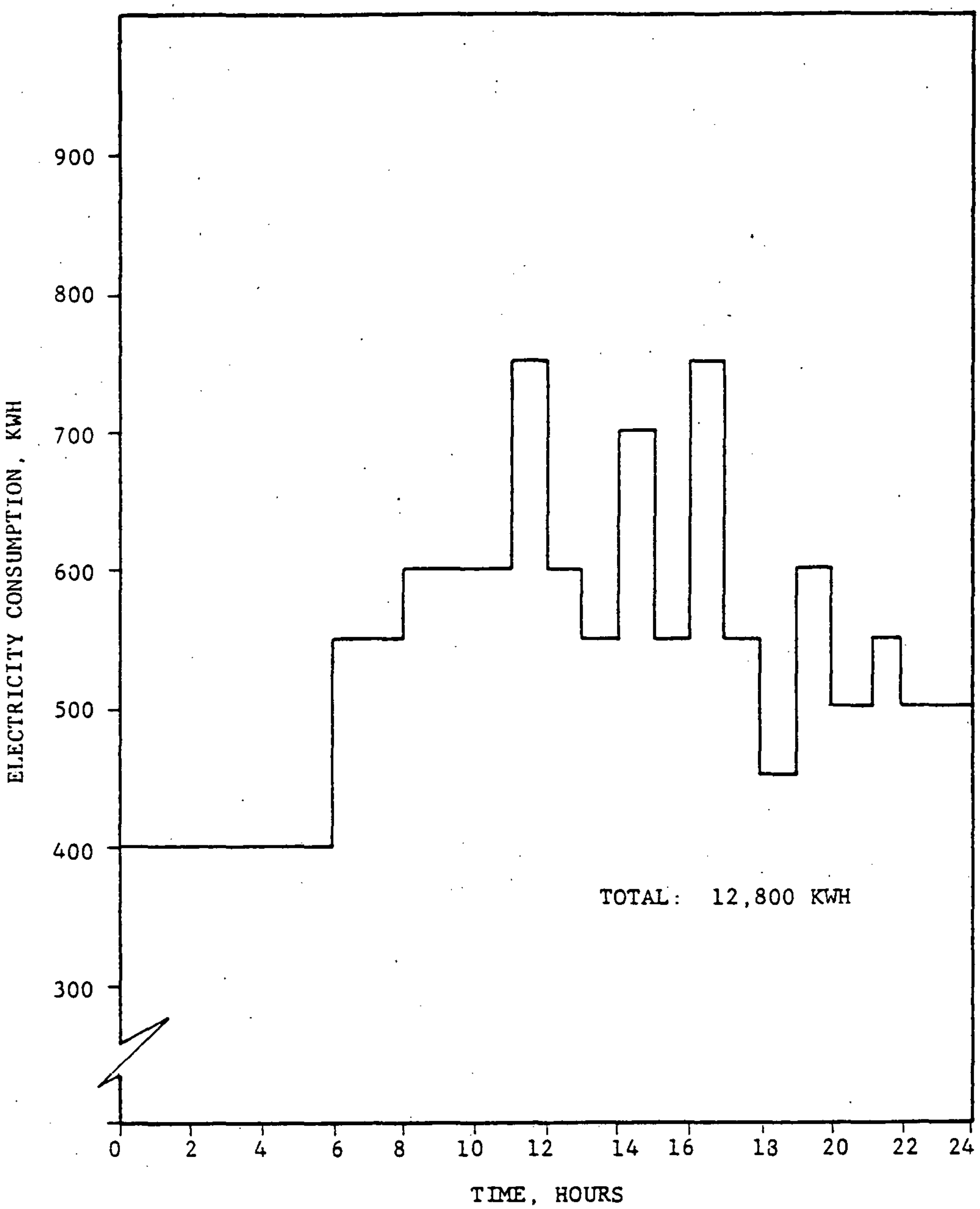


Figure 2-2. 87000 Complex Electricity Consumption (KWH), Duty Day, Wednesday, May 11, 1977

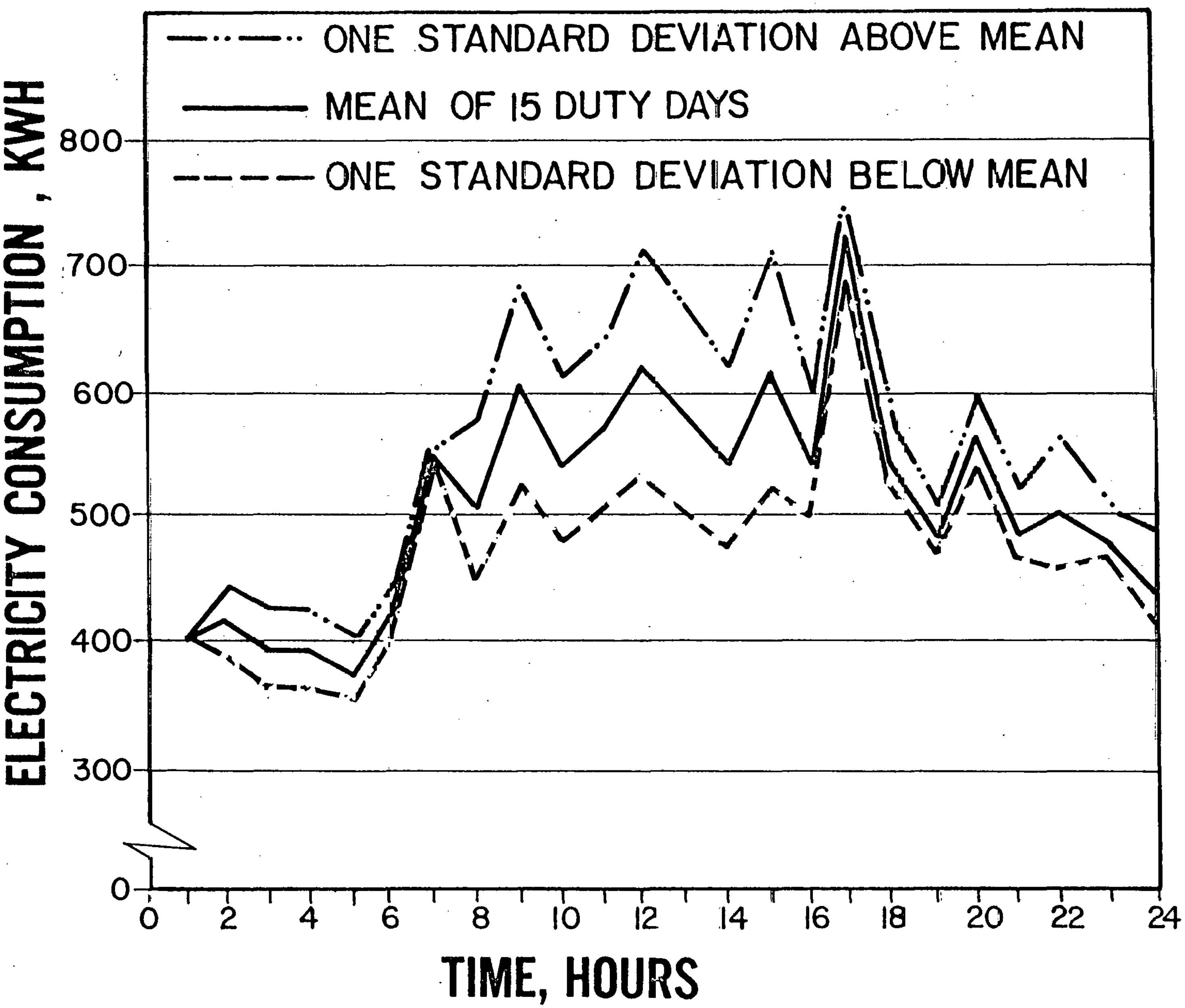


Figure 2-3. 87000 Complex Electricity Consumption (KWH), Average Hourly KW Over 15 Duty Days, May 9-27, '7

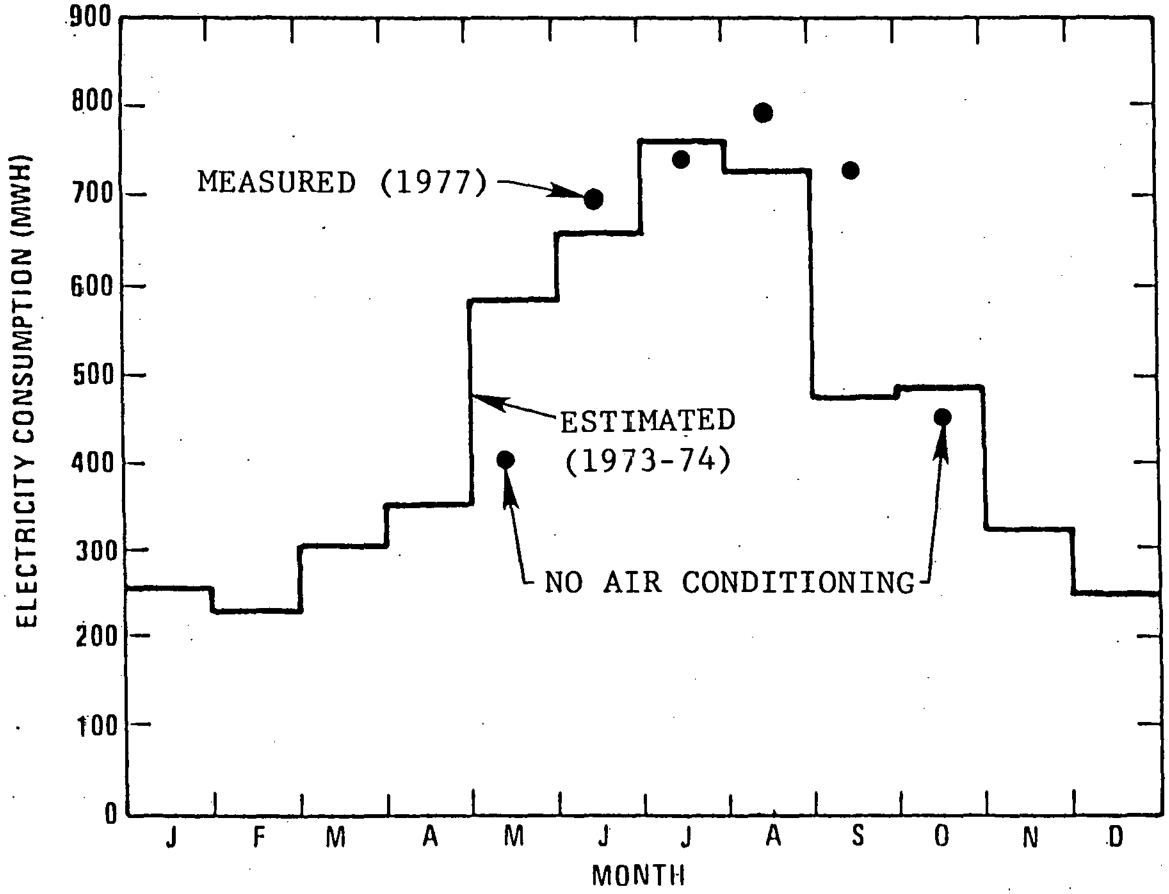


Figure 2-4. Measured and Estimated Electricity Consumption at the 87000 Complex

return, a flow meter for condensate return, pressure sensors, temperature sensors for steam and condensate return, signal transmitters, and recorders.

Requests for quotations have been issued to prospective mechanical and electrical contractors for installation of the instrumentation. This installation was planned for the 1977 air conditioning season, but procurement delays prevented that. Installation will be completed as early in the heating season as possible.

2.4 87000 Complex Studies

Information and data on the 87000 Troop Housing Complex have been collected on a continuing basis since the complex was tentatively selected as the LSE-I installation site in 1975. Aside from the energy requirements, discussed in Section 2.3, studies during this contract period have been concerned with developing information which, in turn, will influence the final design details.

Installation of the collector field and of major system components such as storage tanks requires consideration of soil characteristics. As discussed in Section 2.4.1, data from the original 87000 Complex design analysis were supplemented by additional core borings during this period.

Analyses were also performed of the requirements for interfacing both the electrical and thermal energy subsystems for the ATU/Fort Hood Solar Total Energy System with the existing conventional energy systems of the 87000 Troop Housing Complex. It should be emphasized that the electrical and thermal energy subsystems interfacing considerations described in Sections 2.4.2 and 2.4.3 are subject to change as final arrangements are worked out with the Army and the utility companies.

2.4.1 Soil Characteristics

The Army Corps of Engineers' foundation design analysis and soil report for the 87000 Troop Housing Complex include core boring data for all areas on which complex construction occurred. The contract drawings for the 87000 Troop Housing Complex include the area topography, drilling log information, and other civil data. Also on hand is a general soils survey of Bell County.

Since the collector field area was not included in this analysis, ATU solicited bids for a general soils investigation at that site. A contractor was selected and five core borings were taken during the summer of 1977, one each at the center point and mid-points of the diagonals of the area where the collector field is most likely to be installed. A soils report and related soils laboratory testing information are now in hand. These data, in conjunction with the previous data from the Corps of Engineers, are adequate for conceptual design purposes.

Early in the preliminary design it will be necessary to conduct more extensive field investigations to assure site suitability for various LSE-I components. Conditions necessary for economical excavation, site preparation, and foundation stability must be considered. The core borings and tests required will depend upon the final locations selected for specific system elements (e.g.,collector arrays, storage tanks). A thorough topographic survey of the site will be required in the initial months of the preliminary design. Based on the soils information and topographic data thus obtained, a foundation design analysis may then be completed.

2.4.2 Electrical Interfacing

Most of the conceptual design studies have been based on the assumption of co-generation (or parallel generation) with the existing electrical service supplied by Texas Power and Light Company (TP&L) at the 87000 Complex. Therefore, during the present contract period, emphasis has been placed on coordinating the project with TP&L and obtaining official concurrence for the electrical interfacing of the ATU/Fort Hood Solar Total Energy System.

ATU had previously coordinated the Phase II conceptual design effort with TP&L officials and had received unofficial concurrence for parallel generation along with peak demand reduction (peak shaving). However, after the redirection of effort by ERDA and the ensuing conceptual design competition between TRW, Inc., and Westinghouse Electric Co. (See Section 4.2), it became apparent that the Army might have reservations about parallel electric generation. To clarify the Army's position, a letter, dated June 17, 1977, was sent to Colonel J.L. Momeier, Director of Facilities Engineering, Fort Hood, requesting the official views of Fort Hood concerning the manner of operation of the solar-powered electrical generator. The letter pointed out the controversial aspects of operating the solar-powered electrical generator in parallel with the Texas Power and Light Company system through the Fort Hood electrical distribution grid.

A reply, received on July 14, 1977, indicated that the Army opposed the concept of parallel electrical generator operation and recommended that an isolated load be supplied by the solar-powered electrical generator through a quick transfer switch or switches with mechanical interlocks. Fort Hood's opposition was based on safety, legal, and operational concerns.

On the morning of August 22, 1977, project representatives from ATU and Sandia Laboratories met with TP&L officials to seek their cooperation regarding parallel electric generator operation and electrical peak shaving during the remaining phases of the ATU/Fort Hood Solar Total Energy Project. At the conclusion of the meeting, one vice-president summarized his understanding of TP&L's participation as follows:

1. TP&L will cooperate with the solar project if the company is compensated for any costs incurred, including the cost of standby electrical service and any special equipment and/or personnel.
2. TP&L must be free of any liability stemming from the large-scale solar experiment, both its equipment and operation.
3. Any required modifications to the electric service contract must be mutually agreeable to the Army and TP&L.
4. Finally, TP&L participation in the solar experiment is subject to alteration by regulatory authorities, such as the Public Utility Commission of Texas.

A second meeting was held on the afternoon of Monday, August 22, 1977 at Fort Hood's Directorate of Facilities Engineering. The purpose of this meeting was to inform the Director of Facilities Engineering of the results of the morning meeting with representatives of the Texas Power and Light Company. Personnel from DFE, TP&L, ATU, Sandia Laboratories, and TCATA were in attendance. At the conclusion of this meeting, the Director of Facilities Engineering at Fort Hood summarized the Army's position with these observations:

1. The Army Power Procurement Office must approve any plan of operation of the LSE-1 electrical system.
2. Any discussions held prior to Army approval concern only feasibility.
3. Any specific plan to allow parallel electric generator operations must be approved by the Office of the Chief of Engineers and the Department of the Army prior to contract negotiations between Fort Hood and Texas Power and Light Company.

Close contact was maintained with TP&L during the remainder of the contract period. The company was informed of new developments and of the design status, particularly in the areas of electrical subsystem design, interfacing, and the proposed method of operation. Liaison and coordination with the Texas Power and Light Company will continue throughout the system design phase. An initial task during the next phase will be the development of a memorandum of understanding between the key agencies involved in the electrical interfacing of LSE-1.

2.4.3 Thermal Systems Interfacing

One of the primary interfacing considerations is the existing thermal energy distribution system for space heating and domestic hot water in individual buildings of the 87000 Complex. The interfacing complexity depends upon whether the solar total energy system yields thermal energy in the form of steam or hot water, since the existing system in the 87000 Complex uses steam to produce hot water for space and domestic hot water heating.

The existing thermal energy system of the 87000 Complex includes two steam boilers located in the Central Energy Facility (Building 87018), a steam line, and a condensate return line connecting to the mechanical rooms of the buildings in the complex. In most cases, converters (heat exchangers) are used to heat water from the steam in the mechanical rooms of the buildings. Water is heated to approximately 180°F and circulated to the air-handling plenums for space heating. Tap water is heated to approximately 130°F and held in a storage tank for domestic use. Exceptions are the storage areas of the company administration and supply buildings, which are heated by steam-driven unit heaters. The rather small domestic hot water requirements for the company administration and supply buildings (lavatories only) are presently supplied by small electric hot water heaters.

One approach to thermal distribution for a solar total energy system at the 87000 Complex would be to convert the existing system from steam to hot water. This approach, which was studied extensively, would entail:

1. Replacing the condensate return line with a larger line to handle return water.
2. Installing large converters at the Central Energy Facility to produce hot water for the modified thermal distribution system.
3. Removing the steam converters in each mechanical room and installing water/water heat exchangers for heating domestic hot water.
4. Replacing the steam-driven unit heaters in the storage areas by hot water-driven heaters.

5. Interfacing the solar total energy system to the modifed thermal distribution system at the Central Energy Facility so that thermal energy can be provided either from low-temperature storage or from the conventional system boilers when the heat content of low-temperature storage is inadequate. An alternate approach to the interfacing would be to use heat from the steam boilers to augment the heat input from the turbine condenser to the low-temperature primary storage tank when necessary. This would produce less cycling of the boilers and increase their efficiency.

An approach of this type would clearly be advantageous for installation in a new troop housing complex where retrofit could be avoided. Another approach for the 87000 Complex would be to leave the existing system more or less as is and install a parallel hot water distribution system which would interface with the existing system at the mechanical room of each building. These choices are based on early design considerations. The ultimate choice of an approach to interfacing with the thermal distribution system will be based on the final design.

2.5 Environmental, Health, and Safety Studies

The potential effect on the Fort Hood environment of a solar total energy system which includes several acres of solar collectors must be assessed. A preliminary Environmental Impact Assessment was completed in August, 1977 (Reference 8); this study examined the potential affect of the experiment on air quality, water quality (source, supply and storage), area biota, acquatic life, etc. Both short-term construction effects and long-term operational ones were considered.

It should be noted that the final environmental assessment must not be limited to the initial large-scale experiment. After the successful completion of the experimental system, it is anticipated that a number of similar systems will be installed at Fort Hood. Therefore, the final environmental assessment will include consideration of how a number of such systems would affect the Fort Hood area.

Occupational and non-occupational guidelines and standards to be used for controlling noise levels will be incorporated into a detailed safety analysis during the preliminary design phase. Storage and use of petroleum and/or toxic and hazardous materials will be analyzed, with particular attention to the operation of the power generating equipment. The system characteristics, operation, and possible failure modes will be analyzed to identify potential safety hazards. Both classes of hazards must be evaluated: 1) normal operating conditions and 2) failure conditions.

The Department of Defense (DOD) and the U.S. Army have published regulations and guidelines to protect the environment and the health and safety of their employees, both military and civilian. For the most part, these regulations are based on federal laws or on the national codes of the appropriate professional associations. The ATU/Fort Hood Solar Total Energy Program will follow applicable regulations and will identify additional environmental, health, and safety measures as appropriate.

During earlier phases of this program, regulations; and guidelines which could have a significant impact on system design, construction, or operation were identified. Since a Solar Total Energy (STE) system is not a standard system, there are no regulations which address such a system specifically. Many components of the STE system are dealt with in regulations; these regulations have provided guidance for those components. For other components, no guidelines currently exist; these guidelines will have to be developed.

Currently, no major problems with environment, health, or safety are anticipated. The Corps of Engineers, both the Fort Worth District Office and the Chief of Engineers Office in Washington, D. C., are aware of the system design, and they have expressed no specific concerns. Neither the review of references nor the complete and detailed questioning of the professional staff of the Corps of Engineers has revealed potential environmental, health, or safety problems which are unique to a STE system during its construction phase and which cannot be solved by good engineering judgment and design.

System operation will be reviewed by the Fort Hood Safety Officer and the Fort Hood Directorate of Facilities Engineering. The Fort Hood Safety Officer has indicated that the Occupational Safety and Health Act (OSHA) of 1974 and the Department of Labor implementing instructions will be the governing regulations. The Post Safety Officer, who will review the STE project, has not revealed any health or safety concerns. The Safety Office review has consisted of a perusal of appropriate OSHA documents, a briefing on the project, a visit to the Solar Engineering Test Module site, and a detailed question and answer period.

Particular attention will be paid to the control logic to insure that equipment and/or subsystem failures will not cause process excursions to proceed in an unsafe direction. Interactive control processes will be confirmed to mimimize hazards to personnel and equipment. Process variables will be monitored by the operator so that abnormal operating conditions do not lead to system, subsystem, and/or component failure.

Potential climatic conditions will be considered during the safety analysis to minimize or preclude damage to the collector field and appurtenant items. Mechanical design considerations impacting equipment and personnel safety will be important when comparing the results of cost and performance trade-off analysis at both the subsystem and system level.

Representatives from the Health and Environment Activity, USA MEDDAC, Fort Hood, Texas, have met with ATU representatives at the Solar Energy Test Module (SETM) facility to evaluate the site from a medical safety viewpoint. Potential environmental problems such as agents added to the operating fluids, which in turn flow into a water course, were addressed. No environmental concern was stated unless the practice was continued through the large-scale experiment.

The safety of visitors and working personnel was addressed. Signs and security fencing were deemed adequate for protection of visitors. An accident action plan was adequate to insure the timely treatment of any injured personnel.

Potential effects of the test solar collectors on the operation of aircraft are being considered by the Commander, 6th Cavalry Brigade, and the G3, Aviation. Any comments will be incorporated into the Health and Safety Plan to be written during the preliminary design phase.

In addition, the site selected for LSE-I has been evaluated for possible effects upon cultural resources. An archaeological survey of the site has been conducted. This work was completed late in the contract period and the report is not currently available; there are no known cultural resources, however.

2.6 Concentrating Collector Survey

In support of the collector selection process ATU surveyed and evaluated certain collector manufacturers. The survey included trips to a number of collector manufacturers in May, 1977 to inspect their hardware and facilities. Table 2-4 lists these on-site visits and the attendees. In June, 1977, Sandia Laboratories sponsored a two-week Solar Total Energy Workshop. At this workshop, each contractor reviewed his latest designs. Information from other collector manufacturers was obtained via telephone. The conclusions of this study, as well as the discussions on selection criteria, field layout, and auxiliary components, will greatly aid in the selection process.

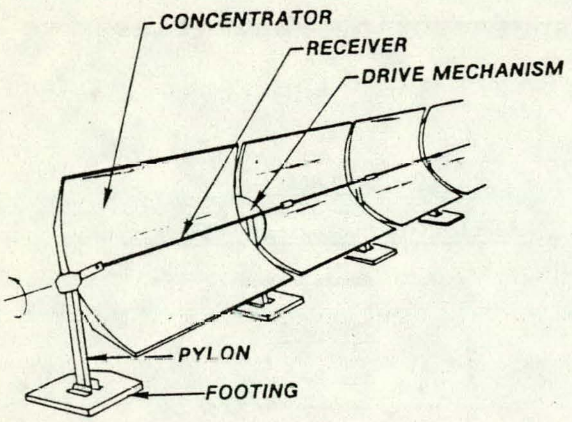
The survey's scope was limited to five generic types of focusing collectors in various stages of development: the parabolic trough, fixed mirror, linear-segmented array, Fresnel lens, and parabolic dish. Configurations that typically depict these generic types are shown in Figure 2-5. Listed below are the definitions for the basic components of the collector module.

1. Concentrator - The device that intercepts solar radiation and concentrates it by optically focusing it on a relatively small area.
2. Receiver or Absorber - The device that absorbs the radiation and transfers energy to a working fluid.
3. Collector - The combined concentrator and receiver unit.
4. Module - A complete unit, including collector, tracking drive and controller, and associated plumbing.

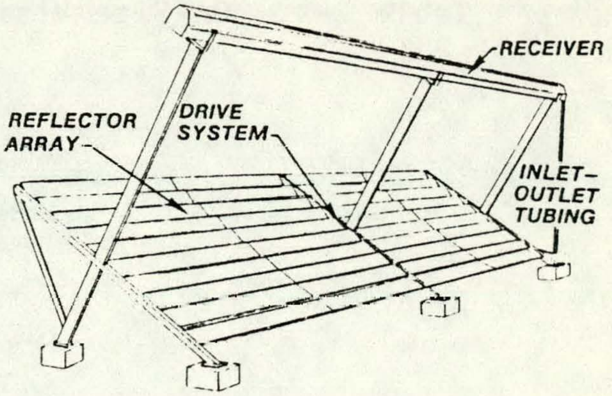
Operating characteristics for the collectors include a temperature range of 280°F to 650°F and a heat-transfer fluid pressure up to 1,600 psi.

Table 2-4. On-Site Visits to Manufacturing Facilities

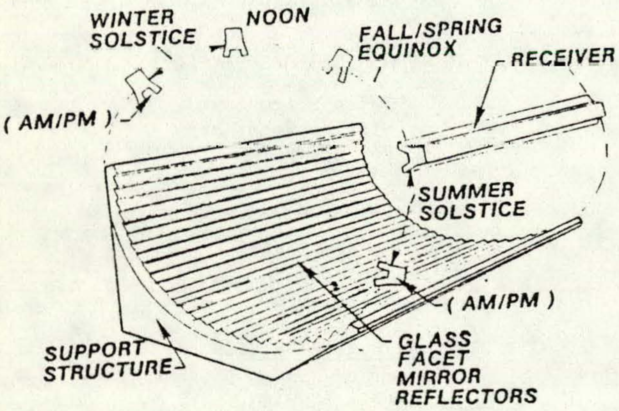
COMPANY	LOCATION	ATTENDEES
Sheldahl Inc.	Northfield, Minnesota	American Technological University James Price Sheldahl Jim Menke Tuck Gove
Acurex Corp.	Mountain View, California	American Technological University James Price Roy Henry Acurex Gary Neuner Ed Rossiter
General Atomic	LaJolla, California	American Technological University James Price William Wachtler Roy Henry General Atomic George Eggers Jim Housman Mike Croft
Arizona Public Service Co. and Hexel Corp.	Phoenix, Ariz. Gila Valley Ranch Gila Bend, Ariz. Casa Granda, Ariz.	Arizona Public Service Earl Knowles Hexel George Branch Sandia William McCulloch American Technological University Roy Henry Bert Hale James Price William Wachtler
Del Manufacturing Co. Jacobs Engineering Co.	Monterey Park, Ca. Pasadena, Ca.	Del Manufacturing Company Manny Delgado George Goranson Norman Riese Jacobs Engineering Company Tony Ferraro Jim Anderson Bernie Eldridge American Technological University William Wachtler Roy Henry



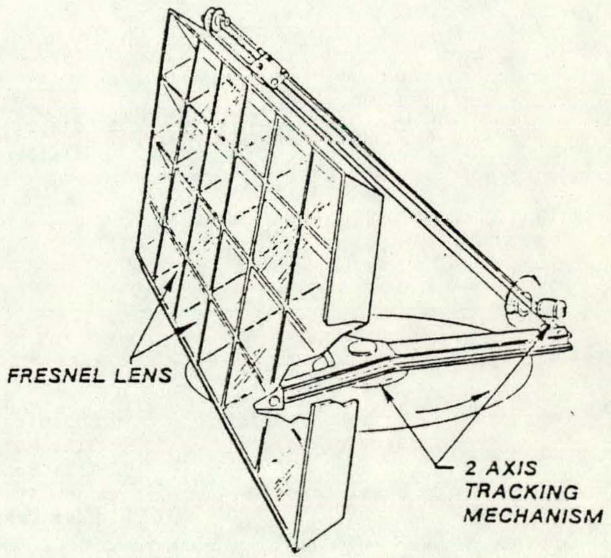
2-5a. Parabolic Trough



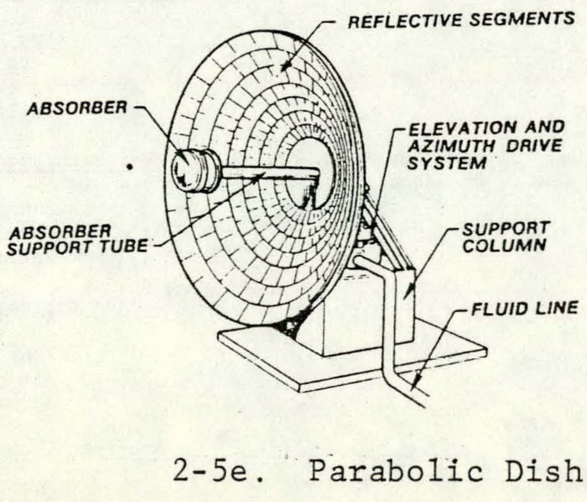
2-5c. Linear-Segmented Array



2-5b. Fixed Mirror



2-5d. Fresnel Lens



2-5e. Parabolic Dish

Figure 2-5. Concentrating Solar Collector Generic Types

Table 2-5. Manufacturer's Collector Features and Status

Generic Type	Manufacturer	Unique Features	Status (Ft^2 Produced)
Parabolic Trough	Acurex	Clamped Coilzak Sheet Forms Optical Contour	Production (12,000)
	Del Manf.	Thermally Sagged Glass Concentrator, Fixed Receiver	Development (Prototype)
	Hexcel	Aluminum Honeycomb Concentrator Has Contour Integrity Without Backup Frame	Production (10,000)
	Honeywell	Lightweight Half-Parabolic Optical Contour, Low-Wind Resistance	Production (*)
	Solar Kinetics	Heavy Duty Construction, Misalignment Compensation	Production (2,000)
	Sunpower Systems	Lightweight Construction	Production (10,000)
Fixed Mirror	AAI	Modular Solar Roof System	Development (Prototype)
	E-Systems	Hemispherical Concentrator, Large Single Module	Development (Prototype)
	General Atomics	Fiber Reinforced Concrete Structure	Development (Prototype)
	Scientific Atlanta	Steel Structure	Development (Prototype)
Linear-Segmented	AAI	Linear Actuators For Reflector Control	Development (Prototype)
	Suntec (Sheldahl)	High-Pressure Receiver Design	Development (Prototype)
	FMC	Fresnel Concentrator Belt	Development (None)
	ITEK	Single-Pass Receiver	Development (Prototype)
Fresnel	MDAC	Cast Acrylic Lens, Two-Axis Tracking	Development (Prototype)
	Northrup Inc.	Extruded Acrylic Lens	Production (120,000)
Parabolic Dish	E-Systems	Unknown	Conceptual (Unknown)
	JPL	Square Glass Mirror Concentrator	Unknown (Unknown)
	Raytheon	Multi-Mirror Reflectors	Development (Prototype)

---

* 40,000 sq. ft. under contract.

2.6.1 Survey Findings

The survey included a total of seventeen manufacturers of high-temperature focusing collectors. The manufacturer's name, the unique features of each collector, and the status of development are summarized in Table 2-5. The manufacturers surveyed were those known by ATU and should not be considered as the only sources of these generic types. The unique features identified in this table point out the major differences between collectors of the same generic type. Production, as used in this table, means that the manufacturer has tooling and a production model and has produced more than three or four test modules or prototypes (of more then 5,000 ft^2). Table 2-5 shows six of the manufacturers to be in the production stage. For the parabolic trough, five manufacturers have production status. Only one other generic type, the Fresnel lens, is in production. The other types surveyed are in various stages of development. Furthermore, the survey revealed that some of the production designs have recent modifications that have not been tested.

The design features and performance, manufacturing, and cost information were compiled and are summarized in Tables 2-6 through 2-8 for each collector generic type. Table 2-6 summarizes the design features. Listed are the available module sizes and the operating temperature ranges, along with concentration ratios and tracking and orientation axes. For the fixed mirror (hemispherical dish) and the parabolic dish, the temperature range could be extended to $1000^\circ F$ because of the large concentration ratios. However, temperatures may be limited by the heat-transfer fluid used.

Both the receiver and concentrator performances for each generic type of focusing collector are summarized in Table 2-7. Performance test data for many of the collectors were nonexistent and much of the quoted performance data are the result of analyses. For this reason, the performance predictions quoted by some of the manufacturers may be very optimistic. Some degree of credibility must be established, and this factor should be considered when comparing the various collectors and generic types on a performance basis. The bright point is that much testing is presently underway and more is planned for the near future.

Table 2-6. Summary of Design Features

Generic Type	Aperture Sizes (Ft)	Temperature Range (^0F)	Concentration Ratio Range	Tracking/Orientation Axes
Parabolic Trough	(2 x 10) to (9 x 20)	300-650	18-60	One/N-S or E-W
Fixed Mirror (Cylindrical Trough)	(7 x 10) to (8 x 32)	300-600	8-32	One/E-W
Fixed Mirror (Hemispherical Dish)	(11 to 200) Dia.	500-1000	30-60 (115 Avg.)	Two/--
Linear-Segmented Array	(7 x 6) to (10 x 40)	600-650	24-38	One/E-W
Fresnel Lens	(1 x 10) to (12 x 15)	280-600	7-20	One or Two/N-S
Parabolic Dish	22 Dia.	600	100	Two/---

--- Not Applicable

Table 2-7. Summary of Performance

Generic Type	Optical Efficiency*	Receiver Efficiency**
Parabolic Trough	0.64 - 0.74	0.70
Fixed*** Mirrors	0.64	0.75
Linear-Segmented Array	0.57 - 0.68	0.79
Fresnel Lens	0.71	0.72
Parabolic Dish	0.87	0.93

* Average Annual Performance
** Based on Thermal Losses
*** Includes the Cylinder Trough Only

Table 2-8. Summary of Manufacturing Estimates

Generic Type	Produced to Date (Ft^2)	Collector Manufacturing Capability (Ft^2/Mo)	Avg. FOB Price ($\$/Ft^2$)	Expected FOB Price When Mass Produced ($\$/Ft^2$)
Parabolic Trough	34,500	157,000	14	13
Fixed Mirror	9,000	50,000	16	12
Linear-Segmented Array	5,000	25,000	18	14
Fresnel Lens	120,000	28,000	32*	29*
Parabolic Dish	760	--	--	30*

* Installed Commercial Field
-- Not Available

Table 2-8 summarizes the estimates of square feet produced and of cost for each generic type. It is seen that the parabolic trough and Fresnel lens account for all but 9% of the total production. Also shown here is the manufacturing capability and the expected F.O.B. price when mass produced. The F.O.B. prices given in Table 2-8 are composites of current data that have been averaged to given an indication of the variations in cost between generic types.

The F.O.B. cost should not be used as the basis for comparing costs because each collector design has different factory and field requirements for assembly (for example, man-hours and labor skills). Installed costs are a more realistic basis for comparison; however, they can be obtained only when the site location and the number of modules for the field are known. This information is needed to determine the production, labor, and shipping costs. Land area, site preparation, and special requirements will also impact the total field cost and must be included to fairly assess collector types.

Cost and performance are further discussed in Section 2.6.2. The discussion that follows indicates the individual characteristics of each generic type.

Parabolic Trough. There are more manufacturers of the parabolic trough collector than any other generic type. Six trough manufacturers were contacted during this survey. They have produced about 34,500 square feet of collectors to date and indicated that they could produce up to 157,000 square feet per month. The collectors vary greatly in size, materials, and design. Sizes vary from a 2 x 10 foot aperture up to an 8.5 x 20 foot aperture. The reflector structures used include sagged glass, polished aluminum over both steel and cast aluminum support ribs, and an aluminum honeycomb structure which requires no backup. The control drives include worm gear, chain, and hydraulic types. Two typical trough receivers are shown in Figure 2-6. One design has the receiver tube completely enclosed within a glass envelope while the second design uses only a half envelope. The half envelope allows for easy replacement. All trough collectors are designed for operation in at least 30 mph winds and survival in 100 mph winds. The annual average concentrator

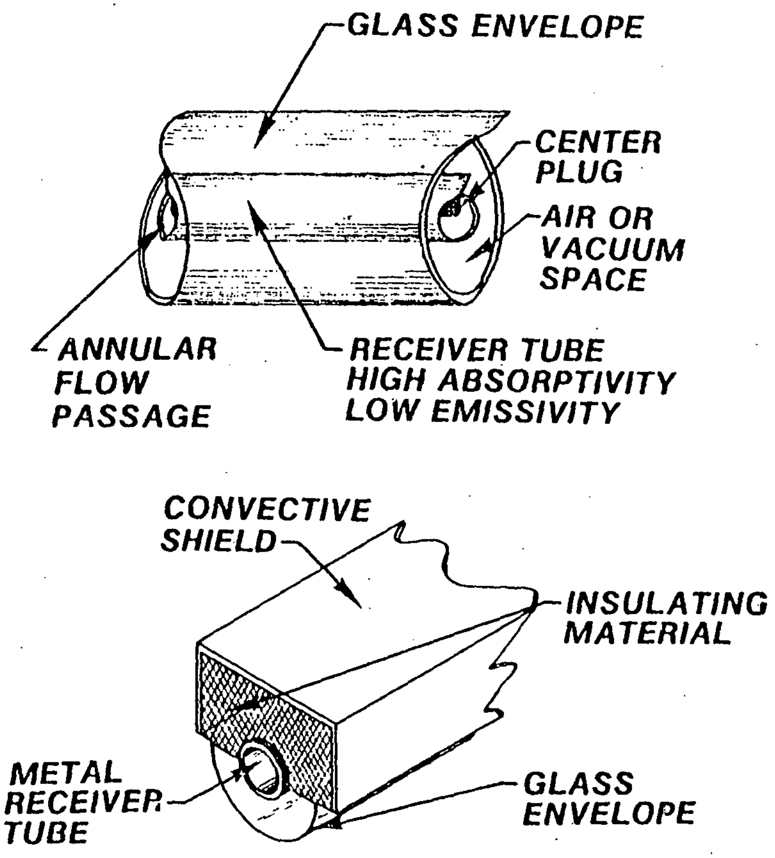


Figure 2-6. Parabolic Trough Receivers

efficiencies range from 0.64 to 0.74, and the operating temperatures range from 300 to 650°F.

Advantages of the parabolic trough include: short focal length, north-south (N-S) or east-west (E-W) axis orientation, lightweight construction, flexibility in module size and site application, and high concentration ratio capability. The disadvantages include: high receiver heat losses and one-axis tracking. The average F.O.B. price of the parabolic trough is $14.00 per square foot. However, quoted installed prices varied from $16.00 to $40.00 per square foot, with most of the variation in the installation cost. All were assumed to be installed on a prepared site.

Fixed Mirror. The survey of focusing collectors included four manufacturers of fixed mirror, moveable receiver collector designs. All manufacturers have built prototypes and are in various stages of development. There are two different basic designs of fixed mirror concentrators. One design is a hemispherical dish with a line receiver; the second is a cylindrical trough with a linear receiver. Approximately 9000 square feet have been produced to date. One of the manufacturers of the fixed mirror trough indicated that 50,000 square feet could be produced per month. Only one 11-foot diameter prototype of the hemispherical dish has been produced. The production design is to be in the 50 to 200 foot diameter range. This design, which has a very high concentration ratio, up to 500, has the potential for temperatures as high as 1000°F. The cylindrical trough design has a low concentration ratio and must use a secondary reflector (see Figure 2-5b) to get the ratio up to the 30 to 32 range. The higher concentrator ratios are needed to obtain temperatures around 600°F. The advantages of the fixed mirror include the potential for low cost mass production and low wind profiles. The major disadvantage of this generic type is the requirement for a moveable or tracking receiver.

Linear-Segmented Array. There are at least four manufacturers of the linear-segmented-array type of focusing collector (see Figure 2-5c). Approximately 5000 square feet have been produced to date and all designs are still in development. The manufacturers indicated that they could produce up to 25,000 square feet per month with their present designs. The average F.O.B. price, $18 per square foot, is higher than all generic types except the parabolic dish. Present designs operate up to 650°F and use either oil or water for the heat-transfer fluid. Advantages of this generic type include fixed receiver designs and small segmented reflectors which allow for easy replacement and factory assembly. The disadvantages include the necessity for individual reflector alignment, long focal length, a preferred east-west axis orientation, and cosine losses at times off solar noon.

Fresnel Lens. Two manufacturers of collectors which use refracting Fresnel lens concentrators were contacted during the survey. The two collectors vary greatly in design and performance. One design has a small aperture (10 square feet), one-axis tracking, a low operating temperature (280°F), and an extruded acrylic lens. More focusing collectors of this design have been produced to date than all other focusing collector designs combined. The low temperature collector can presently be produced at the rate of 28,000 square feet per month. The second design is in development and a prototype is presently being constructed. This design has the following features: a large aperture (180 square feet), two-axis tracking, a high operating temperature (600°F), and a cast acrylic lens. The manufacturer indicated that there would be a very high tooling cost at the start of production and that they would tool up for production only when they could predict a market for at least one million square feet per year. An example of a typical Fresnel lens-receiver configuration is shown in Figure 2-5d. The advantages of the Fresnel lens include compact collector design, low internal shading, and full enclosure of the concentrated energy and the absorber.

Parabolic Dish. Two manufacturers of parabolic dish collectors were contacted to obtain information about their collectors; attempts to establish contact with a third were unsuccessful. One of the two manufacturers has only a conceptual design and no plans for a prototype. A parabolic dish prototype is being constructed by the other supplier and should be tested in the near future. The design includes a 22-foot diameter dish comprised of 248 individual sagged glass mirrors which make up the reflective surface. The manufacturer indicated that this parabolic dish is some time away from mass production, but, because of its high performance potential (average concentration ratio of 100), it could become one of the most cost-effective design concepts. The advantages of the dish include two-axis tracking and a local receiver. The disadvantages include high wind loads and the requirement for a flexible coupling between the moveable receiver and the fixed manifold. An example of the complexity of this coupling is illustrated in Figure 2-7. Because this requirement is common to all collectors with moveable receivers, it is a factor to be considered in selecting a collector type; details of potential couplings are discussed below. Also discussed is the consideration of insulation for the coupling and the field manifold piping.

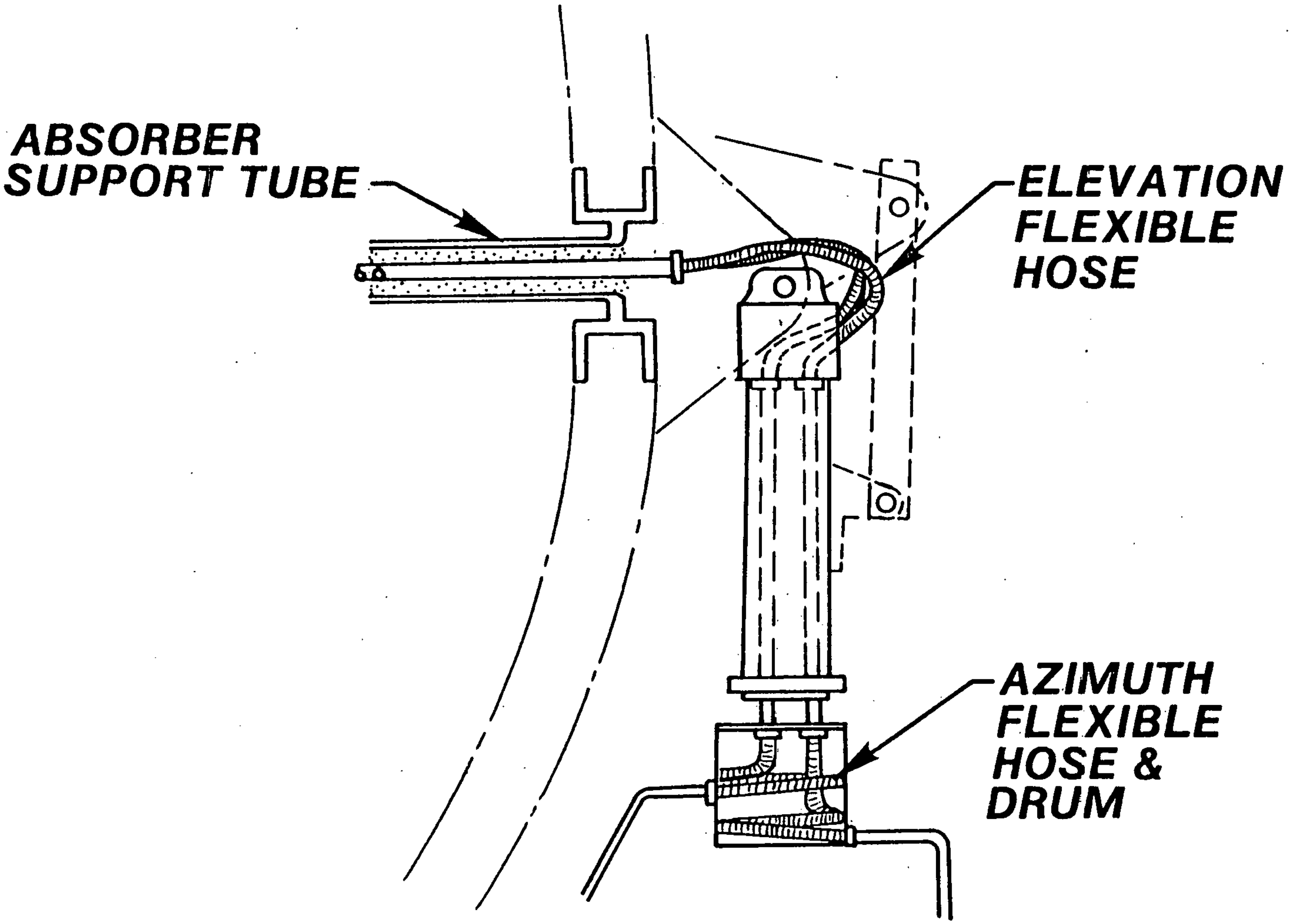


Figure 2-7. Flex Hose Assembly

2.6.2 Collector Evaluation

There are a number of important considerations related to the evaluation of collector designs for large-scale applications. These considerations include the manufacturer's capabilities, special design features, and verification of the design by means of test data. However, the major items to be considered are installed system total cost, including operation, maintenance, and replacement; annual performance; and the collector field layout design. This section outlines the steps required to find a cost-effective system design.

Cost and Performance. One of the steps in selecting a collector consists of soliciting cost data. The collector manufacturers and all other applicable contractors should furnish the following information for a nominal field size and site location:

1. The F.O.B. module cost, including tracking drive and controls, valves, and all the associated plumbing necessary for the field installation on a prepared site.
2. Costs, including man-hours and the associated labor skills, for the field installation and checkout.
3. Site preparation, with foundations for mounting the collector modules and other ground installations that support plumbing, pumps, and miscellaneous components.
4. Estimates of all annual operating and maintenance (O&M) costs over the system life, including man-hours, materials, special equipment, components, and spare parts.

The lifetime capital and O&M costs for the system should be estimated and converted to equivalent annual costs using a life-cycle analysis.

Data are also required from manufacturers to develop a performance model for the collectors. Using the model, along with inputs for insolation and weather data, load profiles, and storage capacity, the useable energy collected can be determined. The calculations should be performed in hourly increments during the diurnal period for each season of the year. These data are then combined to represent the annual useable energy collected. Knowing the annual life-cycle cost and the annual useful energy supplied, the designer can evaluate the candidate collectors from performance and cost standpoints using a figure-of-merit, which is defined as the ratio of life-cycle cost to the annual useful energy supplied by the collector system.

Below are other items which need to be considered in the annual performance calculations:

1. Receiver heat loss as a function of wind velocity.
2. BTU required to heat the collector field up to operating temperature.
3. BTU and time required to bring the field up to operating conditions with marginal available insolation.
4. Degradation of annual performance due to shutdown when the maximum operating wind velocity is exceeded.
5. Various receiver and pipe sizes for the different working fluids, and their flow requirements.
6. Degradation of annual performance due to maintenance downtime.
7. Degradation of annual performance due to the optical degradation caused by dirty reflectors and exposure to the elements.

Collector Field Layout. Collector field layout studies are required in large-scale applications in order to identify the effects of various design variables on the total collector field performance and cost. Because of the load variations for particular solar applications, system optimizations must be performed during preliminary design to ensure that the system output matches the load requirements. A discussion of the many details involved in collector field layout system sizing and cost trade-offs is beyond the scope of this study. However, it should be emphasized that this is a major task to be undertaken during preliminary design and that the information presented in this paper represents a sound basis for the start of the collector field layout task.

A major design objective is to minimize heat, pressure, and parasitic losses throughout the entire fluid flow system in the collector field. The optimization procedure involves varying a number of collector modules in series and in parallel and computing the items listed below as a function of the field orientation, row spacing, and receiver design flow area.

1. Total heat losses in piping, manifolding, and other fluid components.
2. Pressure losses for the above fluid component sizes with given fluid and flow conditions.

3. Costs for the total installed field.

4. Additional collector area and cost necessary to compensate for heat and pressure losses.

Figure 2-8 shows typically how field piping heat and pressure losses and cost are affected by the field configuration. It is apparent that a given number of collector modules per row represents a minimum cost for the collector field.

The alignment of the collector module is largely influenced by the available area at the site, the load profile, and the tracking capability of the candidate collector. For example, if shading effects are neglected, a horizontal one-axis tracking parabolic collector with N-S orientation has 30% more energy available to the concentrating aperture in summer than the same collector with an E-W orientation. A two-axis tracking collector sees 56% more direct solar radiation than a comparable one-axis tracking collector that is oriented E-W. However, in the summer they see approximately the same direct solar radiation.

The better the match between the collector field output and the site load profile, the less collector field area is required. The energy available from E-W and N-S orientations should be based on seasonal calculations, and these results should be compared with the seasonal load demands to determine the field orientations.

The effects of collector spacing and orientation on the shading of adjacent collector rows is more of a problem with N-S axis alignment. North-south collector rows generally require wider spacing than for E-W axis alignments. The row spacing could be limited by the area available at the site. Wider spacing translates into longer manifolds and plumbing, which result in increased costs as well as greater heat losses and thermal inertia. Trade-offs are necessary between the cost of added collector modules and the costs associated with longer manifolds and additional plumbing.

An important consideration that is closely related to collector selection and field sizing is the insulation of the field piping and manifolding between the collector array and the utilization point. Achieving optimum insulation requires consideration of economic factors such as material and installation costs and the increased collector field capital investment required to account for the

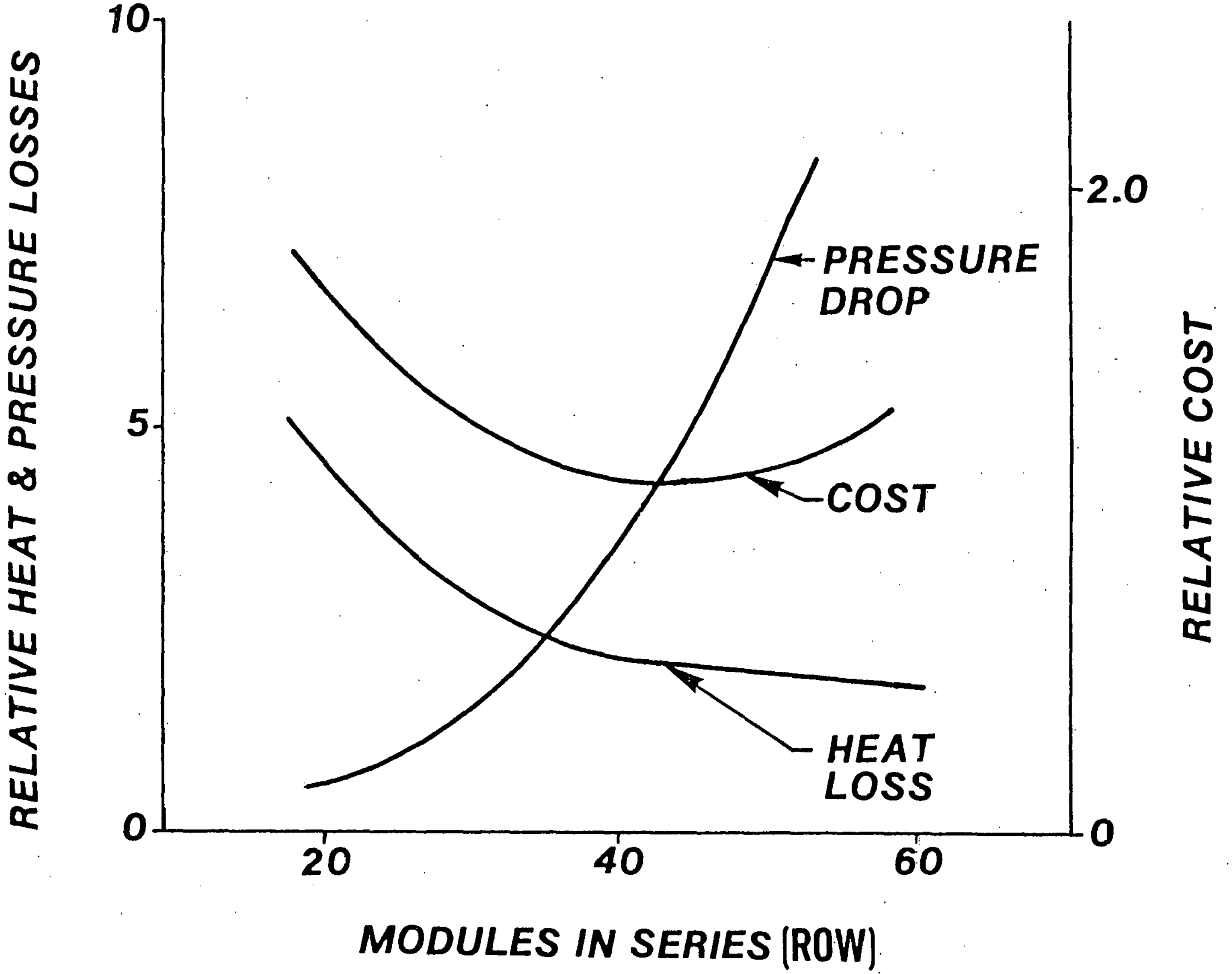


Figure 2-8. Field Configuration and Trends

thermal losses. Other economic factors to be evaluated include environmental protection and the O&M costs over the life cycle of the system. Since the collector field represents a significant portion of the total system cost, it is important that in-depth trade-off studies between collector field efficiency and overall collector field costs be conducted.

Another important consideration in the evaluation of a collector is the means of coupling the receiver to the field manifolding. Most of the generic types of collectors require movement of the receiver relative to the fixed manifold connection. This can present a major design challenge when high-temperature, high-pressure working fluids are required. Flexible hoses, swivel joints, or combinations of both can be used as a coupling mechanism to the fixed manifold and must be considered in the selection of the generic collector type.

To date, most collector designs requiring a nonrigid coupling employ flexible hoses. Swivel joints have been tried in at least two solar installations, but they were replaced with hoses. Use of flexible hoses has been limited to low pressure (50 psi) and temperature (600°F) units. However, both hoses and swivel joints exist for use with high pressure (3000 psi) and temperatures to 750°F.

A limited survey was conducted to determine the availability and operating limits of couplings for solar applications. The following manufacturers of nonrigid coupling were contacted:

1. Hose Manufacturers
    - a. Dayco Corp., Dayton, Ohio
    - b. Flexonics, Bartlett, Illinois
2. Swivel Joint Manufacturers
    - a. Parker Hannifin, Wickliffe, Ohio
    - b. Continental-EMSCO, Garland, Texas.

It was found that systems operating below 325°F and 100 psi are relatively simple to couple due to the wide range of flexible nonmetallic hoses and swivel joints available. However, for system temperatures above 325°F, and pressures exceeding 150 psi, the availability of nonmetallic flexible hoses is limited.

Flexible corrugated metal hoses are available for temperatures and pressures above the range of nonmetallic hoses, but again, as the temperature exceeds 500°F, the selection is very limited, especially where the containment of saturated steam is a requirement with receiver tube diameters of 0.75 to 1.5 inches. A selection of swivel joints is available over a wide range of pressures (some to 15,000 psi); however, as temperature requirements rise above 450°F, the selection again becomes limited. The temperature resistance of the seals and packing is the limiting factor. One swivel joint was located with specifications of 750°F at 3,000 psi. None could be located above this point.

Designers of systems that operate above 325°F must consider the coupling mechanism a significant factor in the collector selection process. Other, equally essential, elements include the compatibility of the working fluid with coupling seals and packings; the torque that may be coupled to the receiver, which could cause damage at high pressures; and the method for insulating the coupling.

The field layout must be designed to accommodate instrumentation, fluid controls, and pumps. Fluid controls are needed for safe and efficient operation of the field. In large-scale applications, the design of this system may be difficult, because of the sudden changes in solar intensity caused by total and partial cloud cover.

2.6.3 Survey Conclusions

The following conclusions were drawn from the survey findings and evaluation:

1. Based on the state of development and predicted production capabilities, the parabolic trough is currently available for large-scale applications requiring operating temperatures in the range of 300°F to 650°F.
2. The extruded Fresnel lens is fully developed for large-scale applications requiring temperatures up to 280°F.
3. Performance data for temperatures above 300°F are very limited for most of the generic types.
4. The operation and maintenance requirements for large collector fields are not well established for any of the generic types.
5. Collector cost evaluations must be based on life-cycle cost for the total collector field. This life-cycle cost should include operation and maintenance.
6. Both swivel joints and flexible hoses are readily available for temperatures up to 350°F and pressures to 150 psi; above 350°F the selection of flexible components becomes very limited with respect to size and pressure rating.
7. Field piping insulation cost should be weighed against the added collector field cost required to make up the piping thermal losses.

Based on the survey findings and conclusions, the parabolic trough is preferred for the Fort Hood LSE-1 project. The major reasons for favoring this generic type are:

1. All parabolic trough component designs are proven.
2. Installation and operating experiences with parabolic troughs exceed those with all other generic forms.
3. Production capabilities presently exist at four parabolic trough manufacturers.

Overall, the risks inherent in the performance, cost, and schedule requirements of LSE-1 can be minimized by selecting a parabolic trough design.

2.7 System Simulation Model

During the initial conceptual design effort (Phase II) the need for a simulation model was recognized. Because of the intricate ways in which the system interacts with sunlight and other aspects of the environment, it was felt that a computerized simulation of the system over time was the best way of estimating system performance. A list of necessary and desirable features and capabilities for the simulation model was formulated during the later stages of Phase II.

It was determined that the simulation model would be needed at the start of preliminary design. However, the development of such a model in its entirity could not be completed by the time it was needed. In order to provide an operational simulation model in the shortest possible time a two-step approach was developed.

First, a survey of existing simulation models was conducted. A model approximating ATU's requirements and readily adaptable to the ATU computer (IBM370/145) was sought. Several models were investigated. Two of them, SOLSYS and TRNSYS, offered features and capabilities similar to those required. TRNSYS (Reference 9) was compatible with the IBM370/145, so it was chosen over SOLSYS (Reference 10) as a basis for the ATU simulation model.

While the survey was in progress preliminary design specifications were being formulated. Information gained in the early stages of the survey was considered in this design. Thus, when the overall simulation program design emerged in February, 1977, TRNSYS was an integral part of its structure. The complete simulation model design specifications are presented in Reference 10.

What emerged from the design process was not a program but a system. A simulation program based on TRNSYS is the basis of the system. Other programs may be involved before or after the simulation program for a given run. Several data files are also an integral part of the system. An overview of the system is provided in Figure 2-9 which shows the various programs and data files and how they relate to one another. The dashed lines represent optional data paths.

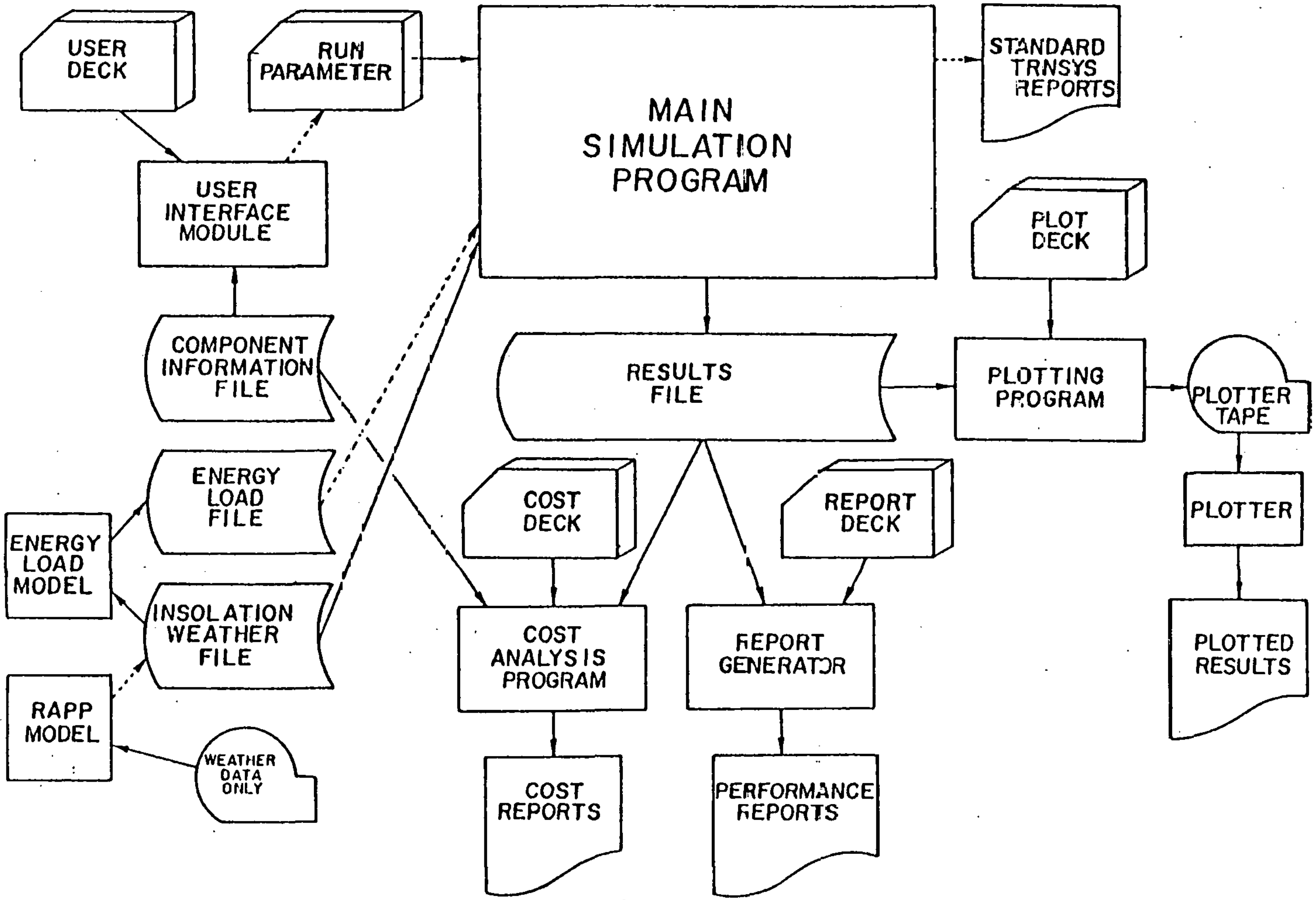


Figure 2-9. Flow Diagram of TRNSYS Simulation System

Because of the LSE-I project redirection, the overall system as shown in Figure 2-9 was not completed. The parts of the system beyond the RESULTS FILE block were not incorporated into the system. The cost analysis program was developed as a separate program. (See Section 4.3.5)

A number of different modifications and extensions were made to the TRNSYS system. Eleven different component subroutines were added to TRNSYS:

1. Type 28: Storage Tank
2. Type 29: Rankin Cycle
3. Type 30: Generalized Focusing Collector
4. Type 31: Cooling Tower
5. Type 32: Unformated Data Reader
6. Type 33: Thermal Consumer
7. Type 34: Continuous Controller
8. Type 35: Steam Generator Turbine
9. Type 36: Condenser
10. Type 37: Condenser Pump
11. Type 38: Energy Load Processor

A description of each of the new component subroutines is given in Appendix C. A complete description of the TRNSYS program and utilization instructions are given in Reference 9.

2.8 Information Dissemination and Training

The entire national energy outlook has changed as a result of the recent emphasis on energy conservation and on alternate sources including solar. The thrust of the Solar Total Energy Program is to have 30 megawatts of demonstration units by the mid-1980's. Progression to demonstrations will proceed through an experimentation phase, a major element of which is the ATU/Fort Hood Solar Total Energy Large-Scale Experiment (LSE-1). Although LSE-1 will be installed at a military post, Fort Hood, Texas, the application is essentially residential in nature and could be readily adapted to apartment complexes or condominiums with central energy facilities.

In order to foster commercial interest in solar power and to satisfy the increasing levels of public interest in the solar program, it is important to develop the capability of disseminating accurate, up-to-date project information. In particular, appropriate military organizations must be kept abreast of the project so they will have a sound basis for planning their future participation and actions. Ideas and plans on information dissemination through site visitor service and on technology transfer are discussed later in this report.

Operation and maintenance of the ATU/Fort Hood Solar Total Energy System will require personnel with specialized training. The first steps toward development of a technical training manual are also described hereinafter.

2.8.1 Site Visitor Service

Solar energy, although not a new energy source, is relatively unknown to individuals not directly involved in solar research, development, or use. Since ATU is located adjacent to Fort Hood, the largest military installation in the free world, it becomes a logical stopping-off point for military and civilian dignitaries. Both the III Corps and Fort Hood and TCATA visitors bureaus regularly contact ATU concerning tours of the Solar Engineering Test Module (SETM) facility at West Fort Hood, briefings on the large-scale experiment, and tours of the 87000 Troop Housing Complex. Local groups, including area water safety councils, men's organizations, ladies' clubs, home builders' associations, and church groups, have requested briefings on the project. Currently, visitors are briefed at ATU, in the West Fort Hood test site offices, or at the TCATA briefing and conference rooms. There are plans to renovate the east wing of Building 91022, which houses the U.S. Army ASL Fort Hood Meteorological Team, to provide a visitors' center adjacent to the SETM and future PTA test site.

In addition, slide and viewgraph presentations are frequently required for conferences. These conferences may involve representatives of Fort Hood and TCATA (Training and Doctrine Command Combined Areas Test Activity), the Corps of Engineers (including area, district, division and Department of Army levels), FORSCOM (U.S. Army Forces Command), the Department of Energy, ATU, and other DOE contractors.

A visitor plan to be completed during the preliminary design phase will include: points of contact, standard operating procedures, itinerary forms, transportation arrangements, hotel and motel lists, maps, etc. Although a brochure on the project has been completed, a new brochure based on the new design directions will be developed. Also, ATU will develop display models of the PTA (2-dimensional) and LSE-I (3-dimensional).

2.8.2 Technology Transfer

As the prime contractor on a solar total energy system in a military application, ATU staff members attempt to remain knowledgeable of other solar programs and technology. This level of awareness is derived from an ATU document library, as well as from participation in seminars, conferences, and solar-related meetings.

The library includes information from the Department of Energy; National Technical Information Service (NTIS); Aerospace Corp.; National Laboratories; and various universities, industries, and other governmental agencies. Periodical literature, newsletters, announcements, and reports have been cataloged. A reading center will be made available during the next phase to the solar staff, as well as to visitors and local individuals, for locating the latest information on various solar technologies.

2.8.3 Training Development

After the program redirection, ATU assumed responsibility for developing educational program requirements for the personnel assigned to operate or maintain a military or commercial LSE.

The primary areas considered were:

1. Overall system operations and performance
2. Collector field and receiver system (piping, valving, pumping, collector field support structure, and safety controls)
3. High-temperature fluid loop and storage
4. Steam generation
5. Turbine generator (electric) operation
6. Condensor
7. Low-temperature storage, space heating, and domestic water heating
8. Control system concept for each subsystem component.

Based on these items, a topical outline for a technical manual for training purposes was prepared, and is included as Appendix D. The outline will be updated and completed as the LSE-I design becomes firm.

III. TEST PROGRAM

III. ENGINEERING TEST PROGRAM

The major new element required for the ATU/Fort Hood Solar Total Energy System is the collector field. Most of the system is based on relatively well-established technology, although the implementation may be unusual in some areas. To supplement the developmental testing of concentrating solar collectors and materials by manufacturers and other groups and, more specifically, to test linear-focusing solar collectors in the actual Fort Hood environment under realistic operating conditions, a program of engineering experiments was initiated as part of Phase II. During the present contract period, this test program centered on the Solar Engineering Test Module (SETM), which became operational in the spring of 1977.

The SETM includes an east-west aligned segmented-mirror, fixed-receiver, linear-focusing collector; an instrumented and controlled high-temperature, high-pressure fluid loop; and a data acquisition system. It is located at West Fort Hood, approximately nine miles southwest of the LSE-I site--the 87000 Troop Housing Complex on the main post of Fort Hood. The concentrating collector installed at the SETM is a 400-ft^2 module of the SLATS^{TM} system manufactured by Suntec Systems, Inc., a subsidiary of Sheldahl, Inc. This choice followed from the collector selection made for reference purposes during the LSE-I Phase II studies (see Section 1.1). The collector and the other SETM equipment are described in Section 3.1 below. Reference 13 gives a more detailed description.

An important objective of the SETM is to determine the amount of solar energy that may be collected by a concentrating collector located at Fort Hood. Such data can verify modeling techniques for predicting the amount of useful solar energy available in the Fort Hood environment and for predicting the performance of concentrating collectors. In addition, this information provides specific performance data on the SLATS^{TM} collector.

Other test objectives include information on receiver heat loss, controls performance, failure modes and maintenance requirements, and concentrator cleaning requirements and techniques. Receiver heat-loss data are essential to understanding overall collector performance. Although the control approach and the system dynamics at the SETM may be different from those associated with the eventual collector field for LSE-I, insights gained from operating experience with the SETM will be useful in future work.

Information on the reliability and durability of the collector and fluid loop equipment gained by routine operation of the SETM over an extended period of time provides yet another benefit. Operational problems, equipment failures, failure modes, etc. encountered with the SETM may be representative of problems that may be encountered with full-scale systems.

Cleaning requirements depend in part upon the collector geometry and the reflector surface material. The amount and type of dust and other airborne substances which soil the reflectors depend upon the particular installation area. Hence, the information developed on cleaning requirements at the SETM is specific to the conditions at Fort Hood and will be helpful in establishing the cleaning requirements and techniques for other types of collectors exposed to the same environment.

The SETM test plan and operation, including various equipment problems encountered, are described in Section 3.2. Section 3.3 describes the data reduction and analysis procedures. Test results and preliminary interpretations are given in Section 3.4. The basic testing originally planned for the SLATS^{TM} collector at the SETM has been completed except for the testing of alternate receiver designs. These designs are undergoing preliminary testing at Sandia Laboratories. Because of delays in the Sandia program, the alternate receivers were not available in time for testing at the SETM during the present contract period. This additional testing would increase the value of the present data by helping delineate the contributions of the concentrator and the receiver in overall collector performance.

While meeting the technical objectives of the SETM testing is particularly important, the SETM also serves as a demonstration and orientation unit for briefing Army and other personnel on LSE-I and for fostering military and civilian interest in solar energy applications. In addition, the SETM is designed to accept modifications necessary to test other types of concentrating collectors considered for use in LSE-I. In fact, the SETM fluid loop and data acquisition system will be modified to support the Collector Field Pilot Test

Array (PTA) planned for the next phase of the project. The PTA will involve the installation and testing of one or more independently operated rows of collectors arranged as they would be if installed as part of the full-scale collector field for LSE-1. One contract task was to develop preliminary plans for the PTA (see IIC of Appendix A, Part II). The results of this task are summarized in Section 3.5.

3.1 Solar Engineering Test Module (SETM)

Installation of the ATU/Fort Hood Solar Engineering Test Module (SETM) began with site preparation work during Phase II, on October 15, 1976. An overall view of the SETM is shown in Figure 3-1. The SLATS^{TM} collector, described in detail in Section 3.1.1, is the most prominent feature in Figure 3-1. The fluid loop is to the right and the control building is in the background.

The decision to locate the SETM at West Fort Hood anticipated that the U.S. Army Atmospheric Sciences Laboratory (ASL) Fort Hood Meteorological Team, also located at West Fort Hood, would provide operational support for the facility. The ASL Fort Hood Meteorological Team also operates the solar instrumentation for the continuing program of insolation measurement and analysis (see Section 2.2). Following review of several candidate sites at West Fort Hood, a convenient and highly visible location near the northwest corner of Gray Army Air Base and TCATA (Training and Doctrine Command Combined Arms Testing Activity) Headquarters was selected. The SETM site at West Fort Hood is at 31 degrees north latitude and 97.75 degrees longitude. The gate is 120 feet south of Building 91022. The site is approximately 2.1 acres in size.

Preparation of this site involved:

1. Grading of the installation areas for the collector module and fluid loop.
2. Drilling and excavation for the reinforced concrete piers and pads necessary to mount the collector module and fluid loop.
3. Erecting forms, placing reinforcing steel, and pouring the concrete piers and pads.
4. Installation of electrical service and connection to the Fort Hood distribution grid.
5. Installation and connection of a water line for the fluid loop.
6. Installation of a drain line and discharge tank for waste water from the fluid loop.
7. Installation of chain link security fences.

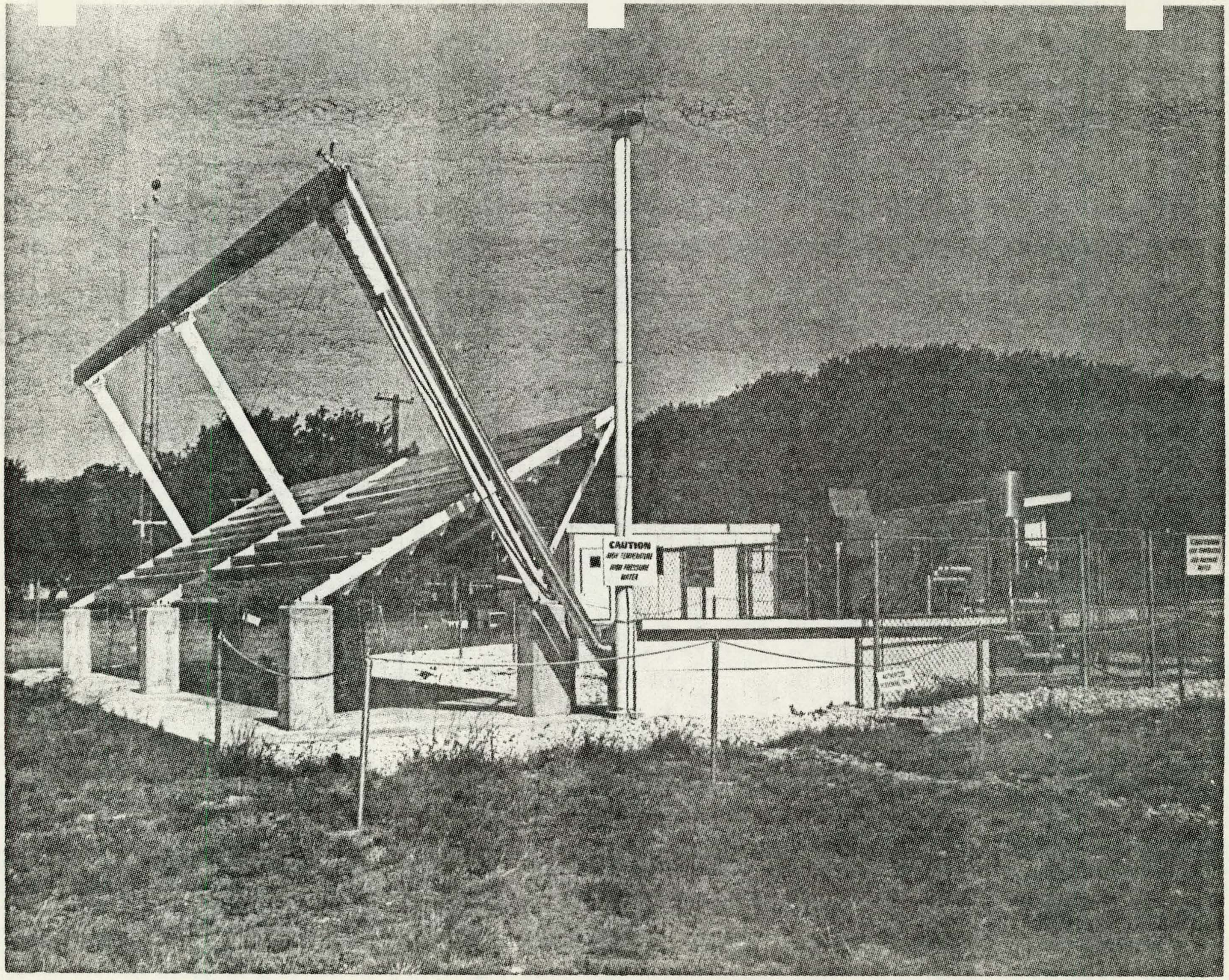


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Figure 3-1. SETM and Associated Equipment

The structures and equipment located within this area are:

1. The collector module
2. The fluid loop
3. The control building
4. Meteorological and solar instrumentation
5. The Lawrence Berkeley Laboratory circumsolar telescope (moved to another site by LBL in September, 1977).

Figure 3-2 is a simplified plan of the site showing the layout.

The operation of the site is a cooperative effort between American Technological University personnel and the ASL Fort Hood Meteorological Team, which is located in Building 91022. The ATU personnel are responsible for the operation and maintenance of the collector module, the fluid loop, and associated data acquisition and control instrumentation housed in the control building. The meteorological and solar instrumentation is operated and maintained by the ASL Meteorological Team.

Provisions for personnel safety are an important aspect of the SETM. Those provisions which are part of the site include:

1. A six-foot chain link fence, with lockable vehicle and pedestrian gates, forming the perimeter of the test site.
2. An inner chain link fence with lockable gates around the fluid loop, the SETM component with the greatest hazard potential.
3. A rope barrier located at a safe stand-off distance from the fluid loop and the collector.
4. Appropriate warning signs mounted on the above fences and barriers.

In addition, a number of safety features and provisions are incorporated in the fluid loop, the controls, and the SETM operating procedures.

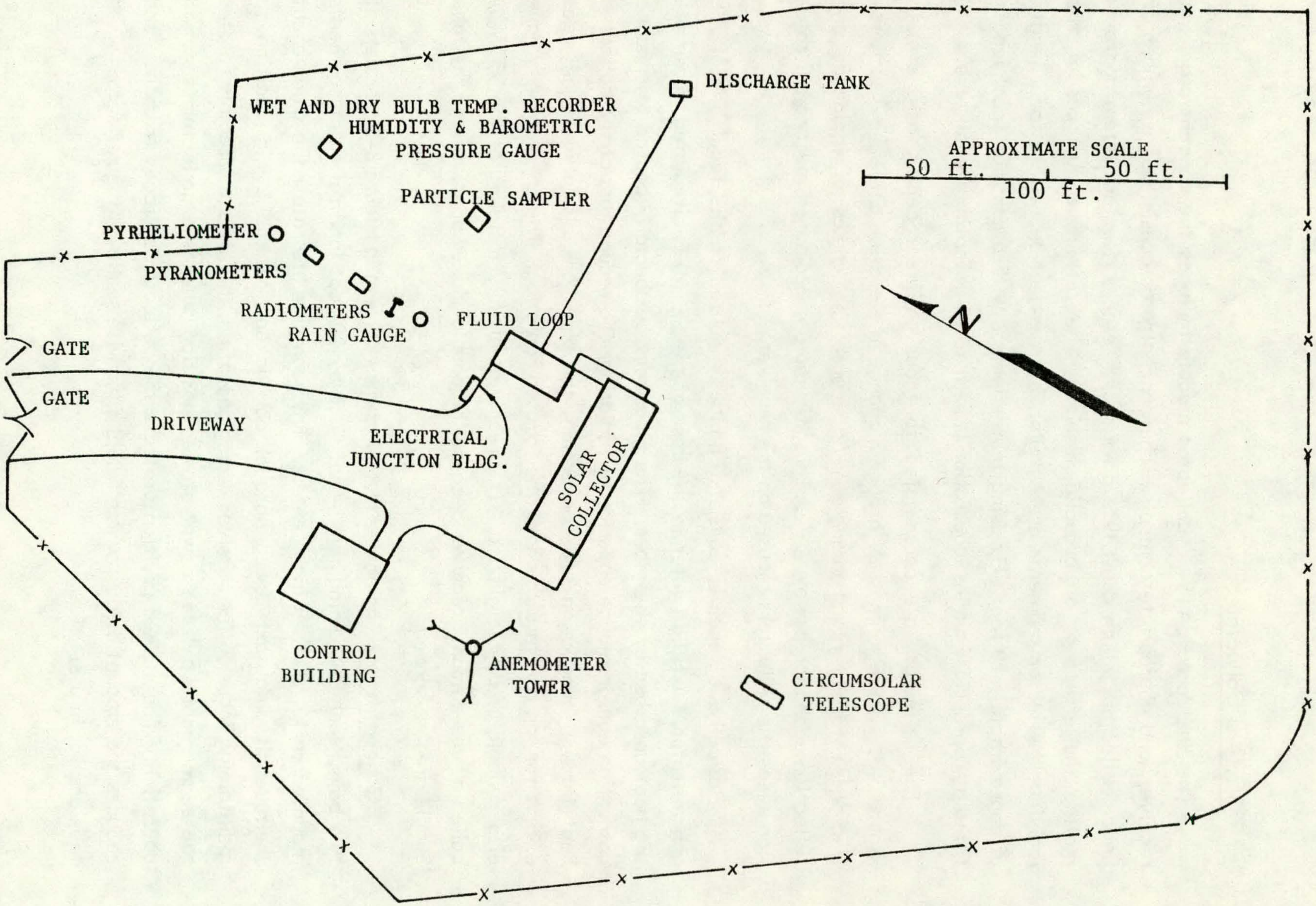

Figure 3-2. SETM Site Plan

3.1.1 Collector

The Sheldahl SLATS^{TM} collector module includes the concentrator, the receiver, and appropriate controls. The concentrator consists of a number of linear reflectors which constitute a form of Fresnel reflector system approximating the effect of a parabolic trough. The reflective surfaces of the individual reflector segments are circular in cross-section, with a focal length of approximately 10 feet. By using ten reflectors with a common focal length tilted at appropriate angles, aberration is kept to an acceptably small level.

The reflectors are coordinated to focus on the receiver, as shown in Figure 3-3. As the sun passes through a change in elevation angle $\Delta\phi$ each reflector is rotated through an angle $\Delta\phi/2$ because the angles of incidence and reflection each increase by $\Delta\phi/2$. Thus, a simple coordinated mechanical rotation keeps the reflectors focused on the receiver.

Basically, a receiver consists of pipes mounted on the focal line of the concentrator. A fluid (water in the case of the SETM) is circulated to remove the heat absorbed by the pipes. The pipes may be specially coated to enhance absorption and/or reduce emission of radiation. To reduce loss of the collected heat through conduction and convection, the pipes are insulated on all sides except for an aperture to admit the focused radiation. The aperture may have either single or double glazing. The receiver initially installed at the SETM is called a "vee-entrant" receiver because the double-glazed aperture and the tube bundle are vee-shaped.

Concentrator. The concentrator, as may be seen in Figure 3-4, consists of two bays, each containing ten 1-foot wide by 20-foot long reflector segments mounted on 12 fourteen-inch centers. The segments are rotated in union about their longitudinal axis by a parallel bar linkage assembly. In addition to maintaining focus on the receiver during operation, the linkage assembly rotates the segments to a "face down" stowed position when the collector is not in operation. The stowed position protects the reflector surfaces from hail and reduces the amount of dust which would otherwise settle on the reflectors when they are not in use.

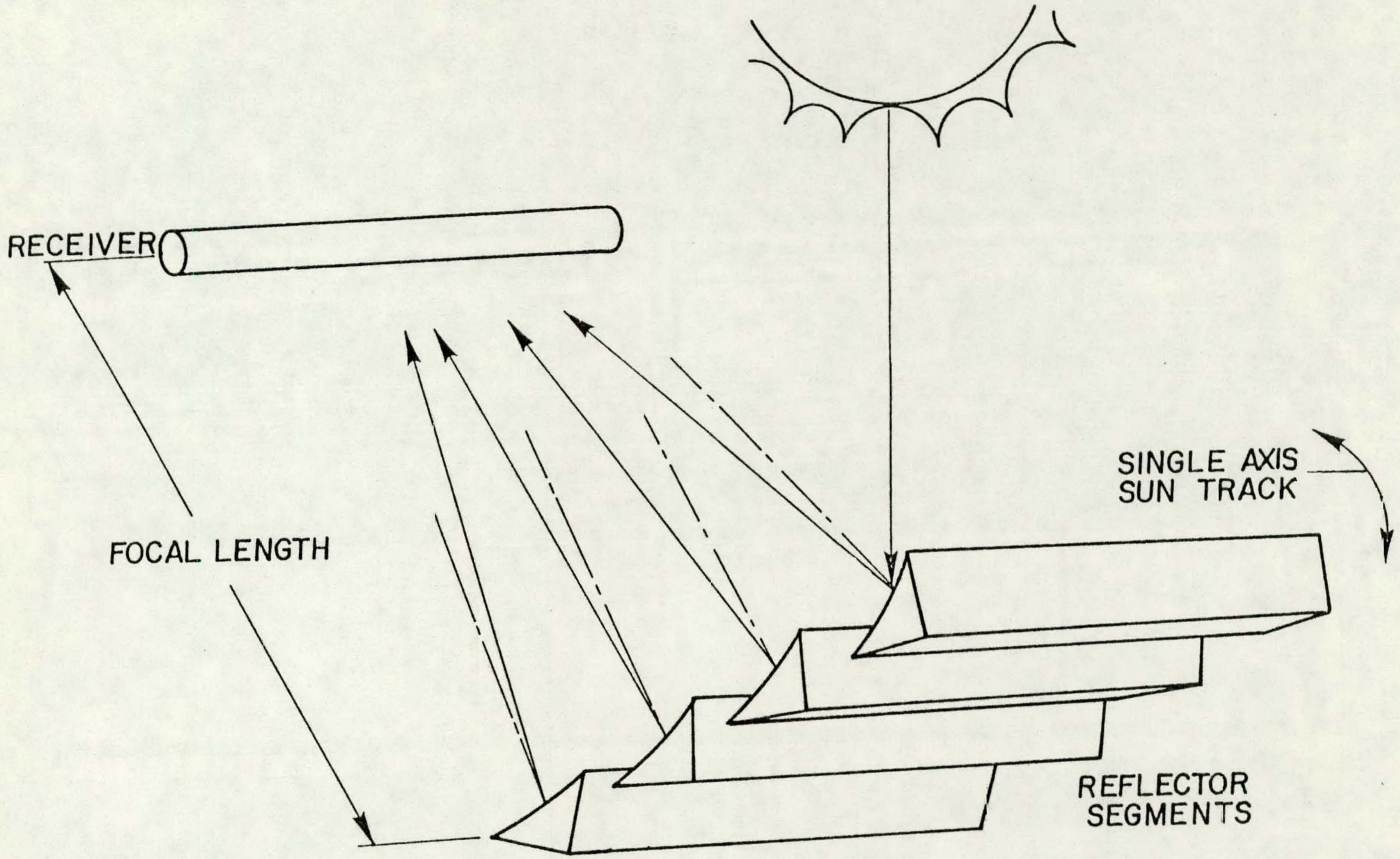

Figure 3-3. Basic SLATS$^{\text{TM}}$ Configuration

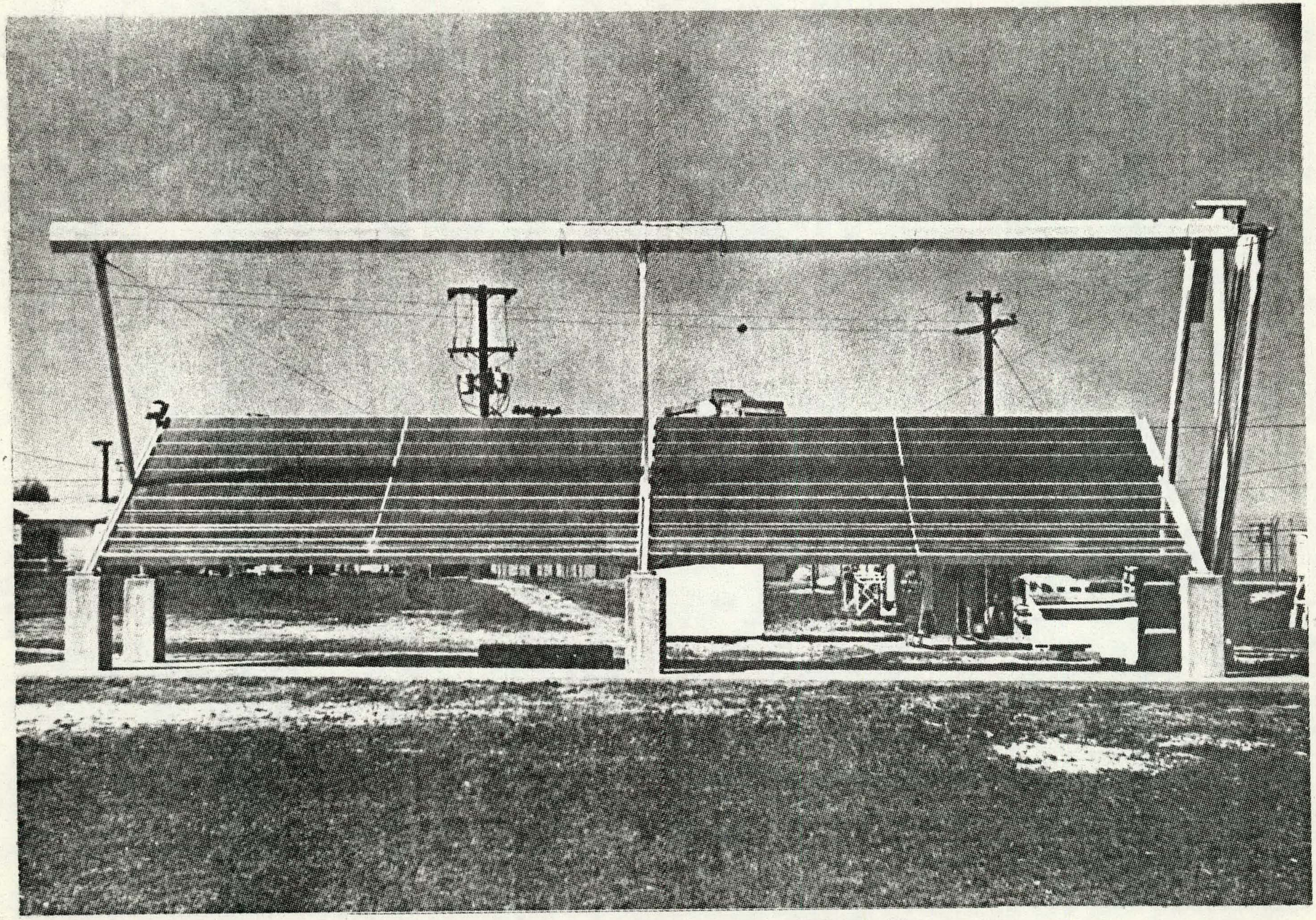

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Figure 3-4. South View of the SETM Collector

Each reflector segment is fabricated from sheet steel formed into a closed triangular section to provide structural rigidity sufficient to withstand steady winds of 100 miles per hour with the segments in the stowed position. The reflective surface consists of vapor-deposited aluminum on a polyester film protected by an environmentally-resistant Teflon coating.* This reflective film is separated from the face of the triangular structure by a polystyrene core which is shaped to provide a focal length of ten feet. When clean, this type of surface has a reflectivity of approximately 0.85.

The construction of the reflector segments is such that the actual reflector area is approximately 394 square feet (rather than the nominal 400 square feet) due to mounting strips which overlap the edges of each reflector. An additional loss of effective reflector area is caused by shadowing from the receiver. This shadow is apparent in Figure 3-4 and, for the relatively large vee-entrant receiver, is approximately the width of one reflector.

The reflector segments are mounted between three parallel structural members which are orthogonal to the segments' rotational axes, with the segment drive mounted on the central member. This assembly (and the receiver) is supported by three cross members mounted on the concrete piers. The reflector array is inclined 31 degrees from horizontal to provide a balance of summer and winter solar energy collection for the Fort Hood latitude.

Receiver. The receiver, visible in Figure 3-4, has six heat-transfer tubes designed for use with water as the heat-transfer fluid. Figure 3-5 shows a typical cross-section of the receiver. A double vee-shaped glass window (60° included angle) provides an optical entrance to the receiver, and also suppresses convection and radiation losses. The sides and back of the receiver are heavily insulated to reduce heat losses. Support for the base of each window is provided by grooves running the length of the receiver and which are attached to the outer shell.

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* Other reflector surfaces are being developed by Suntec Systems, Inc., and current models use silvered glass reflectors. Four of the twenty original reflector segments on the SETM concentrator were found to be defective and were replaced with glass versions (see Section 3.3.4).

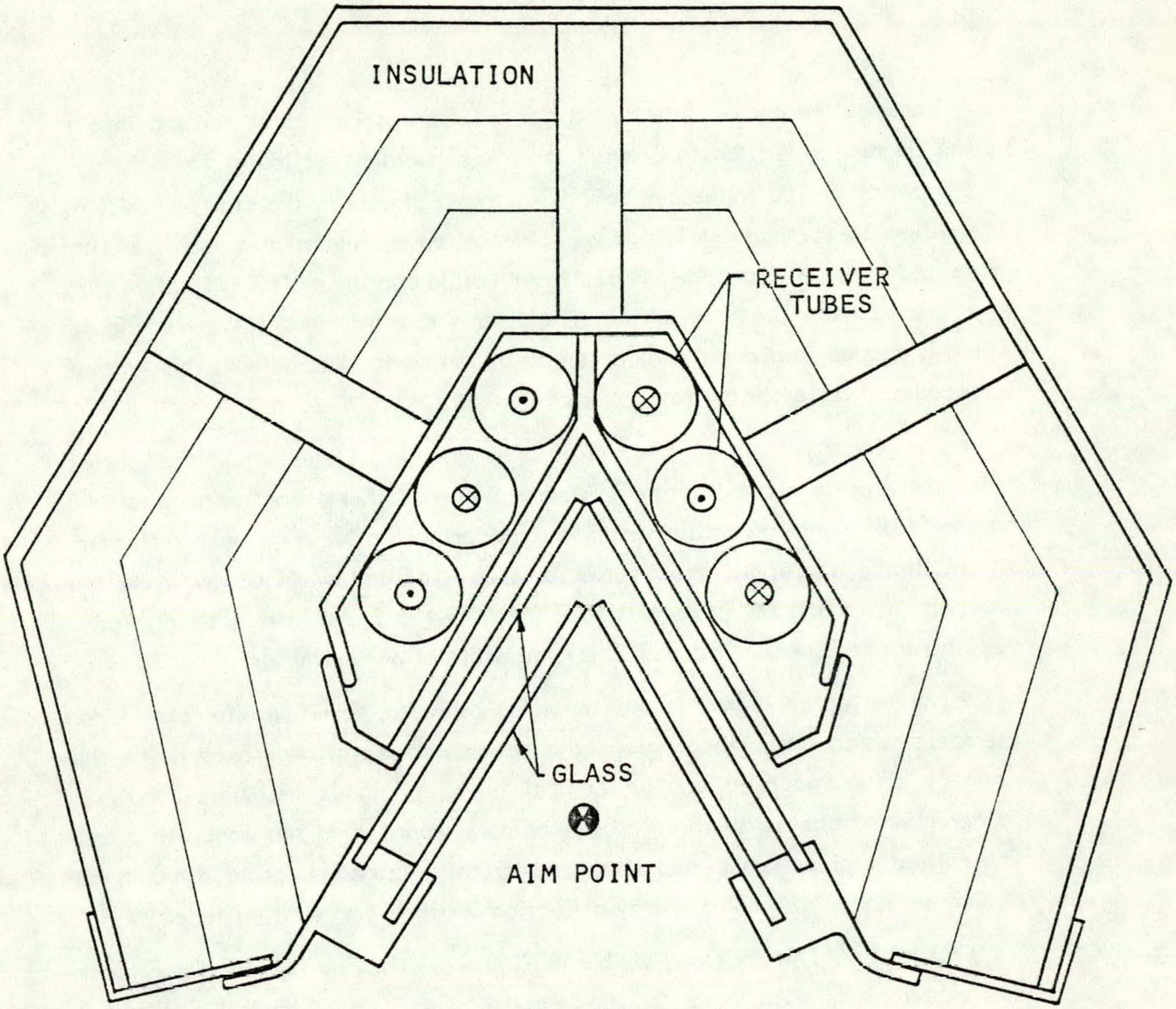

Figure 3-5. Typical Cross-Section of Vee-Entrant Receiver

The reflected light from the concentrator impinges upon the vee-entrance cover glass which is centered on the "aim point". Each ray that strikes the glass is either transmitted or reflected. If transmitted, it may pass through the second glass and strike the absorbing surface of the tubes. If reflected, it will strike another portion of the glass and have another chance to be transmitted.

The principle of the vee-receiver is based upon the fact that, in an east-west oriented linear array, a substantial amount of solar power is collected at off-noon hours, when the light rays reflected by the concentrator strike the receiver at a glancing angle. The vee-entrant design gives the rays two chances to pass through the windows, thus increasing the transmission. As is apparent from Figure 3-5, gaining this potential requires a complicated and bulky receiver design. Receivers of simpler design were also included in the SETM test plan but, as discussed above, these receivers were not available during the contract period.

The heat-transfer fluid (pressurized water) flows through each of six 1.25 inch OD carbon steel boiler tubes which are painted with 3M Nextel to enhance isolation absorptance. The wall thickness is 0.065 inch, allowing operation at 1050 psi and 530°F. Prior to installation, the tubes were hydrostatically tested to 1-1/2 times the maximum operating pressure at ambient temperature. The tubes are held in place within the receiver by steel straps connected to the outside shell through steel supports on five-foot centers. The supports are slotted to allow differential expansion between the inside and outside shells. An inside shell is provided to "nest" the six tubes and to prevent insulation deterioration. The inside shell is also wrapped to provide radiation suppression.

Support for the receiver structure is provided by three mounting yokes attached to the structural members supporting the concentrator array, as shown in Figure 3-6. This method of attachment allows for interchangeability, which facilitates the testing of alternate receiver designs. Inlet and outlet connections to the receiver are through standard plumbing connections provided for mating with the fluid loop. Instrumentation incorporated in the receiver is described in Section 3.1.3.

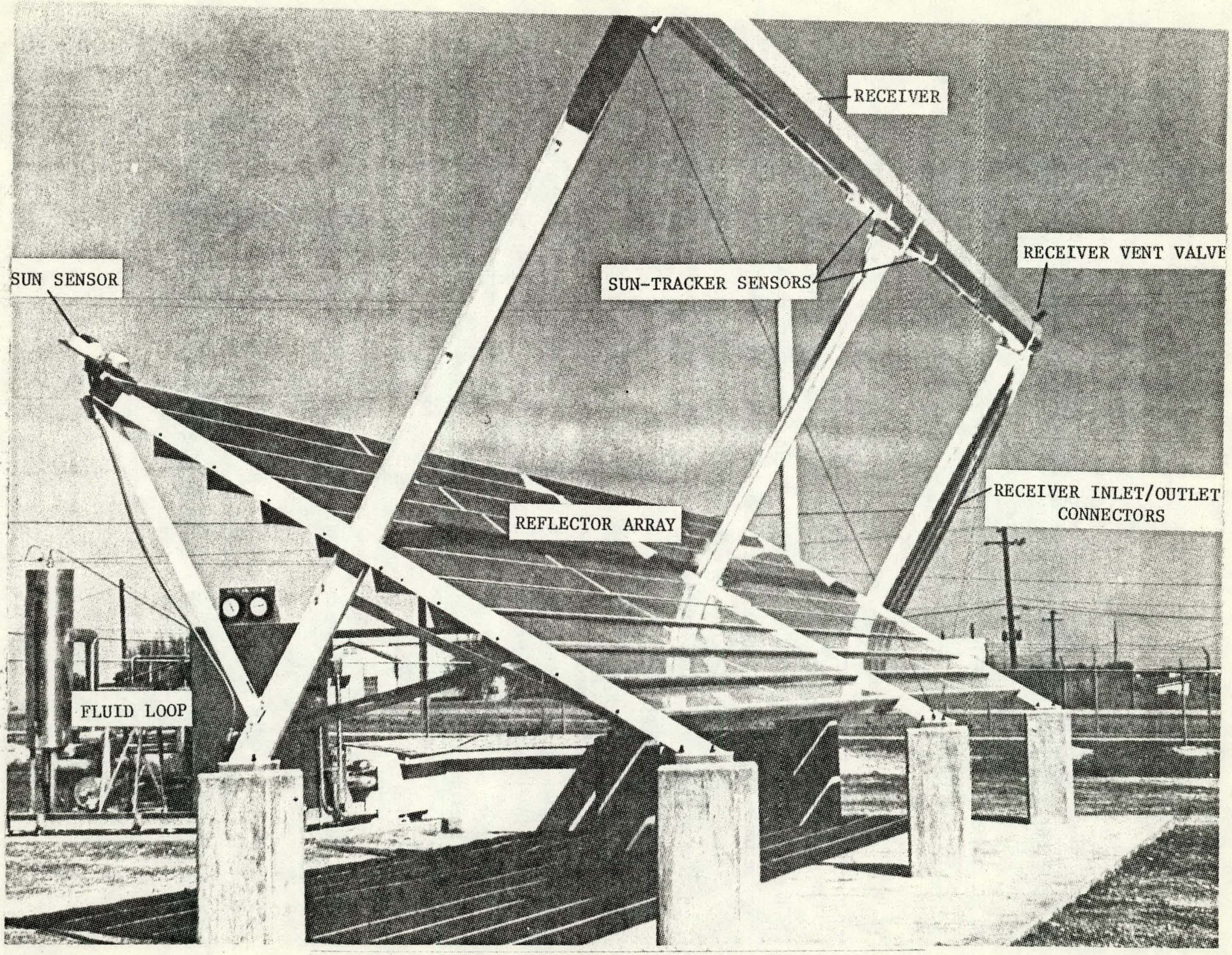

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Figure 3-6. West V of the SETM Collector

3.1.2 Fluid Loop

The purpose of the SETM fluid loop is to provide a flow of pressurized water at controlled rates and temperatures to the receiver and to provide a means of dissipating the heat picked up by the receiver when the collector is in operation. In addition, instrumentation incorporated into the fluid loop is essential to determine collector performance as well as to control the loop. The fluid loop was designed to ATU's specifications by the Barber-Nichols Engineering Company of Arvada, Colorado and fabricated by Solar Kinetics, Inc. of Dallas, Texas.

A schematic of the fluid loop showing the major components is given in Figure 3-7. The main components (clockwise from the right) are the cooler bypass valve, cooler, demineralizer, accumulator, nitrogen pressurization system, pump, recycle valve, and the electric heater. A number of additional valves, vents, etc. are required for control and safety purposes. Most of the SETM instrumentation (sensors and transducers) are also included in the fluid loop. Figures 3-8 and 3-9 show photographs of the fluid loop as viewed from the west and east, respectively. Some of the major components are labeled on the photographs.

A variable flow rate is required to control the temperature rise as water is circulated through the receiver. This is achieved by a fixed-rate pump and a three-way valve for recycling a variable fraction of the water through the pump.

A 15-kilowatt electric heater is used to preheat water to realistic temperatures for test operations. In a full-scale collector field such as that envisioned for LSE-1, fluid entering the collector field from high-temperature storage would probably be in the range of 350-400°F. The water in the fluid loop can be brought up to the desired receiver inlet temperature by solar heating while circulating through the receiver, but this requires additional time and limits the flexibility of the facility.

The accumulator serves two purposes. First, it accomodates the relatively large changes in the volume of water within the system as it is heated from ambient temperature to temperatures in excess of 500°F. Second, valves

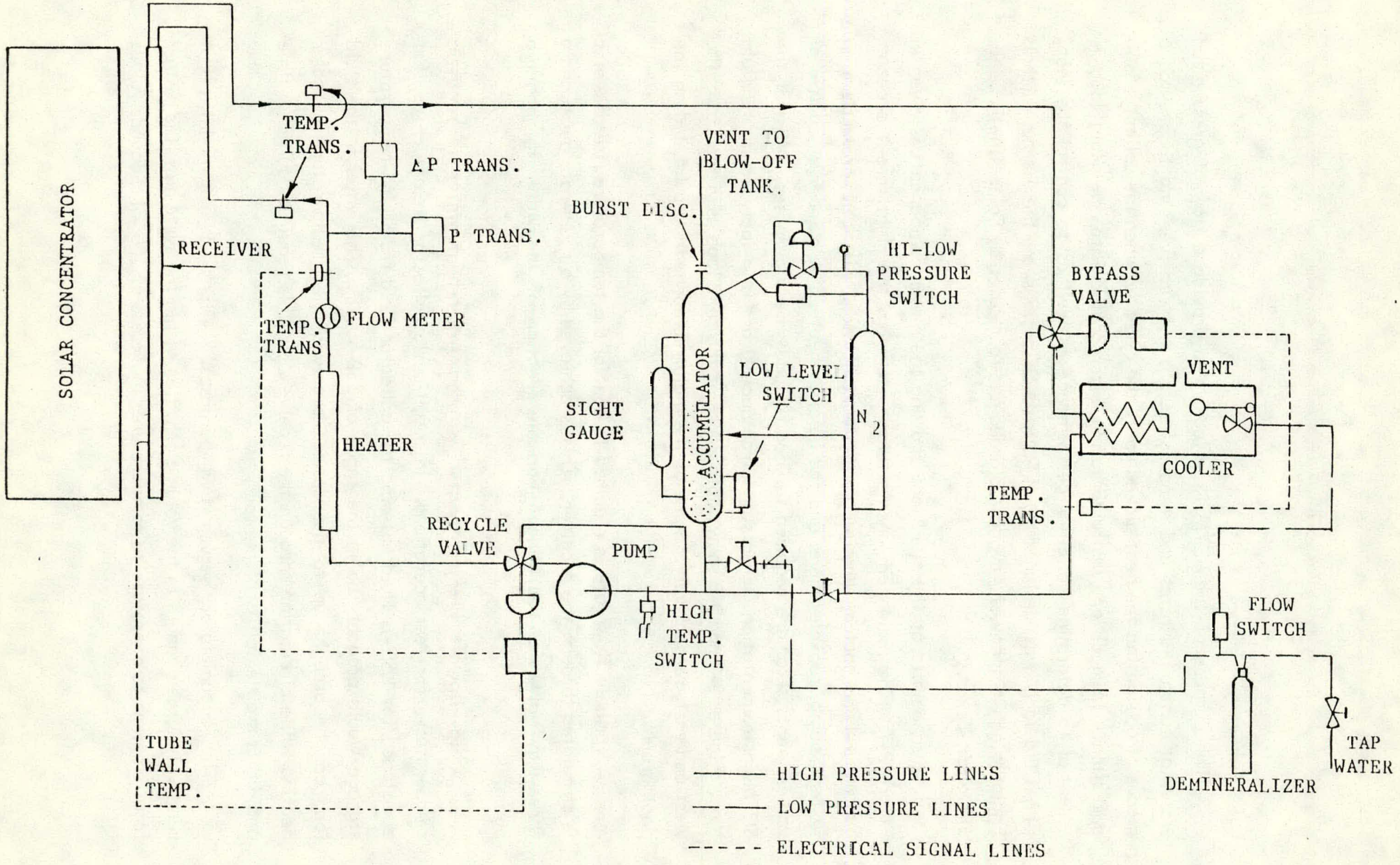

Figure 3-7. Fluid Loop Schematic Diagram

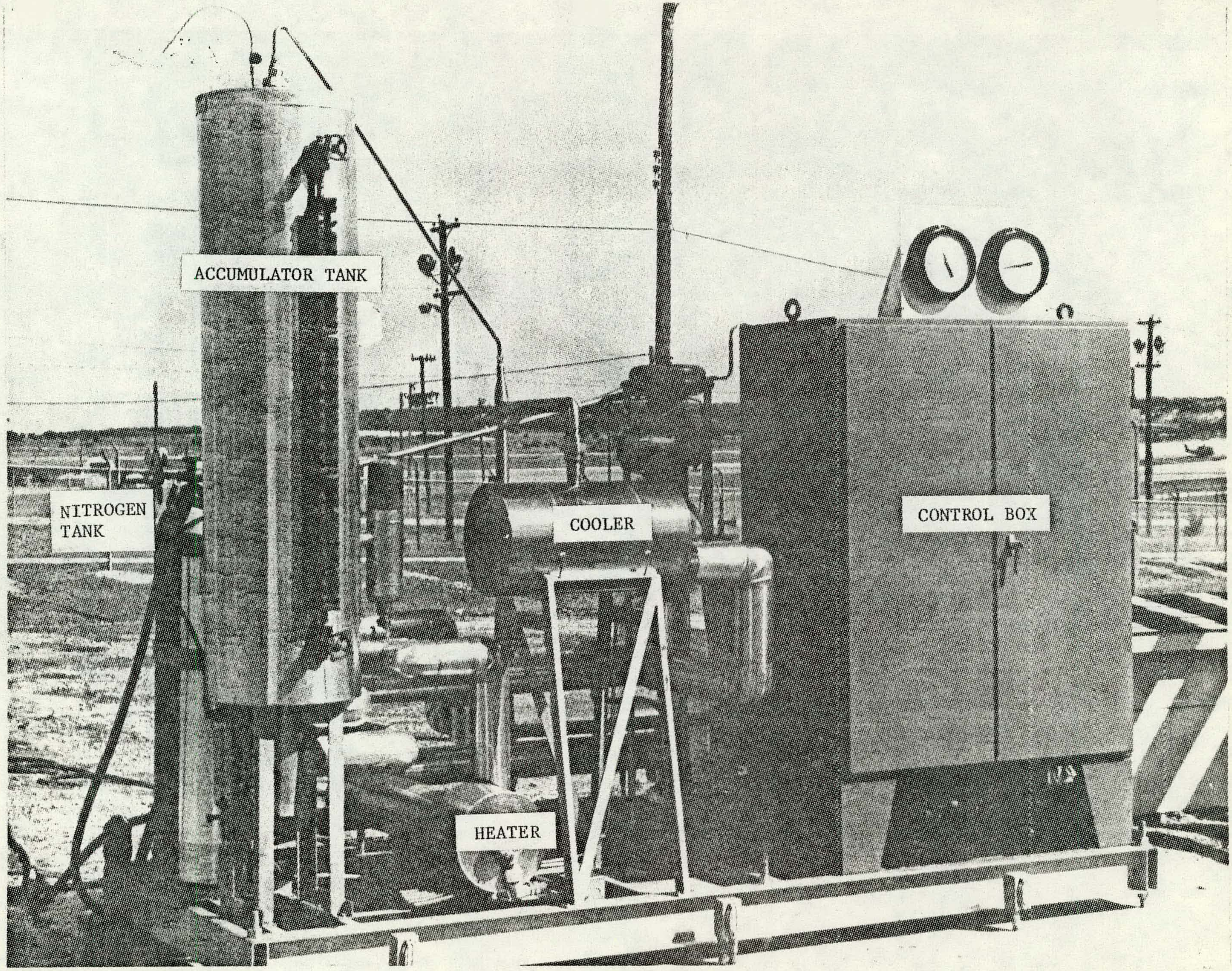

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Figure 3-8. West View of the Fluid Loop

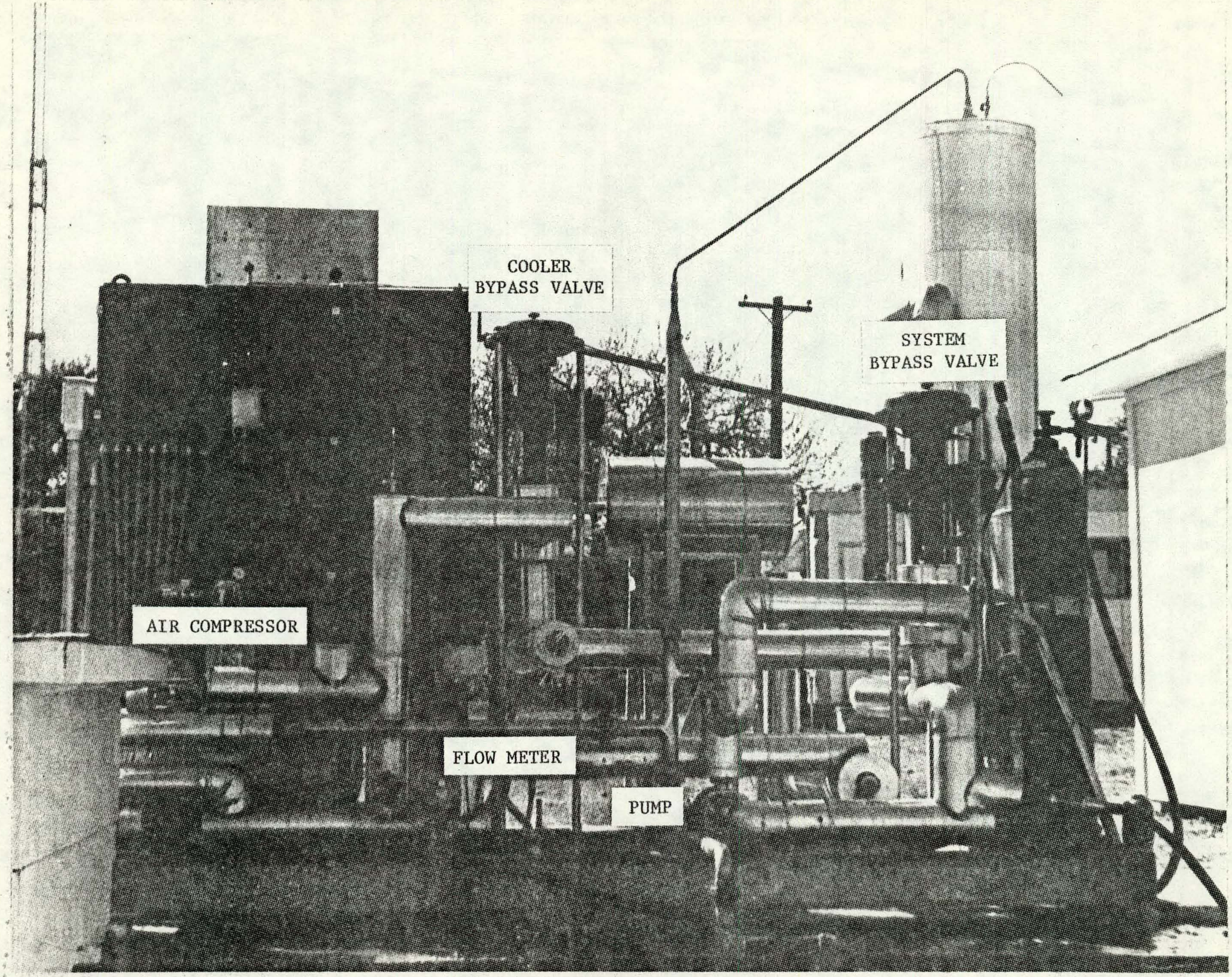

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Figure 3-9. East Vi of the Fluid Loop

may be set to put the accumulator "in line" with the loop rather than operating it in the "passive" mode in which the expanding water simply backs up into the accumulator. In the "in-line" mode, the extra water in the accumulator increases the thermal capacity of the fluid loop and makes it less sensitive to transient conditions.

The nitrogen pressurization system is required to maintain sufficient overpressure in the system to prevent phase change at various operating temperatures. Water used to fill the loop is passed through a commercial demineralizer to help prevent scaling in the loop. In addition, the water chemistry is monitored and controlled to help prevent corrosion. All wetted components of the fluid loop are made of stainless steel to extend their lifetime.

Because of the operating temperatures and pressures, appropriate components for the fluid loop had to be carefully selected and were difficult to find in some cases. For example, although large pumps capable of operating at the required temperatures and pressures are relatively commonplace, an appropriate off-the-shelf pump rated at a few gallons per minute could not be located. The pump used in the SETM fluid loop is a specially modified version of a magnetically coupled pump provided by March Manufacturing Company. The modifications included the use of asbestos insulation and a heavier housing.

A number of features are included in the fluid loop for safety and equipment protection purposes. Pressure relief valves set to operate at 1200 psi are installed in the lines to and from the receiver. These are backed up by a rupture disc with a 1250 psi rating.An accumulator low-level switch activates an alarm in the event that the water level becomes too low. It is backed up by a sight gauge for observing the water level. A high-low pressure switch activates an alarm in the event that the system pressure drops below or exceeds adjustable low- and high-pressure limits. A temperature activated switch is also included to sound an alarm in case the system temperature exceeds 535°F.

Some of the major components procured for the fluid loop are listed in Table 3-1. Specifications and sources are included; several other major components of the fluid loop, such as the accumulator tank and the cooler, were custom-fabricated by Solar Kinetics, Inc., or their subcontractors.

Table 3-1. Fluid Loop Components

COMPONENT	MANUFACTURER	MODEL/SPECIFICATION
Pump	March Manufacturing Co.	Model TE-7S-MD*, 53 gpm 59 ft Head
Flow Transducer	Flow Technology, Inc.	FT-10N125-LJ, 1.25 to 12.5 gpm
Flow Transmitter	Flow Technology, Inc.	S/N 861061
Heater	Emerson Electric Co.	No. 300ID, 240V-3Ø, 15 KW
Heater Controller	Rosemount Nashville, Inc.	Model No. 3212
Air Compressor	Ingersoll-Rand Co.	Model 101520, 1 HP, 20 Gal., 150 psi, Max.
Accumulator Low Level	Ball Manufacturing Inc.	Magnetic Coupling, 1050 psi 550^0
Water Demineralizer	Culligan Water Co.	Two-Bed Resin, 800 Gal. Life Capacity
24 VDC Power Supply	Tele-Dynamics	Manufacturer No. 120-OEM 3, 120 Watts or 10 Amps Max., ±% Regulation
3-Way Pneumatic Valves	Fisher Controls Co.	Design YD
3-Way Valve Process Controllers	Fisher Controls Co.	Type TL101
3-Way Valve Adder-Subtractor	Fisher Controls Co.	Type TL173

* with modifications

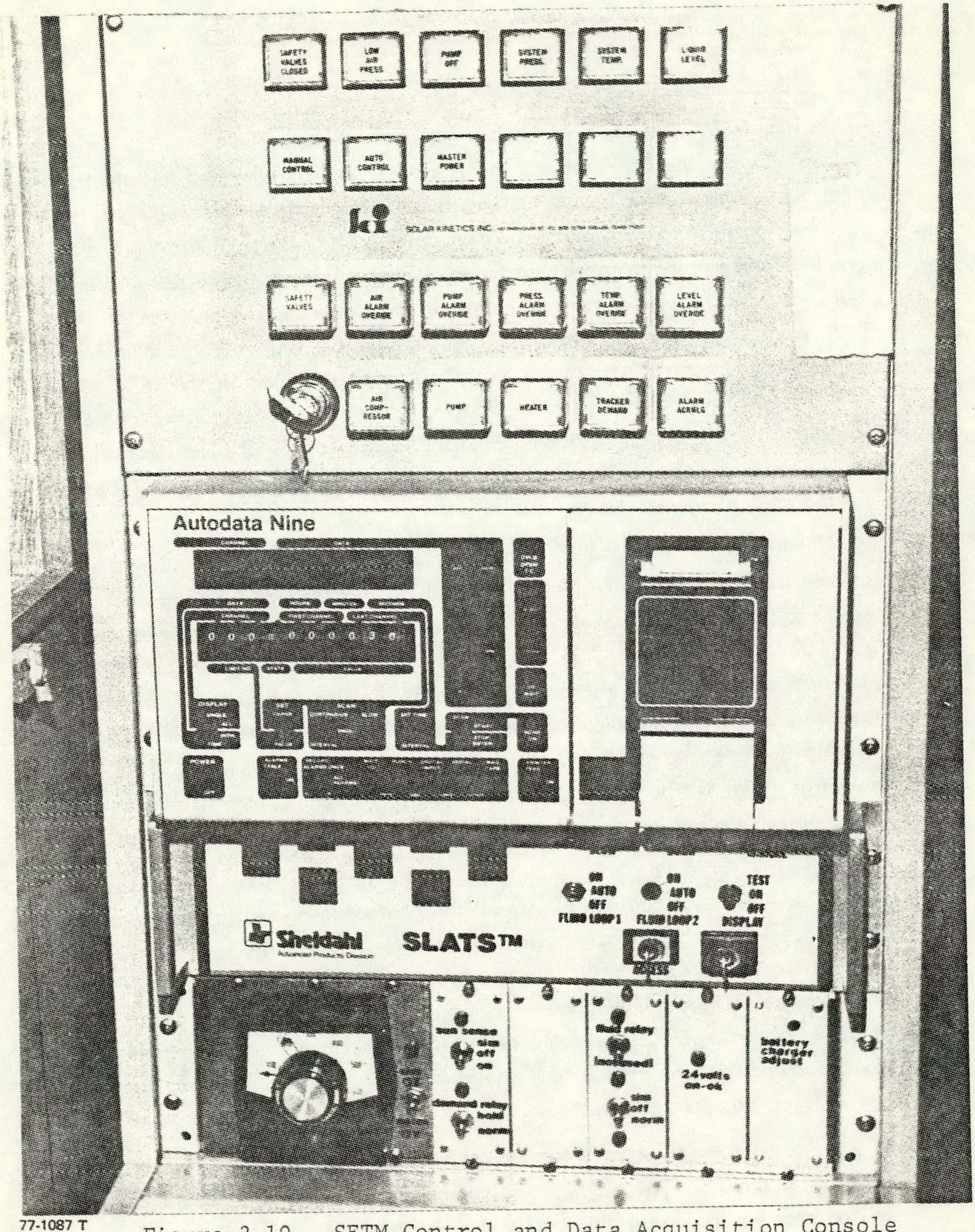
3.1.3 Controls and Instrumentation

The SETM has a hierarchy of controls including automatic control subsystems for the collector, the heat transfer fluid flow rate, the electric heater, and the cooler. Certain instrumentation signals are required for controlling the fluid loop, but the major purposes of the instrumentation are to provide temperature measurements at a number of points in the receiver and fluid loop and to provide measurements of the flow rate and pressure of the heat transfer fluid. An automatic data acquisition system is an important adjunct to the controls and instrumentation. Overall control of the SETM and operation of the data acquisition system is from a master control console located in the SETM control building and shown in Figure 3-10. The signal flow and the logic/control interactions among the major units of the SETM are summarized in Figure 3-11.

Collector. The SLATS^{TM} control subsystem performs three functions: sun sensing, sun tracking (reflector focusing), and system monitoring/protecting. The sun-sensing function determines when the insolation conditions are adequate for operation. The sun-tracking (or reflector focusing) function automatically maintains the proper reflector position for focusing upon the receiver. The system-monitoring function automatically allows the collector to operate if there is demand and adequate solar intensity; however, it shuts the collector down if the demand is removed, if the solar intensity is below threshold, if an over-temperature condition is detected, or if there is a power failure.

The sun sensor consists of two silicon photocells housed in clear plastic hemispheres atop the reflector assembly, as may be seen in Figure 3-6. One hemisphere is masked so that its photocell responds primarily to direct radiation from the sun. The other hemisphere is masked to provide an indication of the relative amount of diffuse radiation. The two signals are electronically compared and the sun sensor is "on" when the direct radiation measured exceeds the diffuse by a preset percentage.

The sun-tracker sensors consist of two identical tubes mounted on the receiver as shown in Figure 3-6. Each tube has a baffle positioned at the center of the receiver aperture; this baffle divides the tube into two equal-length cylinders. The cylinders are uniformly perforated to admit light that is



77-1087 T Figure 3-10. SETM Control and Data Acquisition Console

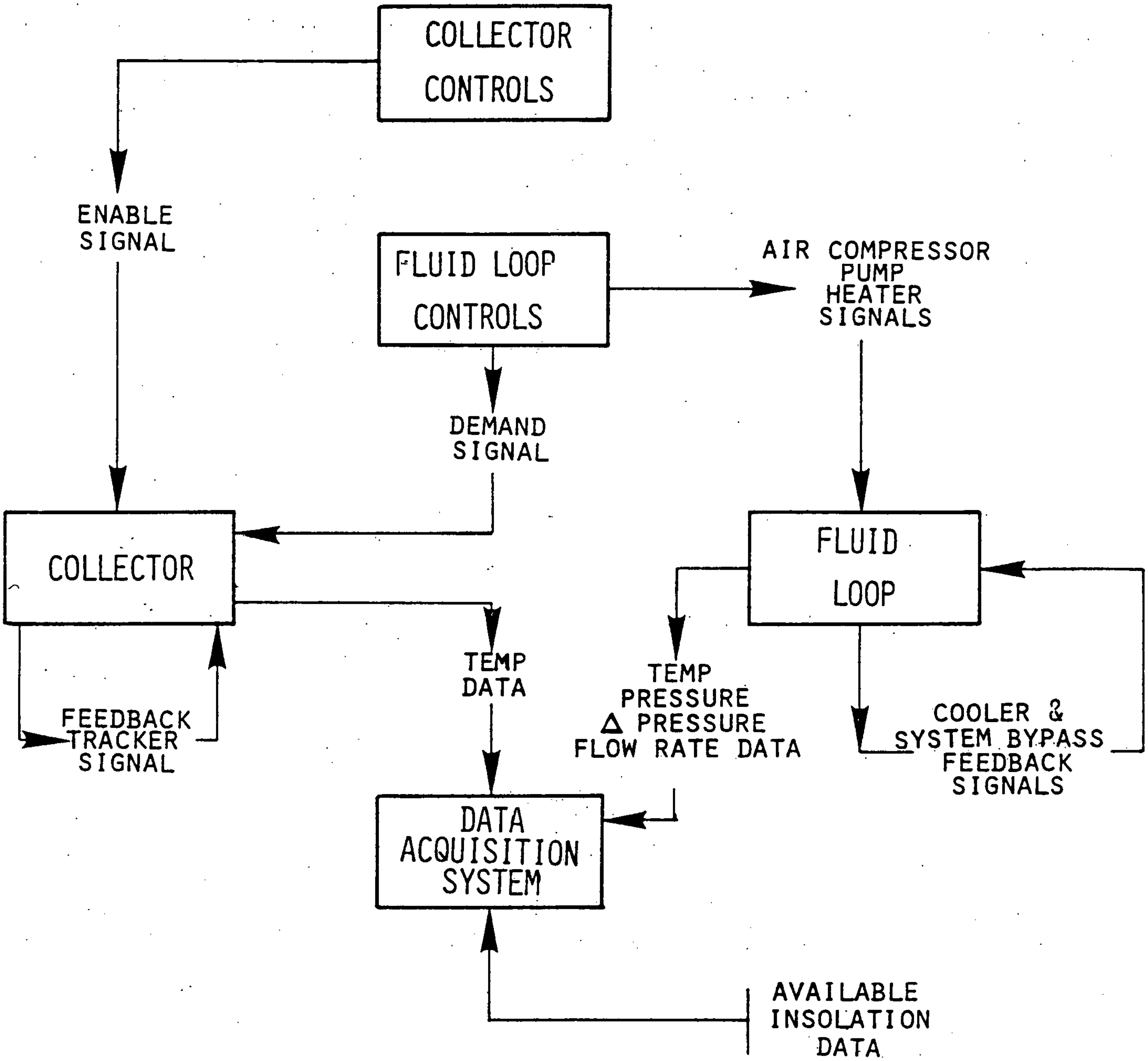


Figure 3-11. SETM Control and Data Acquisition Diagram

concentrated by the reflectors. The insides of the tubes are flat white to reflect the light admitted by the holes to photocells located at the end of each tube. The sun tracker detects the flux distribution at the receiver aperture and produces an error signal proportional to the difference in position between the peak of the distribution and the center of the receiver. The reflector position is adjusted by a closed-loop servo system as required to minimize this signal. The sun tracker is said by Suntec Systems, Inc. to be sensitive to flux position errors of less than 0.125 inch.

Fluid Loop. Two levels of control are provided for the fluid loop. The first level is operated locally and consists of temperature settings, pressure settings, etc. These settings are changed infrequently, and some are maintained by automatic controllers. The second level allows for remotely controlling routine operations from the SETM control building.

The automatic controllers in the fluid loop include two standard Fisher TL101 temperature controllers for the bypass valves and a Rosemount time-proportioned controller for the electric heater. One Fisher controller automatically actuates the by-pass valve to the cooler (see Figure 3-7) as necessary to maintain the desired temperature in the return water. The second Fisher controller activates the pump recycle (or system bypass) valve to adjust the flow rate through the receiver as necessary to maintain the desired temperature increase.

The second level of fluid loop control is used for normal operation once appropriate settings are made on the automatic controllers. The second level consists of two identical control panels for operating the air compressor (required for the pneumatically operated bypass valves), the pump, the heater and for indicating tracker demand. One of the control panels is located in the local control box at the fluid loop for manual operation. The second panel is the upper panel of the master control console shown in Figure 3-10.

Instrumentation. The SETM instrumentation includes sensors installed in the collector receiver, the fluid loop, and the field near the SETM. Two platinum resistor temperature detectors (RTDs) and eleven thermocouple temperature sensors are located at various points along the receiver tube for control and testing purposes. The fluid loop has RTDs at the outlet and inlet and at the cooler; a fluid flow rate meter; a pressure transducer; and a transducer for measuring the differential pressure across the receiver. In addition to the above, nearby instrumentation operated by the U.S. Army Atmospheric Sciences Laboratory Fort Hood Meteorological Team provides data on solar intensity, ambient temperature, wind speed, and wind direction. Table 3-2 identifies the specifications of the more important instrumentation.

Analog signals from several of the more important sensors are digitized, converted to engineering units, and logged by an automatic data acquisition system. The SETM data acquisition system is an Acurex Autodata Nine which is microprocessor-controlled and capable of scanning 40 data channels. It contains an integrating digital voltmeter that converts analog input data to digital form for display and recording. It also has input translation, which permits the operator to select programmed conversion functions which the Autodata Nine will apply to convert, display, and record mixed sensor outputs in engineering units such as ^{o}F, psi, and gpm.

The Autodata Nine, the front panel of which may be seen in the center of Figure 3-10, contains a real-time clock that indicates days, hours, minutes, and seconds. The selectable scan mode permits scanning and recording of the data on selected channels continuously, on demand, or at arbitrary intervals. The digitized and converted data may be displayed visually and/or recorded on the strip printer shown on the right side of the control panel (Figure 3-10). The time is recorded with each scan.

The receiver inlet and outlet RTDs and the flow meter are critical for measuring heat collection or loss. Because in situ calibration of these instruments is not feasible, cross-checks on their accuracy to insure reproducibility as a function of time has been a continuous task since the SETM became operational. Deviations from factory calibration specifications are monitored by cross-checking the RTD outputs with thermocouple measurements at nearby locations on the receiver. The differential pressure is a moderately strong function of flow rate and, for a given absolute pressure and temperature, the relationship is essentially constant. This provides a means of checking the flow meter calibration for consistency. To insure continued accuracy, the flow meter is periodically returned to the factory for recalibration.

Table 3-2. SETM Instrumentation

COMPONENT	MANUFACTURER/MODEL	LOCATION
Platinum Resistance Probe (2)	Yellow Springs Instrument Co.	Inlet & outlet of receiver tube
T-Type Thermocouples (2)	Omega P/N TJ-36-CPSS-116 -G-3	(Immersion) Inlet & outlet of receiver tube
T-Type Thermocouples (2)	Omega P/N TJ-36-CPSS-116 G-3	(Immersion) One 80 ft from inlet other inserted 160 ft from inlet
T-Type Thermocouples (6)	Rolf No. 20114-L10	Skin mounted in a row perpendicular to receiver long axis 4 ft from inlet end
Outlet RTD & transmitter	Fisher Controls Co. Type PM511	Fluid Loop Outlet
Differential Pressure Transmitter	Rosemount Nashville, Inc. Model 1151DP	Across Fluid Loop Inlet and Outlet
Pressure Sensor and Transducer	Robinson-Halpern Co. Model 144B	Fluid Loop Outlet 6 ft. from end.
Cooler RTD & Transmitter	Fisher Controls Inc. Type PM511	Outlet Side of cooler & Cooler bypass
Wind Speed Indicator	Bendix, Aerovane Model 20	South of Control Building
Wind Speed and Direction Recorder	Rett Products	Inside Control Building
Wind Direction Indicator	Bendix	South of Control Building
Pyranometer (30^{o} tilt)	Eppley Mod. 15 No. 6363A	ASL Instrument Station
Normal-Incidence Pyrheliometer (NIP)	Eppley NIP Mod. No. 8118E6	ASL Instrument Station

3.2 SETM Test Plan And Operations

A preliminary test plan for the SETM was developed during Phase II and included in the final report (Reference 5). The test plan was revised and published in March, 1977 (Reference 14). As SETM operations proceeded, the test plan was updated and included in Reference 13, which was published in July, 1977. The July version of the plan, which is the basis for testing reported herein, is summarized in Section 3.2.1.

The SLATS^{TM} collector was installed in November, 1976 and the fluid loop was installed in late January, 1977. Systems integration and checkout were performed during February and March. Routine testing at the SETM began in April, 1977 but was hampered by unseasonably bad weather throughout the spring. During the remainder of 1977, the SETM was operated more-or-less routinely, and a large quantity of test data was obtained. The operational experience with the SETM during this period is discussed in Section 3.2.2.

The first few months of test operations served as a shakedown period during which a number of problems were identified and corrected. Some problems continued through the testing period, but these did not materially impair the operation (the average SETM "down time" since April, 1977 has been approximately 10 percent). Section 3.2.3 discusses SETM reliability and gives specific information on some of the more significant problems encountered.

3.2.1 Test Plan

The test objectives require that collector performance and heat-loss data for a number of controlled operating conditions (i.e., receiver inlet temperature, ΔT) be taken over extended periods of time. Ideally, the external conditions (insolation levels, meteorological conditions, etc.) would also be controlled to systematize and expedite the tests. Since this cannot be done, it was necessary to accept the fact that weather conditions introduce problems in following a specific testing sequence and schedule, and to adopt the daily testing activities to the prevailing conditions.

Overall collector performance data are obtained by measuring flow rate; receiver inlet and outlet temperatures; and system pressure while circulating pressurized water through the receiver with the collector in operation. Auxiliary data required for analysis and interpretation include direct insolation level as indicated by the normal incidence pyrheliometer (NIP), ambient temperature, wind speed, and wind direction. Instantaneous values of all of the above items are logged at time intervals typically in the range of five to fifteen minutes. In addition, the concentrator reflectivity is measured approximately once a week.

The original design concept developed for LSE-1 (see Section 1.1) was based on the following assumptions:

1. Use of the SLATS^{TM} collector
2. Use of water as the heat-transfer fluid for the collector field
3. Receiver inlet and outlet temperatures of 400°F and 530°F, respectively.

An operating pressure of 1050 psi was assumed to give an ample margin to prevent phase change. The SETM was originally designed to facilitate testing within the above range of operating conditions. However, since the operating conditions for the system design have not been finalized, the test plan was broadened to include a lower limit of 350°F for the receiver inlet temperature.

The collector inlet and outlet temperature selected for the full collector field cannot be used simultaneously at the SETM because a full collector field would be comprised of rows of collector modules. Each row would contain several modules comparable in size to that incorporated in the SETM. The receivers of such a row of modules would be connected serially. Therefore the effective inlet and outlet temperature would be different in each module, although the average receiver temperature of each module would be similar (assuming one or more complete "round trips" of water through serially connected receivers).

It was thus apparent that the SETM testing should involve receiver temperature differentials (ΔT) representative of single collector modules rather than an entire row. A ΔT of 30^o was selected for this purpose, resulting in receiver inlet water temperatures of 350, 380, 410, 440, 470, and 500^oF. The test plan (Reference 13) included measurements of these temperatures as a function of insolation level, time of day, day of year, etc.

An additional test parameter for the overall performance is the cleanliness of the reflectors. To provide a quantitative measure of the degree of soiling, two small test reflectors are mounted on attachments to the SLATS^{TM} reflector segments so that they experience about the same soiling as the entire reflector array. These two test reflectors are of Teflon-coated aluminized polyester and are flat instead of being slightly concave like the regular reflector segments. They are removed weekly and placed in a special periscope-like holder which is placed over a normal incidence pyrheliometer (NIP) to make an indirect measurement of the reflectivity. The NIP reading, I_o', as decreased by double reflection from the test panels, is used, along with the corresponding uninterrupted NIP reading, I_o, to calculate the reflectivity:

$$R = \sqrt{\frac{I_o'}{I_o}}$$

Several measurements of reflectivity are averaged to overcome the effects of localized soiling or surface irregularities on the test panels.

Concentrating collectors have the characteristic that, at a given receiver temperature, the efficiency of collection increases with the amount of insolation present. The reason for this is that the receiver loses heat at a relatively constant rate regardless of the rate of heat input. Since the overall performance of a collector depends upon the amount by which the heat-collection rate exceeds the heat-loss rate, the heat-loss rate is an important factor in overall collector performance. Thus, it is important that heat-loss data be obtained for receiver temperatures and ambient conditions corresponding to those specified above.

The electric heater incorporated in the fluid loop is normally used to maintain a constant receiver inlet temperature during heat-loss measurement. Originally, measurements of receiver heat loss were planned primarily when insolation conditions were not suitable for heat collection measurements (i.e., during cloudy weather or at night). However, early results indicated that the heat-loss rates are significantly less when the receiver is exposed to strong insolation. Thereafter, many of the measurements were made during good insolation periods, thus competing for time with the heat collection measurements.

Finally, it is noted that verification of such collector functions as automatic defocus, reflector alignment, and sun tracking could be included in the test plan. Functions such as these were initially verified as part of the checkout of the SETM, however, and they are routinely reconfirmed as the quantitative performance testing is carried out.

3.2.2 Operations

The SETM was considered operational on or about April 1, 1977. Of the 275 days from that date through December, 1977, heat-collection and/or heat-loss data were obtained on 118 days, the system was down 43 working days for repairs, and 85 days fell on weekends or holidays. The remaining 29 days were used for reporting, planning, and miscellaneous activities.

Of the 118 days on which data were obtained, 66 were allotted to heat-collection and 52 to heat-loss measurements. Both the heat-collection and heat-loss measurements were made for receiver temperature ranges based on the test plan summarized in Section 3.2.1. Table 3-3 gives the dates on which heat-collection data were taken with the water temperatures in the indicated ranges.

Table 3-4 shows the distribution of dates according to the number of hours during which heat was collected. Heat-collection time totalled approximately 265 hours for the 66 days, averaging out to approximately 4 hours of testing per day. The primary reason for this low average is that the system often started cold in the mornings and required several hours to warm up.

Heat-loss data were usually taken at night or during cloudy weather until it was observed that direct solar heating of the receiver materials apparently had an impact on the heat-loss rate. Most heat-loss data were then taken during exposure to sunlight.

Of the 43 workdays the SETM was down for repair, 30 days were pump-related, 2 days were due to flow meter problems, 2 days were because of collector tracker problems, 4 days were for repair of the air compressors, and 5 were for miscellaneous maintenance and cleaning. The following section reviews some of the operational problems encountered with the SETM.

Table 3-3. Distribution of Heat Collection Test Dates by Receiver Temperature Range

Receiver Temperature (°F)					
350-380	380-410	410-440	440-470	470-500	500-530
8/3	6/13	4/23	4/22	4/25	4/5
8/9	7/20	6/6	5/12	5/24	6/8
11/17	9/15	6/28	5/25	5/26	8/31
12/2	11/23	6/29	7/12	5/27	11/12
12/6	11/30	6/30	7/18	6/7	
12/15	12/1	7/1	7/19	7/2	
12/20		7/5	7/21	7/6	
		7/7	7/25	9/29	
		8/19	8/5	10/13	
		8/23	8/17	11/4	
		9/28	8/25	11/9	
		10/4	8/26	12/16	
		10/11	9/30		
		10/12	10/5		
		10/14	10/20		
		10/17			
		10/18			
		10/25			
		10/26			
		11/16			
		12/5			

Table 3-4. Distribution of Heat Collection Test Dates by Test Duration

Test Duration (hours)							
< 1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
4/5	5/12	4/25	4/22	5/24	7/7	5/27	10/26
4/23	6/29	6/6	5/25	6/3	8/3	11/3	
	10/18	6/8	5/26	7/6	8/9	11/16	
	11/12	6/28	6/7	7/20	8/19	12/2	
	12/20	6/30	6/13	7/25	8/23		
		7/1	7/2	8/5	8/25		
		8/17	7/5	9/28	8/26		
		8/31	7/12	9/30	9/29		
		9/15	7/18	10/4	10/5		
			7/19	10/14	10/12		
			7/21	10/17	11/4		
			10/11	10/20	11/23		
			10/13	10/25	12/1		
			11/17	11/9	12/16		
			11/30	12/5			
			12/15	12/6			

3.2.3 Equipment Reliability

A secondary objective of the SETM testing is to obtain information on the reliability and durability of the collector and of the equipment used in conjunction with the collector for testing purposes (i.e., the fluid loop, controls, and data acquisition equipment). While reliability and the failure modes of a full-scale collector system may be different in many aspects, it is anticipated that practical information gained from operation of the SETM will provide useful insights.

Operating experiences and problems encountered with all aspects of the SETM other than the collector are described below; the few collector problems encountered are described in Section 3.3.4.

Flow Meter. Fluid flow rate is a critical measurement in the testing of solar collectors. The instrument chosen for use at the SETM is a model manufactured by Flow Technology, Inc. (No. FT-10N125-LJ). A small turbine wheel is spun by the fluid as it passes through the in-line flow meter and a pulse signal is induced in a pick-off coil outside of the casing as each turbine blade passes. The pulses are amplified and converted to d.c. by the flow-meter's specially calibrated transmitter.

The flow meter was damaged in March, 1977 while the receiver was being flushed with acid to remove rust. The turbine was etched sufficiently to alter its measuring characteristics and was replaced. In September, 1977, the flow meter was returned to the factory for a calibration check. The results indicated that, although the calibration was still within acceptable limits, the pick-off coil had become partially grounded to the casing. A new pick-off coil was installed and no flow meter problems have been experienced since.

Pump. The SETM operates using a closed loop system that circulates approximately 30 gallons of filtered water with anions and cations removed. The water is treated with 40 ml of 35 percent hydrazine and 60 ml of 10 normal solution of sodium hydroxide to absorb the dissociated oxygen at high temperatures. The SETM uses a magnetic coupled impeller-type pump to circulate the heated and pressurized water through the collector. The pump is a modified version of a standard March Manufacturing Company. The pump normally is used for circulating caustic, acidic, or highly toxic chemicals. The magnetic coupling obviates the need for shaft seals since the impeller is magnetically induced to turn on a short stationary shaft within the pump housing. The modifications made to the pump by March Manufacturing Company to permit operation at high temperature and pressure include:

1. A strengthened housing,
2. Shortened impeller magnets and case,
3. The use of samarium-cobalt magnets,
4. Asbestos insulator rings to reduce heat transfer to the motor,
5. A Vitron O-ring gasket,
6. A revised bearing running clearance (0.007").

This experimental pump has been responsible for the majority of SETM failures. Aside from one failure of the pump drive motor bearing pump problems fall into two distinct categories: problems with the magnetic coupling and problems with the bearing.

On March 23, 1977, the pump was disassembled after developing an unfamiliar noise following approximately 100 hours of operation. Disassembly revealed a broken graphite bearing. The bearing was replaced but the pump impeller coupling magnets had degaussed to an extent that subnormal performance was evident. Subsequent examination led the Raytheon Company, manufacturers of the magnets, to conclude that the cause of the failure of the magnets was leakage of the treated water through the heliarc-welded stainless steel casing around the samarium-cobalt magnets. March Manufacturing Company felt that the failure might be due to the high pressure and temperature conditions, resulting in the magnets being damaged by the hydrostatic load combined with internal strain.

A new impeller was fabricated by March Manufacturing Company as a replacement for the defective impeller. After approximately 800 hours of operation, the second impeller also lost a substantial portion of its magnetic strength. This time, the progress of the failure was recorded by the data acquisition system; over the course of thirty minutes, the pumping capacity was reduced by a factor of two as the magnetic coupling rapidly lost its effectiveness.

At this point, ATU consulted with March Manufacturing Company and Sandia Laboratories to determine if the stainless steel case leaked, and exactly what process was destroying the magnets. The defective impeller was removed and a penetrating dye and developer were used to check cracks in the stainless steel casing. Many cracks were apparent but it was unclear if any of these cracks penetrated the casing.

The impeller was sent to Sandia Laboratories where a number of additional tests were performed. First, the cracks were verified with penetrating dye. Next, the impeller was x-rayed, but no new information was revealed. In the last test, the impeller was placed in a vacuum for some time and then pressurized in a helium chamber. Upon removal, from the chamber, a helium snitter revealed helium seepage from one of the cracks, thus confirming a leak into the interior of the magnet casing.

Actions taken to prevent future magnet degaussing addressed both possible causes of the failures. The void space inside a spare impeller was filled with epoxy to further reduce the possibility of the magnets coming in contact with system fluid. Another impeller was built with a heavier casing to better resist the hydrostatic pressure, and a thorough dye penetrant check was made during the manufacturing process. No magnet degaussing has been observed thus far in the operation of the redesigned impellers, but more operating time is required to give conclusive results on the success of the modifications.

The other cause of frequent pump failure is the shaft and bearings which position the impeller in the pump housing. The original arrangement used a ceramic shaft and thrust washer operating with a graphite bearing. The graphite bearings wore very quickly (approximately 200 hours operation) and occasionally broke. The ceramic shafts also were prone to breakage.

A nickel alloy, Hastelloy C, was substituted as the shaft material and eliminated the shaft breakage problem. However, the bearings still wore too quickly. An aerospace grade graphite bearing was machined and installed, but its useful life was no better than the standard bearing. The probable reason for the rapid bearing wear is that a large bearing running clearance is used to permit differential thermal expansion of the parts without bearing seizure. Further experimentation is required to determine if the running clearance can be reduced without impairing pump operation.

The following observations summarize the experience gained in operating the pump:

1. Ceramic shafts are too brittle for this application; Hastelloy-C should be used,
2. Vitron O-Rings are acceptable for use to 530°F,
3. The running clearance is critical to the life of the bearing,
4. Graphite bearings seem to wear too fast for general usage regardless of the care used in setting up the pump.

Burst Disc. The SETM fluid loop has several safety devices which prevent the plumbing from experiencing excessive pressure. Two relief valves are adjusted to release fluid if the system pressure exceeds 1200 psi; for back-up a burst disc ruptures at a pressure of 1250 psi. In April, 1977, the burst disc ruptured and released the system pressure prematurely (1082 psi, 507°F). A discussion of the event with the burst disc manufacturer revealed that the disc was made of stainless steel and was rated at 1250 psi for ambient temperature operation only. A nickel alloy, Inconel 600, burst disc was substituted since its strength is less dependent upon temperature. It endures the corrosive environment as well as stainless steel and has been used successfully for several months.

Plumbing. The fluid loop plumbing is of stainless steel and most connections are welded. The threaded couplings which are not welded are those of the various components of the loop which require servicing or replacement. Leaks have not been a major problem, but, as a practical matter, a completely leakproof system appears impossible. The only forced system shutdown caused by plumbing problems occurred when the gasket of the accumulator sight gauge blew out. No corrosion problems have arisen with the fluid loop.

Data Acquisition System . Difficulties were encountered in establishing a data acquisition system which dependably and accurately logged the test information. Four independent error sources, all associated with the Accurex Autodata Nine data logger, were located as enough data for thorough review and cross-checking accumulated. Three of these error sources were due to improperly selected electronic converters; the fourth resulted from "drift" in the zero setting of an electronic circuit. Once identified, these problems were readily eliminated. Further, all erroneously recorded data were corrected since the errors were systematic in nature.

Fluid Controllers. The fluid loop has two automated control systems; one maintains the return water temperature by routing part of the water through the cooler, and the other regulates the temperature rise of the water circulating through the receiver by adjusting the flow rate. The first controller has performed flawlessly throughout the resting period. The flow rate controller also works well when the temperature inputs change slowly but there have been instances when the fluid flow has not increased rapidly enough after a period of cloud cover. The problem, which is viewed as a design or functional problem rather than a reliability one, may be different for the 400 square foot module than for a row in a full-scale collector field. In the SETM, the fluid loop plumbing represents a larger portion of the flow path length than its counterpart, the manifolding and heat exchanger, would in a collector field. A predictive sensor may be useful in reducing the controller response problem.

Summary. Table 3-5 summarizes the relative performance of the SETM equipment components. "Significant Problems" are defined as those problems which cause errors in the data, major inconvenience to the operators , or the system to be shut-down. "Problems Requiring SETM Shut-Down" is a subset of the above. The data acquisition system and the pump were responsible for nearly sixty percent of the operational problems and the pump alone accounted for 82 percent of all required SETM shut-downs. Aside from the pump failures, there were only three other failures which forced the system into the inoperative mode.

Table 3-5. SETM Equipment Performance Summary

Equipment	Significant Problems		Problems Requiring SETM Shut-Down	
	Frequency	Percentage	Frequency	Percentage
Instrumentation				
Flow Sensor	3	10		
Temperature Sensors				
Pressure Sensor				
Low Water Level Sensor	4	13		
Overtemperature Sensor	1	3		
Data Acquisition System	5	16		
Mechanical				
Plumbing	1	3	1	6
Burst Disc	1	3	1	6
Cooler				
Automatic Controls	2	6		
Pump	13	42	13	82
Air Compressor	1	3	1	6
Total	31		16	

3.3 Data Reduction and Analysis

The SETM has been operated extensively since April and sufficient data have been obtained to satisfy the original objectives except those involving testing with the alternate receiver designs. Data obtained to date are for the original vee-entrant receiver. The alternate receivers were not available for testing at the SETM during the present contract period because of schedule delays in preliminary testing at Sandia Laboratories.

All of the SETM data have been entered into a computer file to facilitate data reduction and analysis. The process of obtaining data and building the file started with the Autodata Nine data acquisition system which converts instrumentation signals to digital form and records them in engineering units (see Section 3.1.3). Measurements were made at selected time intervals and were printed along with the local time on a paper tape.

The data on printed paper tape are manually transcribed to either collector heat-gain or receiver heat-loss calculation forms. Meteorlogical data, reflectivity data, etc. were also entered on the forms. Preliminary reduction of the data was then performed (see Section 3.3.1) to provide operator information. The basic data were later keypunched on computer cards for building the data file on magnetic tape. Any necessary adjustments for calibration or systematic errors were made as the data files were built on magnetic tape.

The magnetic tape files consist of records, each of which contains header information followed by the data from ten instantaneous measurements. A header contains information that is common to all ten points in that record. The header for heat-collection data consists of mode (heat collection or loss), year and date, ambient temperature, wind speed, wind direction, number of days since the last reflector cleaning, and the measured reflectivity of the mirrors. The data points following the header contain information on decimal hours from solar noon, normal incidence pyrheliometer readings, receiver inlet and outlet temperatures, flow rate, and system pressure. Receiver heat-loss data is organized in a similar manner. The header indicates the mode, year and date, and average total insolation; each point has decimal hours from solar noon, ambient temperature, wind speed, wind direction, receiver inlet and outlet temperature, flow rate, and system pressure.

In total, the data collected and entered in the file include over 2300 heat-collection points and 900 receiver heat-loss points. Appendix E lists the basic data from the file in reduced form. Part 1 of Appendix E gives the heat-collection data in sequence by Julian date and solar time. Part 2 gives the heat-loss data arranged in the same manner.

Heat-collection rates or receiver heat-loss rates were calculated as a first step in data reduction. Collector efficiencies were then calculated by considering the solar energy actually intercepted by the collector. These data reduction procedures are described in Section 3.3.1. Section 3.3.2 describes a computer program developed for building the data files and reducing and analyzing the data.

Collector performance depends upon many factors in addition to the actual collector design. For a given design and installation location and orientation, performance depends upon both controllable operating conditions (primarily the receiver inlet temperature and the flow rate, or ΔT which is controlled by the flow rate) and upon many factors which cannot be controlled. The uncontrolled factors include direct solar intensity and total solar intensity (both of which depend upon the day of the year and the time of day, in addition to meteorological conditions), ambient temperature, wind speed, and wind direction. Because of the large number of factors which influence performance and the fact that most of them cannot be controlled or systematically varied, individual measurements may be misleading. Therefore, considerable emphasis has been placed on statistical techniques for analyzing the large body of data to extract information on trends and relationships. These techniques and the results obtained are described in Section. 3.3.3.

3.3.1 Data Reduction

Data reduction involves calculating, from the measured data, the overall energy collection rate or, for heat-loss measurements, the receiver heat-loss rate. Energy collection data taken at times other than solar noon are adjusted to compensate for end losses caused by a fraction of the radiation being focused on a line beyond the end of the receiver. This is necessary for predicting the performance of longer collector arrays.

It is desirable to express collector performance in terms of efficiency to facilitate comparison among collector types. Calculation of efficiency of concentrating collectors from measured performance data requires concurrent measurements of the direct, or normal-incidence, solar radiation available to the collector. At the SETM, this is done with a normal incidence pyrheliometer (NIP), which gives the amount of energy per unit area arriving within a conical aperture of approximately 5.7 degrees, the axis of which always points toward the sun. Although concentrating collectors typically have an acceptance aperture of less than 5.7 degrees (1.5 degrees for the SLATS^{TM}), preliminary data from the Lawrence Berkeley Laboratory circumsolar telescope (Reference 6) indicate that, under most atmospheric conditions, it is reasonable to assume that all of the energy measured by a NIP is available to a concentrating collector, provided that the collector has a two-axis tracking mechanism.

For linear-focusing single-axis tracking collectors, the direct radiation flux is incident upon the reflector surfaces at angles which vary widely with time. The radiation available to a given reflector surface is the radiation current which varies with the dot product between the sun vector and the vector normal to the reflector surface. Thus, if the angle between these two vectors is defined as Θ, the intensity, I, available to a given reflector of the SLATS^{TM} collector is a product of the NIP reading, I_o, and cos Θ:

$$I = I_o \cos \Theta$$

The radiation incident upon each reflector segment at a given time is slightly different because each segment is tilted at a different angle in order to focus on the linear receiver. However, an adequate and convenient approximation is to define the available insolation as the radiation current into an east-west aligned plane fixed at a tilt of 31° from the horizontal and with a surface area equal to the nominal 400 ft^2 of reflector surface area of the SLATS^{TM} concentrator.

The solar energy collection rate is calculated from the measured flow rate and the measured increase in temperature of the pressurized water as it is circulated through the receiver while the collector is in operation. The general equation is:

$$q = M (h_o - h_i)$$

where q is the heat-collection rate in BTU/hr, M is the mass flow rate in lb/hr, and h is the enthalpy of water in BTU/lb at the receiver outlet temperature (o) and inlet temperature (i) respectively. The water pressure must be considered in converting the measured volume flow rate to mass flow rate,, and in determining the enthalpy from standard steam tables (Reference 15).

As in collection rate measurements, the receiver heat-loss rate is determined indirectly by measuring the flow rate and the change in temperature of the pressurized heated water as it travels from the receiver inlet to outlet. The equation used for calculating the loss rate is:

$$r = M (h_i - h_o)$$

where r is the receiver heat-loss rate in BTU/hr and the other terms are as defined above.

The ultimate purpose of the performance data from the SETM tests is to provide a realistic means of projecting the performance of large arrays of linear focusing collectors. As pointed out earlier, end losses reduce the performance of the single module at all times other than solar noon. To make the SETM performance data for times other than solar noon applicable to collector arrays, that are long enough to have negligible end losses, two types of end-loss adjustments are necessary. One is for the purely geometric end-loss effect caused by radiation being focused on a line beyond one end of the receiver, and the other is for the thermodynamic effect—the loss of collected heat by the unilluminated fraction of the receiver.

The geometric factor, F_g, is determined by calculating (for a given sun angle) the furthest distance "downstream" (i.e., beyond the end of the receiver) that reflected rays reach the receiver focal line from each reflector. The end-loss factor is one minus this distance divided by the actual length of the reflector (40 feet). This factor is thus the fraction of the reflector that produces an image on the receiver.

Both end-loss adjustments may be made to the energy collection rate, q, in one mathematical operation:

$$q' = \frac{q}{F_g} + r\ (\frac{I}{F_g} - 1)$$

where q' is the adjusted energy collection rate and the other terms are as previously defined. Dividing q' by 400 ft^2, the nominal area of the concentrator, gives the energy-collection rate that would be expected per square foot of SLATS^{TM} collectors in an array long enough for the end effects to be negligible.

Collector efficiency, without end losses, is given by

$$\eta = \frac{100q'}{I}$$

where η is the efficiency and the other terms are as previously defined. The efficiency of the individual collector module (with end losses) is obtained by substituting q for q' in the above equation.*

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* Note that collector efficiency may be defined in other ways. See Reference 13 for a more complete discussion.

3.3.2 Data Processing Program

Preliminary data reduction was performed as a more-or-less continuous process during testing to provide a better basis for detailed short-term test planning. For this purpose, most of the above equations were programmed on a TI SR-52 calculator. The limited capabilities of the SR-52 require that simplified curve fits be used for the enthalpy of water as a function of temperature and pressure, for pre-calculated values of the geometric end-loss factor, etc. All results reported heretofore have been based on the preliminary data reduction procedures.

To provide high-precision data reduction, as well as to facilitate data management and analysis, a program was prepared for the IBM 370/145 computer at ATU's central computing facility. This program builds the basic files of test data, performs the data reduction described in Section 3.3.2, and provides a variety of reports. As an option, it also performs linear multivariate regression analysis as described below.

A block diagram of the program is shown in Figure 3-12, describing the information flow through the main program and its interaction with the other subroutines. The information on the magnetic tape file, described in the previous section, is accessed by a search and sequence module controlled by user inputs.

The main program accesses the master data file in response to the user input for a particular run. As each data point is examined, the parameter which the user lists first will be compared to the upper and lower limits specified by the user. If this data fails to meet this requirement, the program goes to the next point. On the other hand, if the parameter of the data point falls within the boundaries specified, then the second parameter is examined. If all conditions are met by the data point, the data point is reduced and stored in a temporary file for printout after all the other points in the master data file have been examined.

The data reduction module is used to compute heat-gain or -loss values from the retrieved data. For this purpose, the physical properties of water are calculated from a subroutine modeled after the ASME program which gives values identical (to five significant digits) with those found in ASME Steam Tables (Reference 15). Another subprogram is used to accurately determine:

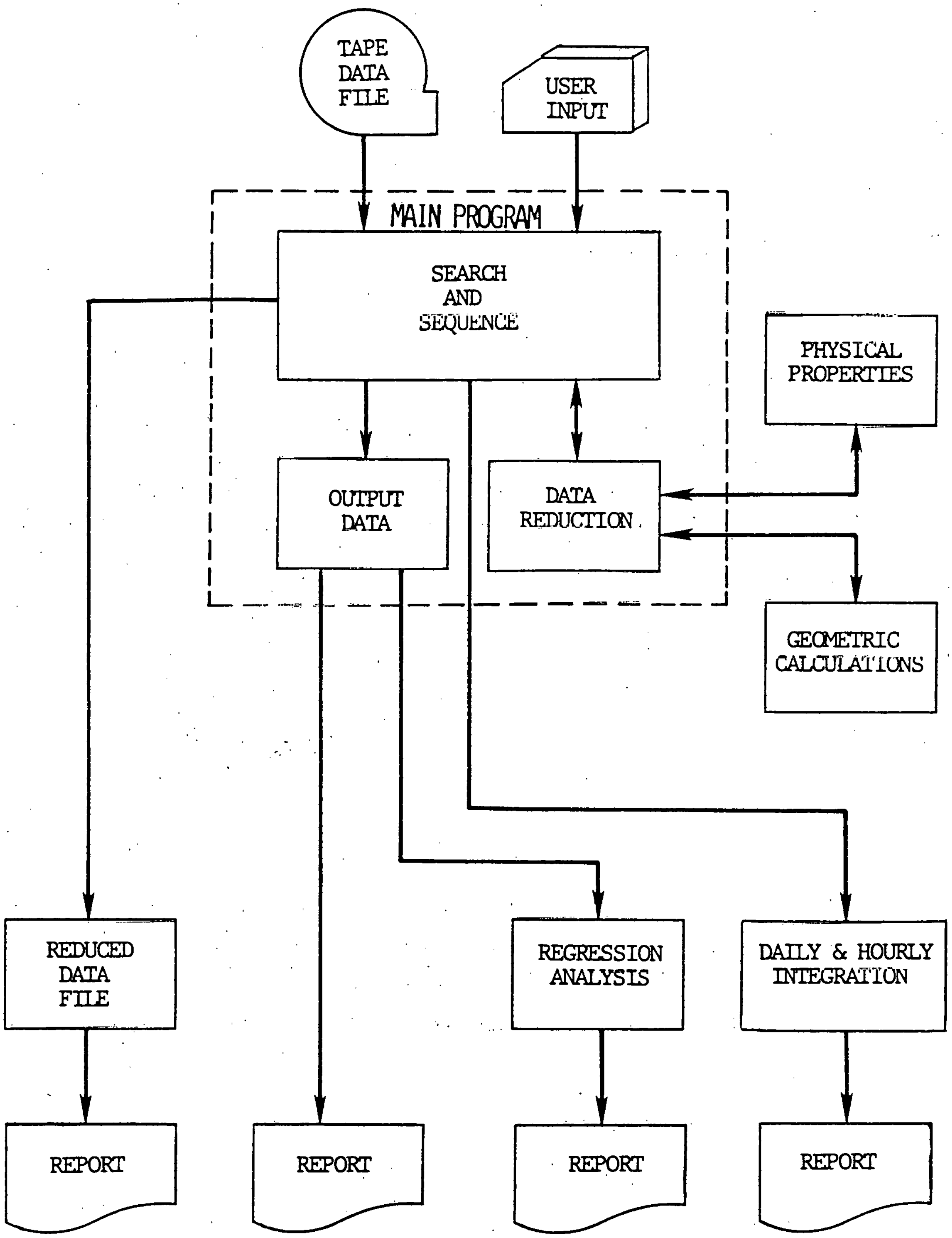

Figure 3-12. Data Processing Flow Diagram

1. the cosine of the angle between the sun vector and a normal to the concentrator plane;
2. the average cosine factor for the concentrator considering each reflector individually; and
3. the geometric end-loss factor

Selected data is temporarily stored in an output data file until all the data have been examined. The selected data is sequenced using increasing values of the first parameter. The output data report is a listing of the reduced data points and the associated parameter limits previously specified by the user, or, optionally, the data may be passed directly to the regression analysis routine. Another type of report available from the program is a listing of the reduced data in chronological order, as in Appendix E. Finally, another option provides for integration of the measured instantaneous solar availability and energy-collection rates over selected periods of time. Results of this type are indicated in Section 3.4.

The regression routine is well suited for characterizing the influence of environmental and operating variables on collector performance because it can examine the entire data set or selected subsets and accommodate the variations of as many as ten independant variables. It is not necessary to hold all but one variable constant as with a graphical method of relating system output to system inputs. Additionally, the program uses a least-squares routine to fit the data so that the "goodness of fit" can be quantified. Correlation coefficients are calculated as a guide for constructing the system model for which the regression analysis produces coefficients. High correlation between the output and an input suggest that the input variable should be included as a linear term in the modeling equation. Statistics based on the standard error of the regression coefficients and the sample size establish confidence limits for each of the terms of the regression equation.

A more detailed discussion of the regression analysis technique and a description of its application to the SETM test data are given in the following section.

3.3.3 Regression Analysis

Ideally, one should be able to selectively reduce and examine the test data to determine the dependence of collector performance upon specific parameters. However, because of the large number of independent variables which influence the collector performance, this approach is relatively ineffective and can lead to erroneous conclusions. Therefore, the linear multivariate regression analysis routine incorporated in the program described above has been used extensively in statistically examining the test data.

Regression Technique. "Regression analysis is concerned with the derivation of a mathematical model with which to relate quantitatively the variation of a dependent variable with the variations of one or more independent variables" (Reference 16). The method of least-squares analysis aids in establishing the validity of "dependency" relationships which may exist. (Cause and effect can be inferred only to the extent that the user's modeling equation is a mathematical analog of the physical system.)

The regression line (the functional expression which predicts the dependent variable) is the line in n-space (1 dependent variable and n-1 independent variables) which minimizes the sum of the squared deviations of the predicted from the actual value of the dependent variable. Regression analysis is based on the following assumptions:

1. A linear functional expression is an appropriate model of the relationships between the dependent and the independent variables (or functions of the independent variables).
2. Values of the dependent variable corresponding to a set of independent variables are normally distributed.
3. The standard deviation of the dependent variable is the same for all values of a given independent variable
4. The independent variables are mathematical or fixed (not random) variables.

The IBM Scientific Subroutine Package subroutines CORRE and STPRG form the basis for the regression analysis routine included in the data processing program described above. The input information necessary to perform regression analysis falls into two categories (1) the input data; and (2) the "regression parameters." The input data consists of vectors of information about the system being analyzed, the values of each vector having been recorded at the same point in time. One of the values in each vector can be considered the system "output"; it is this value which the regression equation will predict. The remaining elements are system variables which may influence the system output (dependent variable). The regression parameters indicate which element of a vector is the dependent variable and which elements are to be deleted from the analysis.

The regression routine examines a large number of performance observations and produces a least-squares curve of the data using one or more of the independent variables. The predicted value of the dependent variable is equal to an intercept constant plus the sum of the products of the partial regression coefficients and their respective independent variables. The first equation generated uses one independent variable only, this variable having the highest correlation with the dependent variable. A second equation is then produced using the two independent variables with the largest correlation coefficients with the dependent variable. The "stepwise" procedure begins by examining the effect of having chosen the first independent variable rather than the second and, using a predetermined criterion, decides to retain or delete this variable. The remaining independent variables are each successively included in new regression equations, and each is reexamined to determine if the previously included independent variable should be retained.

At each step, several statistics are computed which indicate the "goodness of fit". Given that each successive equation is a fair representation of the system under investigation, the best equation is the one which gives the highest adjusted multiple correlation coefficient and the lowest adjusted standard error of estimate. The adjusted multiple correlation coefficient is a value between zero and one which indicates the fraction of variation in the dependent variable which can be explained by variations in the independent variables. The adjusted standard error of estimate is interpreted as meaning that approximately 68 percent of the prediction errors are less than ± the value of the standard error. T- values, when compared with a T- distribution table, gives confidence limits for each of the independent variables. For example, any T- value with an absolute value greater than 2.576 and coming from a data set containing more than 120 observations implies that there is less than a 1.0 percent chance of making an error in rejecting the null hypothesis that there is no linear relationship between that independent variable and the dependent.

For a more detailed description of the stepwise multivariate regression procedure, see Draper and Smith (Reference 17.)

Variables and Relationships. The dependent variables of interest from the SETM test data are the solar energy-collection rate, q', and the receiver heat-loss rate, r, as defined in Section 3.3.1. The collection rate with end losses removed, q', is deemed to be of broader utility than the single module collection rate, q. Moreover, the results of a statistical analysis of q rather than q' would be obscured by the role of end losses as an additional variable.

The main independent variables which could influence the solar energy collection rate are:

Direct Insolation, I (BTU/hr-ft^2)
Reflectivity, R (unitless)
Average Receiver Temperature, T (^{o}R)
Ambient Temperature, T_a (^{o}R)
Wind Speed, W (mph)

The same independent variables, except for I and R, also influence the receiver heat-loss rate which, of course, is manifested in the collection rate.

There are other independent variables which are less obvious and/or significant. These include the total hemispheric radiation, I_t, which directly heats the top and sides of the receiver, thus decreasing the net heat loss from the receiver. Wind direction should also be a factor in determining the receiver heat-loss rate, but its influence was not discernable. A weak heat-loss dependence upon flow rate was observed (see Section 3.4.1), but flow rate was not treated as an independent variable because the effect seems to result from a small systematic instrumentation error.

From consideration of the physical processes involved in the performance of the collection, it is apparent that neither the net solar energy-collection rate nor the receiver heat-loss rate should exhibit linear dependence upon all of the above independent variables. Therefore, as a first step in the regression analysis, it is necessary to formulate equations which give the dependent variables, q' and r, as linear functions of the independent variables after transformation.

The gross energy-collection rate is the energy-collection rate that would be measured if there were no receiver heat losses. Thus, the gross collection rate is the sum of the measured (net) energy-collection rate and the receiver heat-loss rate:

$$q'_g = q' + r$$

The gross heat-collection, q'_g, rate may also be expressed as

$$q'_g = CIR$$

Where I is the direct insolation actually available to the concentrator as defined in Section 3.3.1, R is the reflectivity of the concentrator and C is a constant which depends upon the collector geometry, the transmissitivity of the receiver aperature, the absorptance of the receiver tubes, etc. Combination of the above equations gives the relationship

$$CIR = q' + r$$

which is useful in performing a coordinated regression analysis of the independently measured values of q' and r.

In particular, by first performing a regression analysis of the body of measured data for r and determining an expression for r, values of r for conditions corresponding to those prevailing for each measurement of q' may be calculated and added to q' to obtain values for CIR. A regression analysis may then be performed to find a representation for CIR and, finally, an equation for the net heat-collection rate, q', may be developed from the relationship;

$$q' = CIR - r.$$

An alternative would be to perform a regression analysis directly on the data for q'. However, since q' depends upon r (and hence upon the independent variables that determine r), and r is relatively better defined from the direct measurements of heat loss, it follows that a better over all characterization of the net heat-collection rate, q', and its dependence upon the numerous independent variables should result from the coordinated approach defined above.

Receiver Heat Loss. Consideration of the obvious receiver heat-loss processes leads to the following idealized linear equation for r:

$$r = a + bK(T^4 - T_a{}^4) + c\,(T - T_a) + d\,(T - T_a)\,(W^{0.61}) + e(I_t)$$

Where the constant a, and the coefficients b, c, d, and e are to be determined from the measured data by regression analysis, and K is the Stefan-Boltzmann constant (1.718×10^{-9}). The $T^4 - T_a{}^4$ term represents radiation losses, the $T - T_a$ term represents conduction losses, and the $(T - T_a)W^{0.61}$ term represents convection losses which are assumed to have an exponential dependence upon wind velocity, W, as suggested by McAdams (Reference 18). The term $e(I_t)$ accounts for the effect of direct solar heating of the receiver upon the heat-loss rate.

Exploratory runs indicated that the radiation, conduction, and convection terms were excessively mulicollinear. In particular, the dependence of heat-loss rate upon the conduction term correlated somewhat with both the fourth power radiation term and the exponential convection term. As a compromise, the above equation was modified to consolidate the conduction and convection terms:

$$r = a + bK(T^4 - T_a{}^4) + c\,(T - T_a)(1 + W^{0.61}) + d(I_t)$$

Results of runs made assuming this formulation gave an adjusted multiple correlation coefficient of 0.565 and an adjusted standard error of 4.593 BTU/hr-ft^2 (typical heat-loss rates are in the range of 25 to 45 BTU/hr-ft^2).

The final equation and coefficients thus determined for the receiver heat-loss rate is

$$r = 11.17 + 0.021K(T^4 - T_a{}^4) + 0.003\,(T - T_a)(1 + W^{0.61}) - 0.007\,(I_t)$$

This equation was used for performing the end-loss adjustments described in Section 3.3.1 and in performing the coordinated regression analysis of the energy-collection data described below.

The above regression analysis used the heat-loss data file in Part 2 of Appendix E but with transient data removed. Data were considered transient if either the inlet or outlet water temperatures changed appreciably from one data point to the next. If the water temperature of the data point being tested varied more than 48°F per hour between adjacent points, the data were assumed to be transient and hence rejected. This test was performed on both inlet and outlet water temperatures.

Energy Collection Rate. The next step in the regression analysis was to use the above expression for r to calculate receiver heat-loss rates for conditions (i.e., for values of the independent variables) corresponding to those prevailing at the time each value of q' was measured. These were combined with q' as described above to obtain the gross energy-collection rate, q'_g, which, as described earlier, is assumed to be of the form:

$$q'_g = CIR$$

A regression analysis of q'_g yielded

$$q'_g = 20.1 + 0.519\,(IR)$$

with an adjusted multiple correlation coefficient of 0.834 and an adjusted standard error of 16.681 BTU/hr-ft^2.

Subtraction of the receiver heat-loss rate from the gross collection rate gives the net energy-collection rate:

$$q' = q'_g - r.$$

Substitution of the regression analysis results for q'_g and r gives q' in terms of the independent variables:

$$q' = 8.93 + 0.519(IR) - 0.021K\,(T^4 - T_a^{\ 4})$$
$$- 0.003\,(T - T_a)(1 + W^{0.61}) + 0.007\,(I_t)$$

This equation represents the overall performance of the SLATS^{TM} collector tested at the SETM and gives the dependence upon the various test parameters as indicated by statistical analysis of the test data.

The data input (Appendix E, Part I) to the above regression analysis was limited to steady-state afternoon data taken for receiver temperatures greater than 400°F. Transient data were also deleted in the same manner described in the receiver heat-loss rate analysis.

Exploratory regression runs examining different solar time groupings of data revealed that the morning data had a larger "noise" component than the post solar noon data. Different start-up temperatures and times caused more widely varied apparent collection rates during the morning since the massive receiver was at many different states of thermal "charge". For regression analysis, only the afternoon data was used.

Further data deletion resulted from an observed multicollinearity between reflectivity and receiver temperature. An examination of the data itself revealed that the average receiver operating temperature had, on balance, been declining during the nine months of testing because more emphasis was placed on high operating temperatures during the early testing. Since the reflectivity was relatively low for the first thirty percent of the data collected (i.e., prior to the first time the mirrors were cleaned), there was an artificially-created relationship between reflectivity and operating temperature. This autocorrelation was reduced by deleting some low-temperature data taken late in the period.

3.4 SETM Test Results

The section discusses the results obtained during the SETM testing and includes sections on receiver heat-loss rates, energy-collection rates, and reflector cleaning. All SETM test data are in Appendix E; representative and integral data are discussed in this section.

Representative results, including interpretations, are given in Section 3.4.1 for receiver heat-loss rates and in Section 3.4.2 for energy-collection rates. Mirror cleaning requirements are discussed in Section 3.4.3.

Other than the four defective reflectors mentioned in Section 3.1.1, no major functional difficulties were encountered with the SLATS^{TM} collector during the testing. A minor problem with the automatic focus control subsystem occured early during the testing, but this was corrected by replacement of a printed circuit board in the controller.

The interpretations and observations on the performance of the SLATS^{TM} collector reported herein must be regarded as provisional pending further study and analysis of the data.

3.4.1 Receiver Heat-Loss Rate

The heat-loss characteristics of the receiver are important factors in determining overall collector efficiency since the efficiency is based on the net energy-collection rate (i.e., the difference between gross heat collection and receiver heat losses). The more that is understood about the effect of insolation, size, operating temperature, wind speed, wind direction, and ambient temperature on receiver heat loss, the more likely it is that concentrating collector performance can be projected with accuracy and that means can be found for improved receiver design.

As mentioned in Section 3.3.1, it is necessary to adjust the collecor performance data for end-loss effects at times other than solar noon. These adjustments involve both geometric losses and heat losses from the unilluminated portion of the receiver, thus creating another requirement for receiver heat-loss data.

Based on preliminary tests using a mock vee-receiver, it has been estimated that a heat-loss rate of approximately 30 BTU/hr could be expected for each square foot of the SLATS^{TM} collector (Reference 5). Calorimetric measurements made early in the actualtesting program revealed heat-loss rates generally in excess of this prediction. These measurements also indicated that significant variations in the heat-loss rate resulted from changes in operating and environmental variables. Thus, because of the importance of the receiver heat-loss rate and its dependence upon a large number of independent variables, emphasis was placed on obtaining enough heat-loss data for a meaningful analysis. To this end, over 900 measurements of receiver heat-loss rate were made. Part 2 of Appendix E lists the reduced data as well as the fundamental measured quantities.

Multivariate regression analysis was applied to the heat-loss data (see Section 3.3.3) in order to characterize the thermal performance of the receiver. The equation developed from the analysis gives the receiver heat-loss rate, r, in (BTU/hr-ft^2):

$$r = 11.17 + 0.021K(T^4 - T_a^4) + 0.003(T - T_a)(1 + W^{0.61}) - 0.007(I_t)$$

where T = Average Receiver Temperature (°R)

T_a = Ambient Temperature (°R)

K = 1.718×10^{-9} (Stefan - Boltzmann Constant)

W = Wind Speed (mph)

I_t = Total Insolation (BTU/hr-ft^2)

Figures 3-13 and 3-14 show plots of receiver heat-loss rate as a function of average receiver temperature based on the above equation. In each figure the ambient temperature was assumed to be 75°F. This value was picked as representative of conditions common during the testing.

It can be seen that receiver temperature strongly influences the heat-loss rate; the non-linearity is attributable to a strong thermal radiation heat-loss component. Wind speed also effects heat loss rather strongly. The small, but significant, heat-loss rate dependence upon the intensity of solar radiation striking the receiver housing is illustrated in Figure 3-14.

As mentioned in Section 3.3.3, a weak heat loss dependence upon flow rate was also observed. In particular, the heat-loss rate was found to increase by less than one BTU/hr-ft^2 when the flow rate was increased by one gallon per minute. A physically realistic dependence upon flow rate, if discernable at all, would be exactly the opposite of that observed; increased fluid mixing with increasing flow rate would tend to accelerate heat loss. Therefore, it was concluded that the observed dependence is an anomaly probably resulting from small systematic errors in the basic measurements of receiver and outlet temperatures, or in the flow rate. Indeed, a cursory uncertainty analysis indicates that systematic errors within the approximately $\pm$ 0.5°F accuracy of the resistance temperature sensors could account for the heat loss dependence upon flow rate.

Overall, the flow rate dependence is of little consequence in view of the fact that typical flow rates are on the order of two gallons per minute whereas the overall heat-loss rate is generally in the range of 25 to 45 BTU/hr-ft^2.

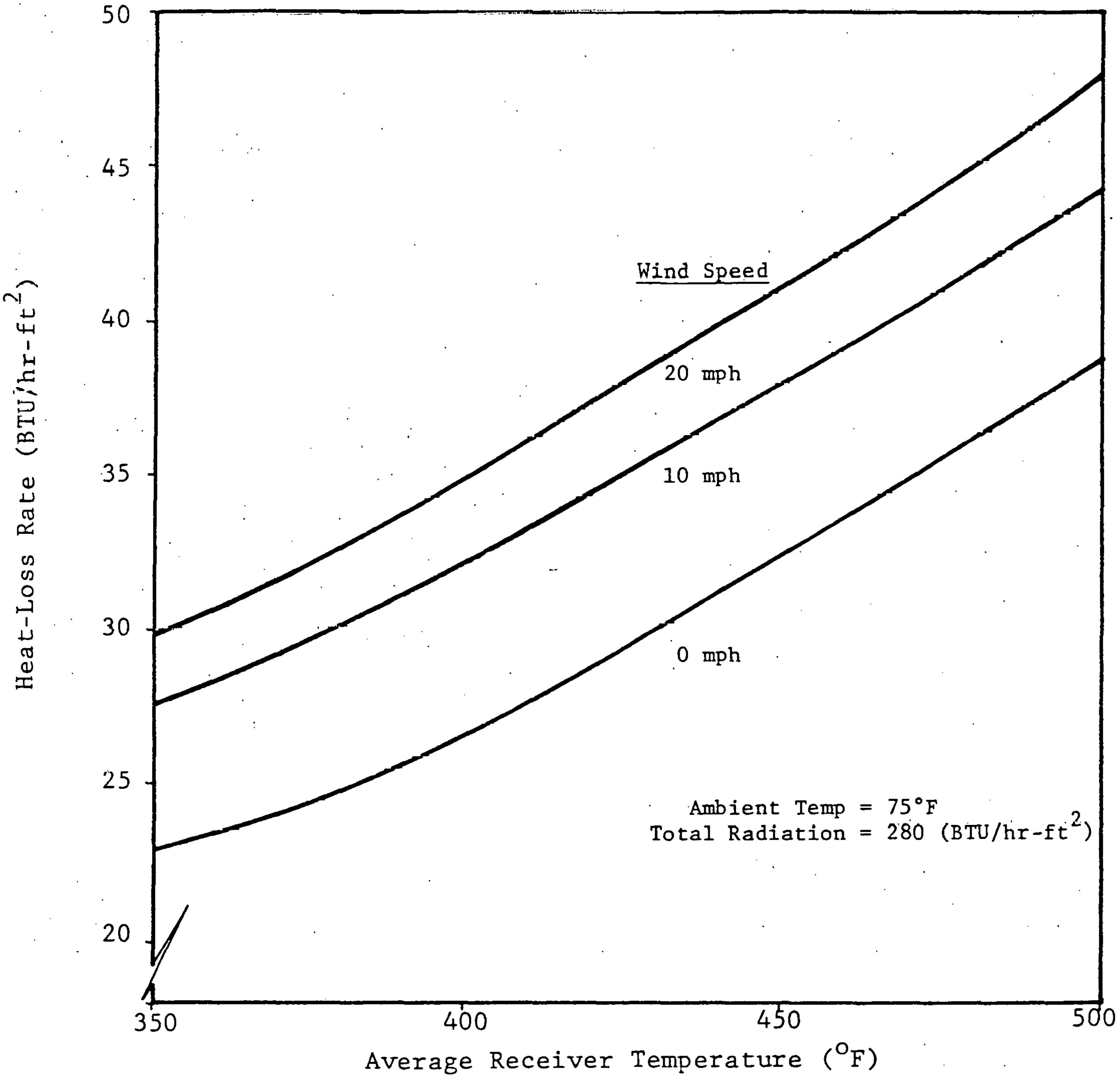

Figure 3-13. Receiver Heat-Loss Rate as a Function of Receiver Temperature for Various Wind Speeds

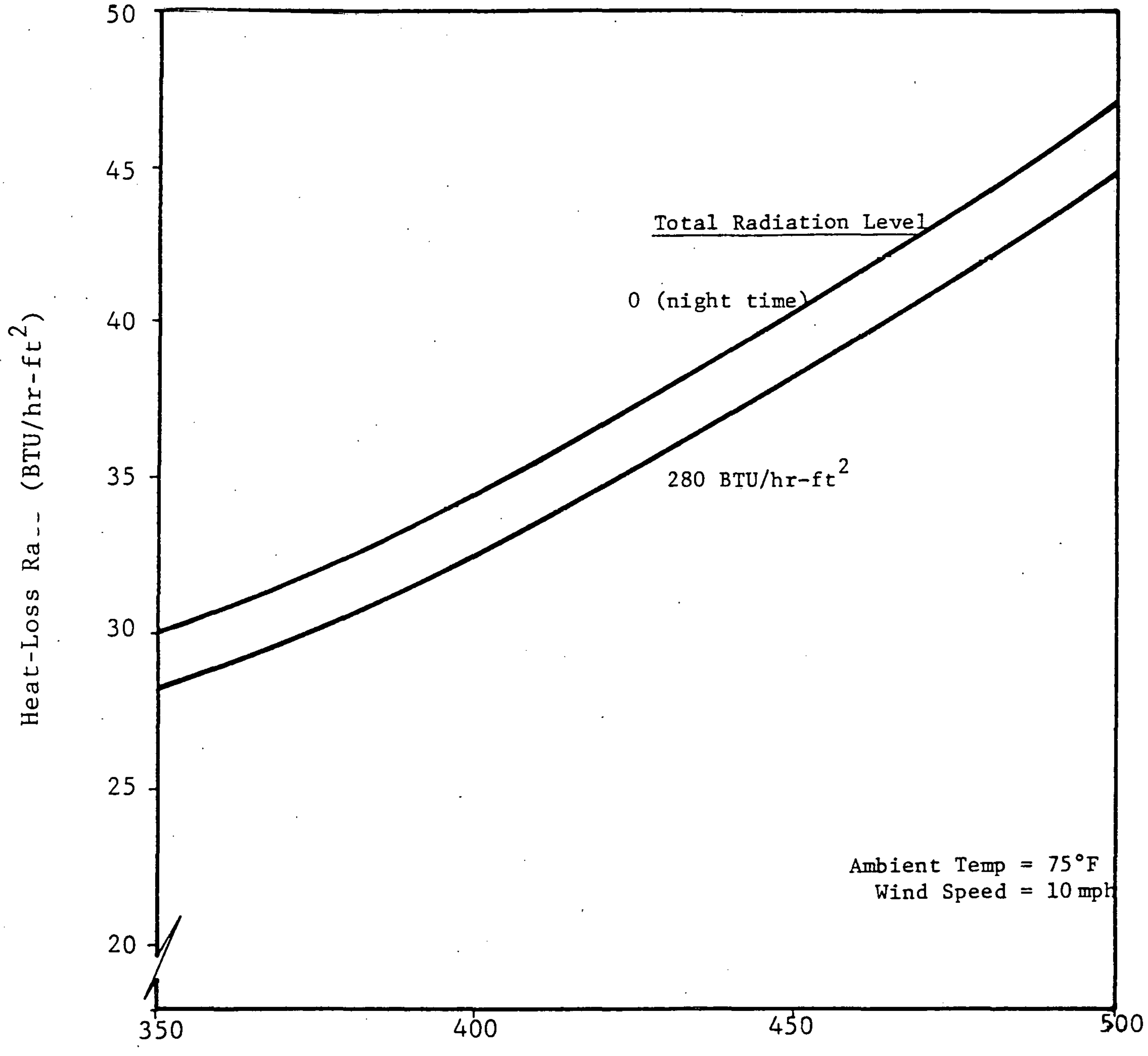

Figure 3-14. Effect of Total Radiation Level on Receiver Heat-Loss Rate as a Function of Receiver Temperature

3.4.2 Energy-Collection Rate

All of the measured collector performance data have been reduced and end-loss adjustments have been applied based on the receiver heat-loss rate relationship described above. Part I of Appendix E gives listings of the reduced data with and without the end-loss adjustment. Included in the listings are the fundamental measured data from which the heat collection rates were calculated. Examination of the heat-collection data listed in Part I of Appendix E reveals a number of peculiarities that merit explantion. First, a value of "****" is indicated for the efficiency in a number of cases. This notation means that a numerical value is not available or that a calculated numerical value would have no meaning. In many cases, a significant heat-collection rate may be indicated at times when the direct radiation intensity is zero. Under these circumstances, a meaningless instantaneous efficiency of infinity would be computed; therefore, no efficiency is printed out.

In other cases, a collection efficiency of greater than 100 percent or a negative collection efficiency may be printed out. This occurs when the direct radiation is extremely low or when the heat-collection rate is negative (actually a net heat-loss rate). Such data are caused by the finite time (on the order of minutes) required for water to circulate from the receiver inlet to the outlet. For example, with intermittent clouds, high direct radiation levels might prevail during much of the time a given increment of water is passing through the receiver and then drop to a very low level at the time the water is exiting the receiver. Data taken during such transient conditions must be either adjusted or dropped from most types of analysis.

Figures 3-15 through 3-17 show plots of available insolation and collected heat versus time of day for a variety of days. Figure 3-15 is for a day with intermittent insolation. The receiver inlet temperature was in the range 400 to 470°F and the reflectivity was approximately 0.77. The ambient temperature was 90 to 96°F and the wind was approximately 10 mph from the south. The "available" insolation is that intercepted by a plane tilted south 31° from the horizontal, and closely approximates the energy current per square foot of collector aperture. The "collected" insolation is that actually collected per square foot of reflector surface.

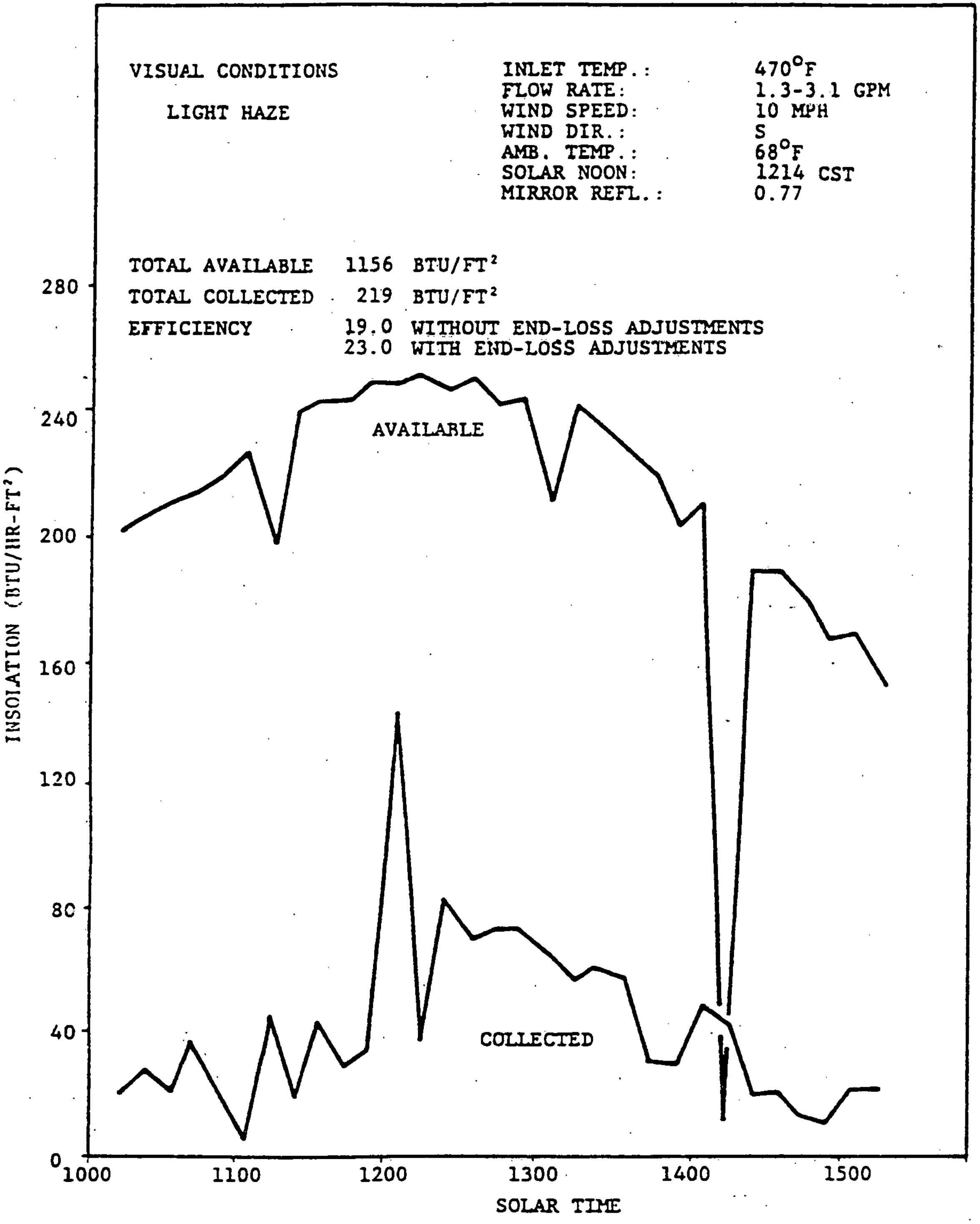

Figure 3-15. SLATS™ Collector Performance on November 4, 1977

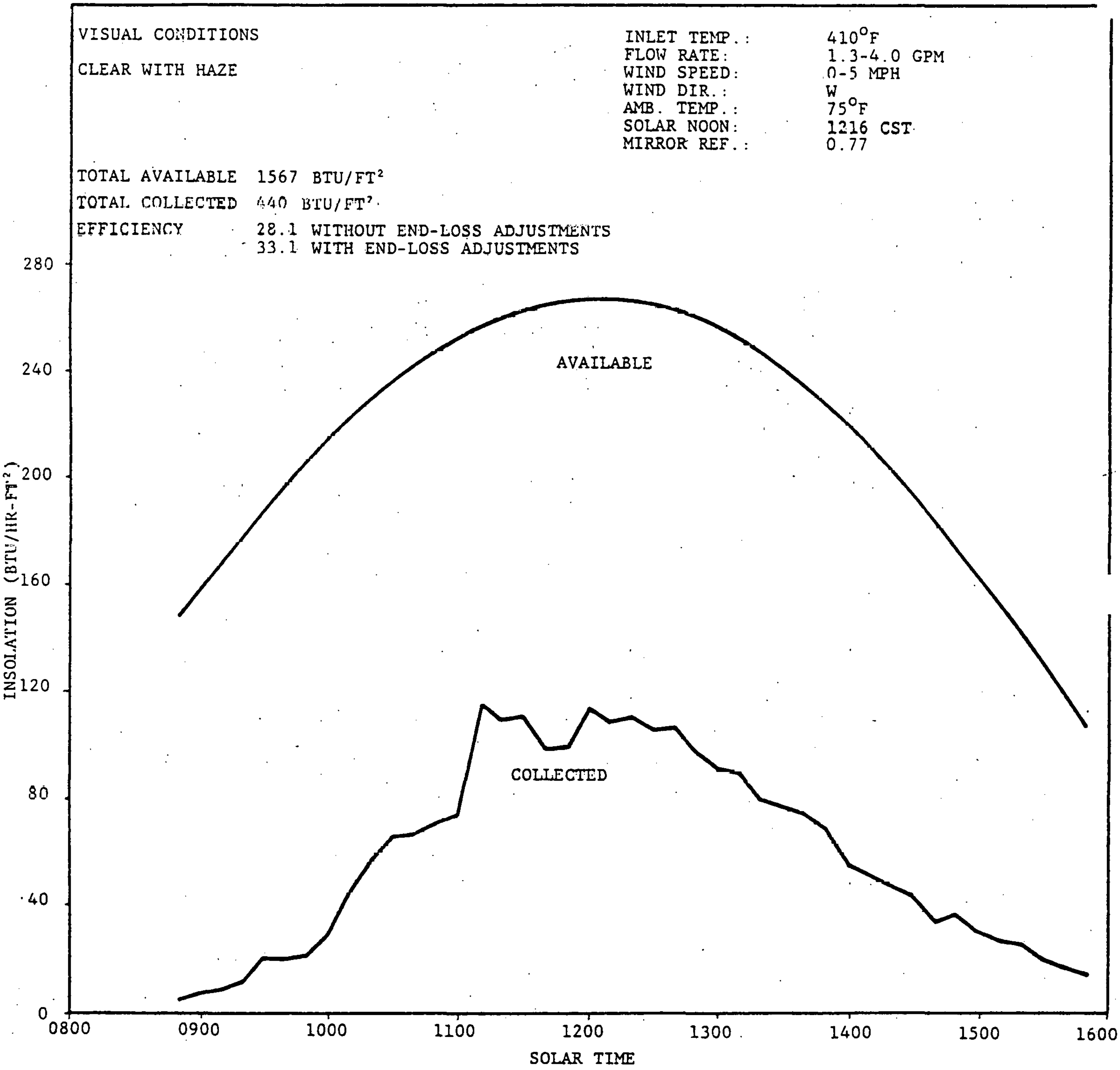

Figure 3-16. SLATS^{TM} Collector Performance on November 16, 1977

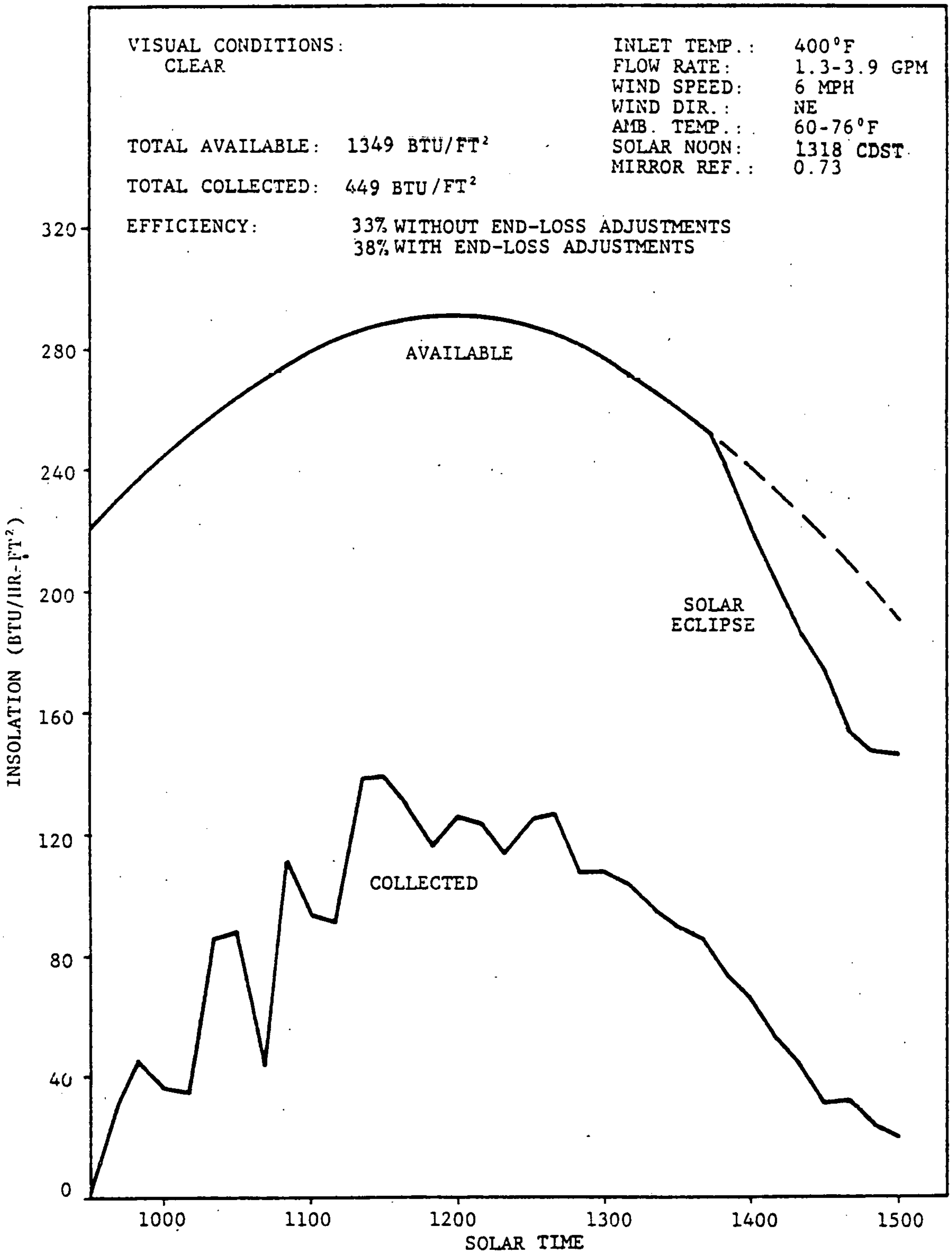

Figure 3-17. SLATS™ Collector Performance on October 12, 1977

The integral of the available insolation shown in Figure 3-15 over the duration of the test run is 1156 BTU/ft^2, and the integral of the collection rate is 219 BTU/ft^2. This indicates an overall efficiency of 19 percent for this collection period. When adjusted to remove end-loss effects, the overall efficiency is 23 percent.

Data are shown in Figure 3-16 for a relatively clear day with some haze. The receiver inlet temperature was 410°F and the reflectivity was approximately 0.77. The wind was approximately 5 mph from the west. The overall collection efficiency - 28 percent with and 33 percent without end-losses - is greater than the efficiency for November 4 (Figure 3-15) because of uninterrupted insolation.

The collection curves are never as smooth as the availability curve because of automatic control system "seeking" to keep the flow rate adjusted to maintain a constant ΔT while the receiver inlet temperature remains fixed. For example, the small peak before solar noon in Figure 3-16 was induced by a manual change in the cooler controller setting. Since several minutes are required for water to circulate through the receiver, a sudden decrease in inlet temperature creates an illusion of increased collection rate because the return water temperatures do not drop suddenly, thus giving an unrealistically high ΔT.

Figure 3-17 is for a clear day (October 12) during which a solar eclipse occured. The effect of the eclipse on the available insolation is apparent, starting around 1350 hours solar time. The dashed curve shows what the availability would have looked like without the interruption. The receiver inlet temperature was 400°F and the reflectivity was approximately 0.73. The wind was approximately 6 mph from the northeast. The integral of the available insolation over the duration of the test run is 1349 BTU/ft^2 whereas the integral of the collection rate over the same period is 449 BTU/ft^2. Thus, an overall efficiency of 33 percent is indicated for the SLATS^{TM} collector for this collection period. However, when adjusted to remove end-loss effects (which would not be significant for a very long collector array), the overall efficiency increases to 38 percent.

Table 3-6 summarizes collector efficiencies based upon heat- collection data integrated for all sixty-six of the daily runs. As may be seen from this table, the nominal overall efficiency of the SLATS^{TM} collector may be characterized as generally in the 20-40 percent range. The exact value depends upon concentrator reflectivity, meteorological, and insolation conditions, receiver temperatures, etc. It should be noted, however, that all test data were indiscriminately included in the integrations. Therefore, because of the rather coarse time intervals available for the integrations, the calculated efficiencies may be less accurate for days with strong transient conditions. Multivariate regression analysis was applied to the heat collection data to delineate the dependance of performance upon the various parameters. This process is described and the results given in Section 3.3.3.

It should be noted that the performance data discussed herein are all for the SLATS^{TM} collector with reflectors of Teflon-coated aluminum vapor deposited on a polyester film, except for four (out of twenty) which were replaced by new model silvered-glass (second surface) reflectors. The replacements were required because four of the original reflectors would not focus sharply over the length of the receiver due to warpage or other reasons. The manufacturer claims that the reflectivity of the glass reflectors is approximately 10 percent greater than that of the original reflectors. If this is the case, use of glass reflectors throughout should cause an approximately corresponding increase in overall collector efficiency; thus a peak efficiency under steady-state conditions on the order of 50 percent would be expected.

All of the test data taken during this contract period are also for a single type of receiver: the vee-entrant receiver which has been superceded by a "planar" two-tube receiver of a much simpler and less costly design. The heat-loss as well as the transmissivity and absorptivity of the newer designs will be different. An important aspect of the SETM test plan was to include at least limited testing of one or more of the alternate receiver designs with the same concentrator and in the same test environment. This would enable separation of receiver and concentrator performance, thus providing a better basis for model verification.

Table 3-6. Summary of Heat-Collection Data

Date	Operating Period (Solar Time)	Meteorological Conditions	Reflectivity	Average Receiver Temp. (^{0}F)	Avg. Available Insolation (BTU/hr-ft^2)	Efficienc	
						η_1	η_2
4-5	1202-1237	Partly cloudy 5 mph wind	0.63	520	230.4	48.6	50.3
4-22	1226-1347	Clear 10 mph wind	0.63	460	273.9	31.7	35.5
4-23	1227-1242	Partly cloudy 5 mph wind	0.63	420	231.3	19.5	20.9
4-25	1227-1357	Clear 13 mph wind	0.63	500	251.7	29.7	34.0
5-12	1214-1350	Clear-haze 5 mph wind	0.63	470	233.5	28.4	31.7
5-24	1113-1453	Mostly cloudy 8 mph wind	0.63	460	111.8	15.8	18.9
5-25	1137-1458	Partly cloudy 7 mph wind	0.63	480	162.2	9.4	12.3
5-26	1226-1428	Partly cloudy 8 mph wind	0.63	470	178.6	28.5	32.1
5-27	0800-1428	Clear-haze 8 mph wind	0.63	440	195.8	31.8	41.3
6-6	1135-1200	Partly cloudy 5 mph wind	0.65	480	207.7	35.2	35.9
6-7	1110-1305	Clear-haze 7 mph wind	0.65	490	237.7	30.6	32.1
6-8	1104-1322	Clear-haze 0 mph wind	0.65	510	238.6	30.8	32.6
6-13	1028-1417	Few clouds 5 mph wind	0.65	400	222.5	31.2	34.1
6-28	1153-1428	Partly cloudy 10 mph wind	0.65	400	178.8	21.1	24.3
6-29	1302-1432	Partly cloudy 10 mph wind	0.65	400	120.3	12.0	17.3
6-30	1222-1458	Partly cloudy 10 mph wind	0.65	400	124.7	22.9	28.
7-1	1150-1355	Partly cloudy 10 mph wind	0.65	410	120.0	25.4	28.7

Table 3-6 (Cont'd)

Date	Operating Period (Solar Time)	Meteorological Conditions	Reflectivity	Average Receiver Temp. (^{0}F)	Avg. Available Insolation (BTU/hr-ft^2)	Efficiency η_1	Efficiency η_2
7-2	1059-1502	Partly cloudy 14 mph wind	0.65	455	195.8	24.2	28.5
7-5	1153-1508	Partly cloudy 8 mph wind	0.65	410	135.9	19.1	25.0
7-6	1010-1434	Partly cloudy 8 mph wind	0.65	470	199.6	26.9	30.3
7-7	0907-1452	Clear to partly cloudy 8 mph wind	0.65	425	182.0	20.7	25.8
7-12	1147-1453	Clear-haze 12 mph wind	0.83	425	221.4	28.8	33.1
7-8	1118-1448	Partly cloudy 8 mph wind	0.83	440	187.7	28.7	32.6
7-19	1120-1445	Partly cloudy 5 mph wind	0.83	425	179.3	27.5	31.3
7-20	0952-1405	Partly cloudy 8 mph wind	0.83	390	206.4	28.4	31.9
7-21	1115-1445	Partly cloudy 8 mph wind	0.83	435	171.5	26.9	30.9
7-25	1025-1435	Clear with high haze 7 mph wind	0.83	385	225.9	28.4	31.8
8-3	0849-1451	Clear turning to partly cldy 2 mph wind	0.83	400	206.0	20.7	25.6
8-5	0931-1450	Partly cloudy 8 mph wind	0.81	430	197.1	27.8	32.4
8-9	0905-1420	Partly cloudy 7 mph wind	0.81	375	142.3	29.7	35.1
8-17	1157-1442	Clear with high clouds 5 mph wind	0.81	385	230.8	31.2	35.7
8-19	0911-1332	Partly cloudy with haze 8 mph wind	0.79	425	136.6	14.0	17.8

Table 3-6. (Cont'd)

Date	Operating Period (Solar Time)	Meteorological Conditions	Reflectivity	Average Receiver Temp. (^{0}F)	Avg. Available Insolation (BTU/hr-ft^2)	Efficiency η_1	Efficiency η_2
8-3	0900-1450	Clear-haze 10 mph wind	0.79	425	217.7	30.0	35.0
8-25	0901-1439	Clear-haze turning partly cloudy 5 mph wind	0.79	440	207.5	26.3	30.8
8-26	0911-1411	Clear 12 mph wind	0.79	445	225.5	28.3	32.5
8-31	1205-1415	Partly cloudy 8 mph wind	0.79	485	159.5	20.6	25.2
9-15	1228-1507	Clear turning partly cloudy 8 mph wind	0.76	396	189.2	25.7	32.0
9-28	1121-1531	Clear-haze 5 mph wind	0.74	400	226.3	33.0	38.6
9-29	1023-1602	Clear-haze 8 mph wind	0.74	430-460	226.1	25.8	31.2
9-30	1016-1456	Clear-haze 12 mph wind	0.74	440	249.1	30.0	34.3
10-4	1044-1525	Clear-high clouds 10 mph wind	0.82	400	237.7	34.9	40.1
10-5	1044-1525	Clear-high clouds 10 mph wind	0.82	400	237.7	34.9	40.1
10-5	0804-1434	Partly cloudy 8 mph wind	0.82	440	157.4	27.3	33.9
10-11	1147-1458	Clear 15-20 mph wind	0.75	420	243.8	25.5	30.1
10-12	0934-1453	Clear 6 mph wind	0.75	400	253.1	33.4	37.7
10-14	1005-1155	Clear-some high clouds 10 mph wind	0.82	420	269.5	39.1	42.5
10-17	1044-1453	Few High clouds 10 mph wind	0.82	400	250.8	38.0	42.3

Table 3-6 (Cont'd)

Date	Operating Period (Solar Time)	Meteorological Conditions	Reflectivity	Average Receiver Temp. (^{0}F)	Avg. Available Insolation (BTU/hr-ft^2)	Efficiency η_1	Efficiency η_2
10-18	0934-1104	Clear 4 mph wind	0.82	410	237.0	16.9	21.0
10-20	1105-1455	Partly cloudy 8 mph wind	0.81	400-470	189.1	35.5	40.3
10-25	1128-1541	Partly cloudy 0 mph wind	0.80	445	193.4	29.4	35.5
10-26	0908-1519	Clear haze 5 mph wind	0.79	455	240.8	32.4	37.8
11-3	1042-1529	Mostly cloudy 10-15 mph wind	0.77	455	71.6	0	0
11-4	1004-1534	Partly cloudy 10 mph wind	0.79	485	210.2	19.0	23.2
11-9	1033-1453	Clear 15-20 mph wind	0.82	440-515	268.7	21.6	24.9
11-12	1029-1249	Clear 5 mph wind	0.79	355-520	287.4	23.9	25.3
11-16	0855-1545	Clear-haze 0-5 mph wind	0.79	425	229.3	28.1	33.1
11-17	1032-1402	Clear-haze then partly cloudy 8 mph wind	0.79	365	247.4	33.7	36.3
11-23	0943-1516	Clear turnign partly cloudy 4 mph wind	0.73	395	240.5	30.8	35.0
11-30	1134-1454	Clear 2 mph	0.73	385	254.7	31.6	35.2
12-1	0904-1453	Clear 6 mph wind	0.73	405	224.3	28.7	32.7
12-2	0902-1452	Clear 5 mph wind	0.73	365	248.6	29.9	33.9
12-5	1103-1453	Clear 10 mph wind	0.73	425	242.0	26.1	29.2
12-6	1125-1246	Clear 7 mph wind	0.73	365	284.4	34.7	35.7

Table 3-6 (Cont'd)

Date	Operating Period (Solar Time)	Meteorological Conditions	Reflectivity	Average Receiver Temp. (^{0}F)	Avg. Available Insolation (BTU/hr-ft^2)	Efficienc	
						η_1	η_2
12-15	1144-1514	Clear 14 mph wind	0.82	365	243.2	30.0	35.0
12-16	0941-1451	Clear with late dust 18 mph wind	0.82	485	231.1	23.6	27.1
12-20	1233-1353	Partly cloudy 12 mph wind	0.59	370	248.1	19.4	22.2

3.4.3. Reflector Cleaning

A study of mirror soiling problems and cleaning requirements and procedures was included as an integral part of the SETM test plan (Reference 13) published early in the testing phase. This section reports the findings and subsequent actions taken as a result of the reflector cleaning studies.

The collector was installed in November, 1976 and the reflectors were not cleaned until July 12, 1977. No means of measuring reflectivity was available until the removable mirror samples described in Section 3.2.1. were installed at the time of the first cleaning. However, based on their general appearance and the results of prior exposure testing of identical sample reflectors in the Fort Hood environment (see Appendix D of Reference 5), it is estimated that the reflectivity of the Teflon-coated aluminzed-polyester reflectors was approximately 0.63 before the first cleaning. This value was assumed to apply from April through June 3, 1977 when four Teflon-coated aluminized-polyester reflectors were replaced with glass reflectors. At this time, the overall reflectivity was assumed to increase to 0.65 where it remained until July 12, 1977 when the mirrors were first cleaned and the reflectivity measured.

Figure 3-18 shows a history of the reflectivity and cleaning times during the nine-month testing period. During the period from July 12 to early October, the mirror soiling rate was not severe and the mirrors were not cleaned until early October. However, from early October to the end of December, seasonal cool fronts passing through the area produced low humidity which resulted in rapid dust build-up on the Teflon-coated reflectors. This was thought to be due to static electricity, since a similar build-up did not occur on the glass-covered reflectors. This dust was readily removed by a clear water rinse, whereas the cleanings in early July and early October used a vinegar and water solution as recommended by the manufacturer and described in Appendix A of Reference 13.

Experience with cleaning the reflectors suggests that wash intervals of as much as two months might be adequate for the months of April thorugh September. However, more frequent cleaning may be required during the fall and winter months. It was also observed that the water in the Fort Hood area

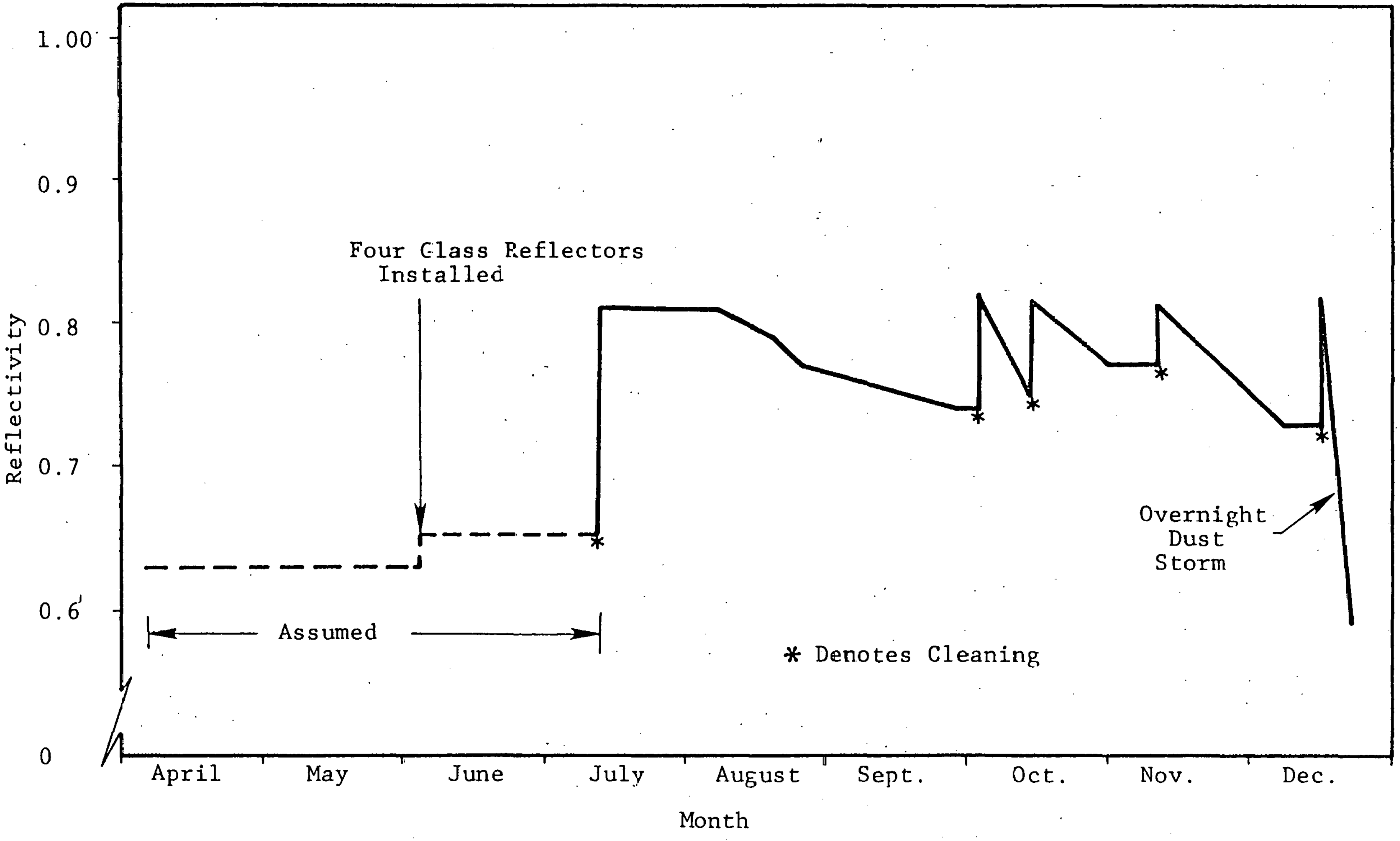

Figure 3-18. Reflectivity as a Function of Time

left water spots on the reflectors if allowed to dry naturally. Consequently, the rinse water must be blotted off after each wash, an approach that would be too tedious for cleaning large collector fields.

3.5 Collector Field Pilot Test Array (PTA)

The collector field will be one of the largest cost elements in the ATU/Fort Hood Solar Total Energy System and is the only major system element that is based on relatively new technology. Thus, it is the most significant single risk factor in the system. The SETM collector test program was designed to reduce this risk by obtaining early data on the performance of linear-focusing solar collectors in the Fort Hood environment. The Collector Field Pilot Test Array (PTA) virtually eliminates the risks of transferring small-scale results to full-scale collector fields, and will yield a number of additional benefits.

Requirements for the PTA fall into two categories. The first category includes the results necessary to support and/or verify the design effort for LSE-1. These results should provide:

1. Directly applicable performance data (both steady state and transient) concerning the Fort Hood environment.
2. Performance data for the physical arrangement and operating conditions (temperature and pressure) planned for the full-scale collector field.
3. Verification of control techniques.
4. Verification of manufacturing processes and costs.
5. Verification of field installation, alignment, and check-out procedures.
6. Evaluation of various approaches to mirror cleaning and the establishment of required cleaning schedules.

The second category of requirements is tied more closely to performance verification:

1. Preliminary and continuing evaluation of technical levels and specialized training required for Army personnel directly associated with the operation and maintenance of the collector field.
2. Supplementary and awareness orientations for the benefit of support personnel (non-professional) associated with the maintenance and repair of the system (electricians, plumbers, maintenance, etc.).
3. Information necessary to develop Army Standard Operating Procedures and regulations relative to collector field operation.

4. Briefing area for visiting citizens and military, national, state, and local VIPs until the collector field is installed.

5. Evaluation of design modification and improvement and "wringing out" problems and anomalies during the early period of collector field operation, without interfering with normal operations.

IV. DESIGN STUDIES

IV. SYSTEM DESIGN STUDIES

The major objective at the beginning of this contract period was to develop the preliminary design for the ATU/Fort Hood Solar Total Energy Military Large-Scale Experiment. A program plan based on the statement of work (part I of Appendix A) included the following preliminary design steps:

1. Refine conceptual design,
2. Define preliminary design requirements,
3. Perform component and subsystem preliminary design,
4. Perform system level preliminary design,
5. Document preliminary design.

ATU engaged Brown and Root Development, Inc. as the engineering subcontractor to perform the design work. During refinement of the conceptual design, Brown and Root examined a number of alternate design approaches and, as described in Section 4.1 below, further evaluation led to the conclusion that the conceptual design originally developed by ATU was, with minor refinements, an appropriate basis for proceeding with the preliminary design. A concurrent investigation confirmed the selection of Fort Hood's 87000 Troop Housing Complex as the LSE-1 installation site.

Requirements for various subsystems and components were then prepared and presented at an ERDA design review on March 30, 1977. At this time, it became apparent that, although a number of design changes had been made, the design approach was at variance with the latest ERDA guidelines in several areas. For example, ERDA said that LSE-1 should have fossil-fuel backup even though the solar total energy system itself had been designed in accordance with ERDA directions as a retrofit to supplement existing fossil fuel systems.

Subsequent to the March review, while ATU and ERDA were resolving project specifications and making plans for adjusting the system design, Brown and Root Development, Inc. withdrew from the project because of differences of opinion on contractual procedures. ERDA decided that a successor should be determined by a design competition. Westinghouse Electric Corporation and TRW, Inc. were selected for this competition which started June 1 and ended September 30, 1977.

ATU's role was redefined for the period of the design competition as indicated by the modified statement of work (Part 2 of Appendix A). The main change in ATU's role was that, instead of continuing with preliminary design, ATU provided close support for the design competition. The various support activities are described in Section 4.2.

The results of the design competition are reviewed in Section 4.3. Westinghouse Electric Corporation was selected by ERDA and will proceed with the LSE-I preliminary design under subcontract to ATU during the next contract period.

4.1 Refinement of the Original Conceptual Design

At the outset of this contract period, a number of steps toward establishing a baseline design for use during the preliminary design effort were taken. These initial tasks included:

1. An independent review of the ATU Phase II conceptual design (Reference 5) and identification of areas requiring refinements.
2. Investigation of alternate system configurations.
3. Recommendations of a baseline configuration and system size for use during the preliminary design effort.
4. Selection of the installation site and site layout.

The sections that follow review these activities and summarize the major results. Complete results may be found in References 19 and 20.

4.1.1 Alternate Configurations

This effort included an examination of alternative configurations to the basic Phase II conceptual design given in Reference 5 and summarized in Section 1.1. A total of 19 configurations representing variations on three categories, (basic Phase II, binary vapor cycle, flash steam cycle) were investigated. These configurations were screened with the aid of a mass and heat balance computer program developed by Brown and Root Development, Inc., and most were eliminated from further consideration.

The configuration matrix in Table 4-1 indicates the combinations of approaches to vapor generation for the turbine, thermal distribution, and air conditioning represented by the remaining configurations. These remaining configurations were evaluated by use of steady state calculations. The system parameters analyzed in the steady state calculations included collector field flow rates, collector field size, thermal output, and electrical losses.

Due to safety, performance, and operational difficulties, all but three of these remaining configurations were eliminated. The three remaining were the basic Phase II, the Freon 114, and the basic flash steam systems. Each of these was analyzed for clear winter and summer days (24-hour periods) at solstice. The conditions assumed for these calculations were as follows:

1. Turbine inlet conditions

	Pressure (psia)	Temperature (^{o}F)
Phase II	250	520
Freon 114	500	330
Flash	250	400

2. High Temperature Storage

   Phase II: Charged to 530^{o}F with an initial 400^{o}F input to the collector field.

   Freon 114: Charged to 350^{o}F with an initial 220^{o} input to the collector field.

   Flash: Charged to 450^{o}F with an initial 210^{o}F input to the collector field.

3. Low-Temperature Storage

   Phase II and Freon 114: Charged from the turbine exhaust.

Table 4-1. Configuration Matrix

System Configuration	Vapor Generation			Thermal Distribution		Air Conditioning	
	Water Heat Exchanger	Oil Heat Exchanger	Flash	Hot Water	Steam	Centrifugal	Absorption
<u>Phase II</u>							
Basic	X			X		X	
Alternate 1	X			X			X
Alternate 2			X	X		X	
Alternate 4						X	
<u>Binary Cycle</u>							
Isobutane	X						
Freon 14	X						
<u>Flash Steam</u>							
Basic			X		X		X
Alternate 1		X			X		X
Alternate 2	X				X		X

Table 4-2 summarizes the integrated daily system performance at winter and summer solstice. The table shows the energy displacement of the three approaches and compares both the thermal and electrical energy. The Phase II configuration shows a markedly larger electrical displacement during the winter. Its electrical displacement in summer was also larger than that of the flash steam configuration but nearly equal to that of the Freon 114 configuration.

The Phase II concept provides a larger percentage of the required thermal and electrical energy at both summer and winter solstices. However, the final systems decision required consideration of operational simplicity, reliability, and cost effectiveness as well. Ultimately, the Phase II configuration was selected for further evaluation and refinement.

For this evaluation of the Phase II configuration, the thermal and electrical percent displacement was calculated for each day of a model year. These data were integrated over each of the 12 months to obtain the percent of energy displaced each month. The data were also integrated over the year to determine the yearly percent displacement. The percent total energy displaced was calculated by converting of the thermal energy (BTU) to the theoretical electrical equivalent KWH and combining the two components.

The monthly system performance summary for the Phase II baseline configuration with a 220,000 square foot collector field is given in Table 4-3. System performance calculations were also made for collector field sizes ranging from 44,000 to 440,000 square feet. These results, which indicate the relationship between the percent energy displaced and the system size, are discussed in the next section.

Table 4-2. Integrated Daily System Performance Summary

System Configuration	Thermal (10^6BTU)			Electricity (MWH)			Total* (MWH)			
	Required	Useable	Percent Displaced	Required	Useable	Percent Displaced	Required	Useable	Percent Displaced	Parasitic Losses (MWH)
PHASE II										
Summer*	38.06	38.06	100.0	21.731	7.553	34.8	32.882	18.704	56.9	1.15
Winter**	169.46	169.46	100.0	7.871	5.914	75.1	57.522	55.565	96.5	.734
FLASH										
Summer	338.44***	221.46	65.4	7.871	1.057	13.4	107.030	65.944	61.6	.88
Winter	169.46	169.46	100.0	7.871	1.141	14.6	57.522	50.802	88.3	.794
FREON 114										
Summer	38.06	38.06	100.0	21.731	7.063	32.5	32.882	18.214	55.4	2.04
Winter	169.46	148.24	87.5	7.871	2.569	32.6	57.522	46.003	80.0	1.50

* Loads based on average summer day; solar availability based on clear weather at summer solstice.
** Loads based on average winter day; solar availability based on clear weather at winter solstice.
*** Based on the use of absorption chillers for air conditioning.

Figure 4-3. Monthly System Performance

Month	Thermal (10^9BTU) Required	Thermal (10^9BTU) Useable	Thermal (10^9BTU) Percent Displaced	Electricity (MWH) Required	Electricity (MWH) Useable	Electricity (MWH) Percent Displaced	Total* (MWH) Required	Total* (MWH) Useable	Total* (MWH) Percent Displaced	Thermal** (10^9BTU) Rejected	Thermal** (10^9BTU) Percent
January	5.98	2.23	37.2	256.8	74.1	28.9	2010.0	726.6	36.1	0.0	0.0
February	4.61	2.17	47.1	231.9	76.9	33.1	1538.0	713.7	45.1	0.0	0.0
March	4.46	2.47	55.4	256.8	122.3	47.6	1564.0	846.3	54.1	0.2	4.8
April	3.15	1.74	55.1	248.5	100.0	40.0	1171.0	605.7	52.0	0.4	14.9
May	1.18	1.10	93.5	505.7	137.1	27.1	851.4	460.5	54.1	1.4	45.6
June	1.14	1.14	100.0	565.8	153.2	27.1	900.4	487.8	54.2	1.8	51.1
July	1.18	1.18	100.0	642.3	149.7	23.3	988.0	495.4	50.1	1.7	49.2
August	1.18	1.18	100.0	640.4	166.2	26.0	986.1	512.0	51.9	2.0	53.1
September	1.14	1.14	100.0	550.3	126.5	23.0	884.9	461.1	52.1	1.3	43.6
October	3.19	2.05	64.4	256.8	102.4	39.9	1191.0	704.1	59.1	0.3	10.5
November	4.05	2.07	51.1	248.5	96.6	38.9	1435.0	702.8	49.0	0.1	2.3
December	5.31	2.27	42.8	248.5	100.5	40.5	1806.0	765.6	42.5	0.0	0.0
TOTAL ANNUAL	36.58	20.75	56.7	4652.0	1406.0	30.2	15370.0	7485.0	48.7	9.2	25.3

4.1.2 Conceptual Design Adjustments

An analysis of the Phase II baseline conceptual design was performed to further substantiate the design and to determine what adjustments or refinements should be made to improve system performance and cost. This effort included the evaluation of annual performance, initial and recurring costs, and the recommendation of a baseline design for preliminary design purposes.

Several areas were identified for potential improvement. One example was the deletion of a secondary heat exchanger in the cooling tower/condenser circulating water loop. This effort also validated the following concepts:

1. The use of water as the collector working fluid.
2. Multiple tank high-temperature energy storage, with stratified oil/rock storage, a potentially attractive alternative that should be investigated further in terms of cost effectiveness.
3. The use of water/steam as the turbine working fluid.
4. HVAC interface for thermal energy distribution.
5. The control subsystem achieved through commercial, state-of-the-art techniques.

System size was also a subject of further investigation.* Cost effectiveness as a function of system size was examined to determine the most appropriate size for the ATU/Fort Hood Solar Total Energy System. This was done by determining the unit cost for each percent of the 87000 Complex's annual energy requirements displaced by systems of various sizes.

Application of this approach required two system curves: one giving the percent energy displacement as a function of system size and the other giving the estimated system cost as a function of system size. Figure 4-1 shows the results obtained when the performance function is divided by the system cost function. Included are the percent displacement per unit cost for thermal energy alone and for total energy (thermal plus electrical).

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* The size selected during Phase II was set by rigid ERDA guidelines in effect at that time but which have been superceded by new guidelines (see References 5 and 16).

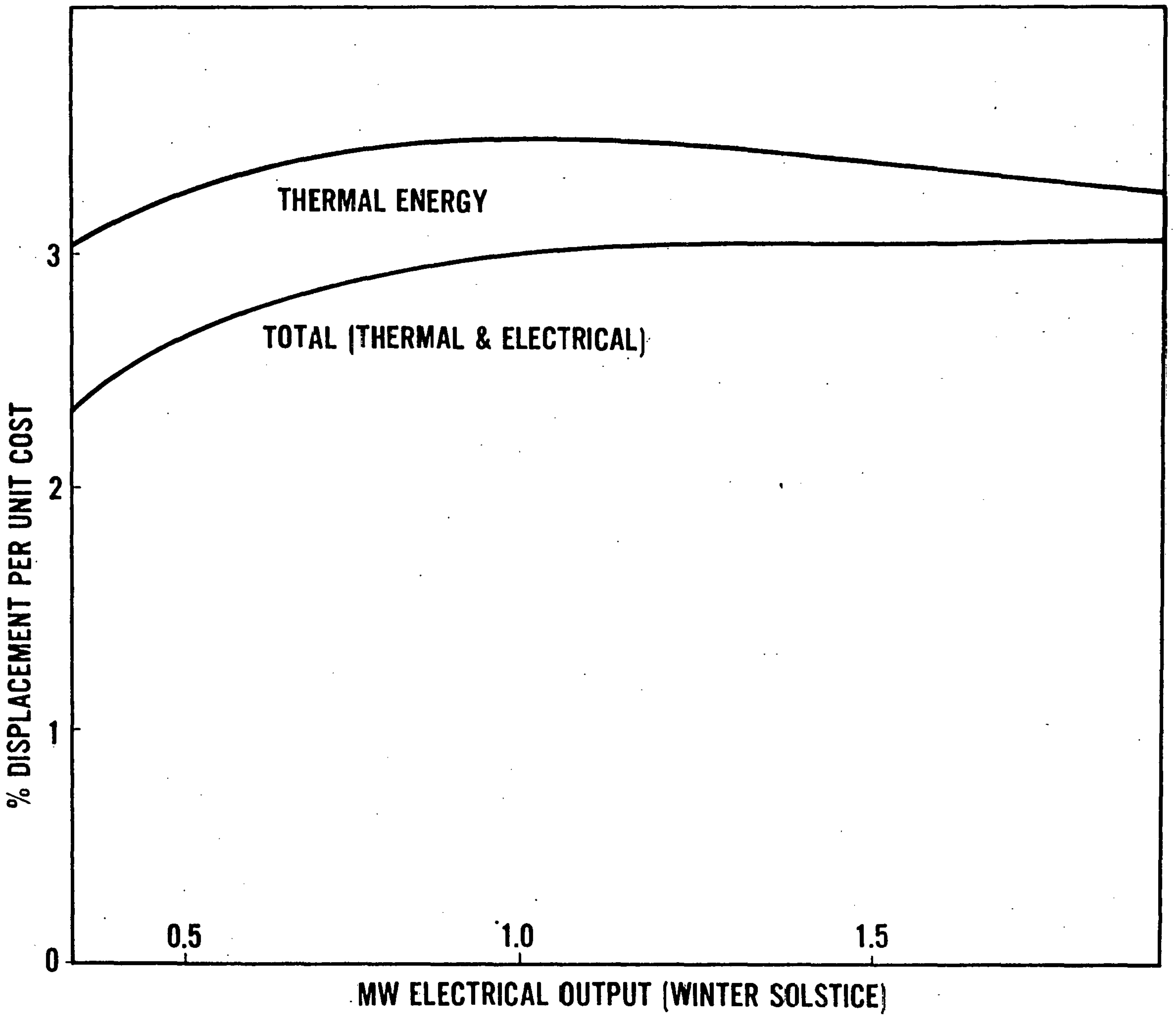

Figure 4-1. Percent Energy Displaced Per Unit System Cost vs. Electrical Output

The thermal energy curve is the more significant of the two because the total curve is influenced by the electrical component, which does not provide as good a basis for sizing. Although the percent thermal energy displacement per unit cost is not extremely sensitive to system size in the range investigated, it was noted that it peaked at a system size corresponding to approximately 1 MW electrical at winter solstice.

It was recommended that the Phase II conceptual design configuration with the refinements be used as the baseline for preliminary design of LSE-1, and that the system size be such that the nominal output is $1MW_e/10MW_{th}$ at winter solstice. Reference 19 gives further details on the evaluation processes and the rationale for the recommendations.

4.1.3 Site Selection and Layout

In 1975 the 87000 Troop Housing Complex at Fort Hood was tentatively chosen as the site for the initial conceptual design for the ATU/Fort Hood Solar Total Energy System (see Reference 5). Despite this choice, a more detailed analysis and evaluation of all candidate troop housing complexes to select the one most suitable to the project was planned before proceeding with preliminary design. This detailed evaluation was carried out early in the contract period reported herein. Factors considered were: size and layout, construction schedule, availability of adjacent areas for solar energy system components placement, impact on the Fort Hood master plan, and, finally, the difficulty and cost of interfacing with existing conventional energy systems. Four troop housing complexes which met the established criteria of the standard plan modular barracks concept were analyzed and evaluated: 87000 Complex, 29000 Complex, 39000 (West) FY75 Complex, and 39000 (East) FY76 Complex.

Each complex was analyzed to determine its physical characteristics and was systematically evaluated to determine the factors listed above. Numerical rankings were developed for each factor. Comparison of the rankings along with consideration of salient advantages and disadvantages revealed that the 87000 Complex was the logical first choice, with the 39000 (East) FY76 Complex second. The complete results of this study are given in Reference 20.

On February 7, 1977, Army approval of the site selected was requested. On February 18, 1977, Army approval was granted. This rapid approval avoided time-consuming delays in staffing through intermediate Army headquarters and is positive evidence of the Army's cooperation in achieving the objectives of this project.

Following confirmation of the selection of the 87000 Complex, a study was made to identify potential sites for the location of the major components of the solar total energy system. These components include the solar collector field, high-temperature thermal storage, power plant, low-temperature thermal storage, and points for interfacing the solar energy subsystems with the existing conventional energy systems.

Preliminary analyses of the possible system layouts at the 87000 Complex were conducted. Criteria for site evaluation were established for each component; where multiple sites were available, each was evaluated against these criteria and arranged in order of merit. System parameters were reexamined and revisions necessary to accommodate site requirements were identified. Finally, conclusions as to the adequacy of the various component sites were drawn. These conclusions revealed that adequate sites are available for location of all solar total energy system components at the 87000 Complex.

Since the site layout studies were based on the initial conceptual system design, the requirements and the results may change as the design approach is finalized. Therefore, rather than a formal report, an internal working paper on system layout possibilities at the 87000 Complex was prepared based on these results.

4.2 Conceptual Design Competition Support

In June, 1977, ATU assumed the role of site coordinator in support of the conceptual design competition between TRW, Inc. and Westinghouse Electric Corporation. In this role, ATU was responsible for military liaison, utilities interface coordination, and providing each contractor with background and site-specific information. Included in this information was insolation availability data, energy load data, environmental data, and the results of previous design studies and analyses. In addition, ATU provided system simulation (Section 2.7) and life cycle cost models to the contractors.

It was important to insure that accurate, concise, and consistent information was delivered to both contractors to enable them to proceed with their designs. In addition to the requirements anticipated by ATU, each contractor requested specific additional information. Exactly the same data were provided to each contractor and information copies of all transmittals were sent to ERDA.

The following subsections describe the major activities undertaken by ATU in support of the conceptual design competition. A very important underlying activity is that of military liaison, described in Section 2.1. This ATU role eliminated the potential problems of multiple points of contact. By being intimately familiar with the regulations, codes, site studies, and various other information specific to Fort Hood, ATU was able to coordinate each activity in a timely and effective manner.

4.2.1 Design Contractor Briefings

Following the program redirection, two briefings were held at American Technological University for the conceptual design contractors, TRW, Inc. and Westinghouse Electric Corporation. The first briefing, a pre-contract orientation, was held on May 11, 1977. The second briefing was held on June 7, 1977, one week after the design contractors started their four-month competitive design effort. In addition to TRW and Westinghouse, each briefing included representatives of ERDA, Sandia Laboratories, Corps of Engineers, Fort Hood DFE, TCATA, and subcontractors to the design contractors.

At the first briefing, the attendees were introduced to ATU and the American Educational Complex and were taken on tours of the 87000 Troop Housing Complex and of the Solar Engineering Test Module. ATU representatives reviewed the project background and history, including the evolution of the design criteria and philosophy. The initial conceptual design developed during Phase II (Reference 5) and the recent refinements to that design (Reference 19) were also described.

A data and information package was provided to each design contractor at the first briefing. The package included:

1. Copies of briefing materials and charts
2. Orientation materials including descriptions of:
    a. 87000 Troop Housing Complex
    b. Solar Engineering Test Module
3. Phase I Report in 4 volumes for the period July, 1974 - March, 1975 (References 1 through 4)
4. Phase II Report for the period April, 1975 - November, 1976 (Reference 5)
5. Conceptual Design Refinement Report (Reference 19)
6. Site Selection Report (Reference 20)
7. Design drawings for the 87000 Complex
8. Listings of estimated energy loads of the 87000 Complex (printouts and magnetic tapes)

9. Insolation data based on model and on measurements (listings and magnetic tapes).

Presentations were given to describe and explain most of the items in the data package. Some of the more important data provided at and subsequent to the briefing are summarized in the following sections.

Sandia representatives described the most recent changes in program direction, gave the current design philosophy, and discussed the guidelines applicable to the competitive design effort as part of the first briefing. One of the major departures from previous guidance was the directive that the solar total energy system supply 60 to 90 percent of the total thermal load (space heating, domestic hot water, and air conditioning) for five selected buildings within the 87000 Complex. However, it was provided that any electricity produced after meeting the requirements of these buildings be applied to the needs of the complex as a whole with emphasis on peak load shaving. The new guidance included two other major changes:

1. High-temperature storage should be sized to provide several hours of operation without solar input (instead of one hour as previously specified).
2. The solar total energy system should have separate fossil fuel backup for stand-alone operation (as opposed to using the existing fossil fuel systems for backup.

Sandia also discussed the uniqueness of Fort Hood as a site for LSE-1. As a military environment, decisions can be obtained at a single point, the commander, rather than having to deal with a multiplicity of customers; thus, it has certain freedoms not easily obtained in the commercial sector.

The second briefing, held on June 7, 1977, further delineated ATU's role as site coordinator. It also included further discussions of the electrical and thermal loads and interfacing considerations, particularly for selected buildings within the 87000 Complex.

A representative from ATU discussed the military liaison function and representatives from the Fort Hood DFE and TCATA described the Army's point of view and elaborated upon the military interest in and support of the project. The balance of the second briefing was devoted largely to a question and answer session, and opportunities were afforded for further examination of the 87000 Troop Housing Complex.

4.2.2 Site Specific Data

The information on the 87000 Complex provided to the conceptual design contractors included architectural and mechanical systems data. Indicated in Table 4-4 are the floor areas of the 87000 Complex. Of interest, too, was the information on the existing mechanical equipment of the 87000 Troop Housing Complex. The centrifugal chillers operate in a lead and lag fashion and are 512 and 436 tons respectively. Heating is provided by two 350 hp gas-fired, low-pressure steam boilers which channel steam to converters in the mechanical rooms of each building. There water is heated to 180°F maximum; it is then circulated to the coils in the air handling equipment. The storage portions of the company administration and storage buildings are heated by ceiling-mounted heaters.

Guidelines for the Fort Hood Conservation program are as follows:

1. Summer Minimum Room Temperature: 78°F
2. Winter Maximum Room Temperature: 68°F
3. Heating: November through March
4. Air conditioning: June through September only.

The five buildings selected for the space heating and cooling loads are listed in Table 4-5. Drawings giving the identification and location of various utility lines for the selected buildings relative to the central energy facility were provided. These include electricity, gas, storm drains, sanitation sewers, water, chilled water, and utility lines. Miscellaneous additional data were supplied upon request during the competitive design effort.

The redirection of the project following conceptual design refinement resulted in reducing the size of the system to supply thermal energy to only the five buildings indicated in Table 4-5. The energy requirements of these five selected buildings were estimated and actual measurements were taken. The thermal and electrical loads for the entire 87000 Complex, as well as for the five selected buildings, were provided to the conceptual design contractors Details of the load calculations and measurements are given in Section. 2.3.

Table 4-4. Floor Areas of the 87000 Complex

Building Type	Number	Floor Area (sq.ft.)		Total
		Air Cond.	Not Air Cond.	
2-module barracks	87007	31,698	---	31,698
4-module barracks	87012	42,264	---	43,264
3-module barracks	87013	31,698	---	31,698
4-module barracks	87015	42,264	---	42,264
4-module barracks	87020	42,264	---	42,264
3-module barracks	87021	31,698	---	31,698
4-module barracks	87022	42,264	---	42,264
Barracks subtotal		264,150	---	264,150
4-Co. Adm. & Stor.	87004	7,151	11,667	18,818
5-Co. Adm. & Stor.	87011	9,564	15,604	25,168
3-Co. Adm. & Stor.	87014	5,382	8,780	14,162
5-Co. Adm. & Stor.	87016	9,564	15,604	25,168
4-Co. Adm. & Stor.	87019	7,151	11,667	18,818
Co. Adm. & Stor.		38,812	63,322	102,134
Brig. Hq.	87005	9,840	---	9,840
Dispensary	87006	4,073	---	4,073
Branch PX	87008	4,696	---	4,696
2-Bn. Hq. & Clrm.	87003	12,381	---	12,381
2 Bn. Hq. & Clrm.	87009	12,381	---	12,381
Gym	87010	---	21,956	21,956
Food Serv. Fac.	87017	15,695	---	15,695
Cen. Engr. Fac.	87018	---	3,327	3,327
Total		361,028	88,605	450,633

Table 4-5. Space Conditioning Requirements

(BTU/day x 10^6)

Building Type	Building No.	Heating	Cooling
3-Module Barracks	87013	10.8	12.4
4-Module Barracks	87012	14.6	16.3
4-Module Barracks	87015	14.6	16.3
3-Company Admin./Storage	87014	3.4	2.0
5-Company Admin./Storage	87016	4.6	3.6
TOTAL		48.0	50.6

The space heating and cooling requirements for the selected buildings are summarized in Table 4-5. The total heating and cooling hourly load profiles for these buildings for the designated design days are shown in Figure 4-2. A total domestic hot water load of 20×10^6 BTU/day was assumed for the five selected buildings, based on a requirement of 40 gallons per person per day (Reference 21).

The estimated hourly thermal and electrical loads for the entire 87000 Complex for the model average year were provided to the contractors on magnetic tape. Hourly load profiles for an average summer and winter day, and the monthly total electrical and thermal energy consumption for the entire Complex, were also provided. These same load data were used during the Phase II conceptual design and/or the subsequent conceptual design refinement (Section 4.1).

The conceptual design contractors were also supplied four different data files relating to solar availability at Fort Hood. Information provided included the following:

1. The model average year including data for every hour of every day of the year. The data consist of the wind speed and direction, ambient temperature, relative humidity, visibility, degree of cloud cover, and both the total isolation and direct solar intensity for perfect clear weather conditions and actual cloud cover/visibility conditions.
2. The solar intensity and weather data for the worst summer months (i.e. June, July, and August) during the nine year period 1961-1969. The worst summer month is defined as the month with the lowest ratio of monthly total direct solar intensity to degree-days.
3. The solar intensity and weather data for the worst winter months (i.e December, January, February) during the nine year period 1961-1969. The worst winter month is defined in the same manner as the worst summer month.
4. The solar intensity and weather data measured at Fort Hood during the period September, 1974 through December, 1976.

These data were provided to the conceptual design contractors on magnetic tape in a format suitable for direct use in their system design studies.

Printed copies of the data indicated above were also provided. The sources of data and the procedures used in the development of the above information are discussed in Section 2.2.

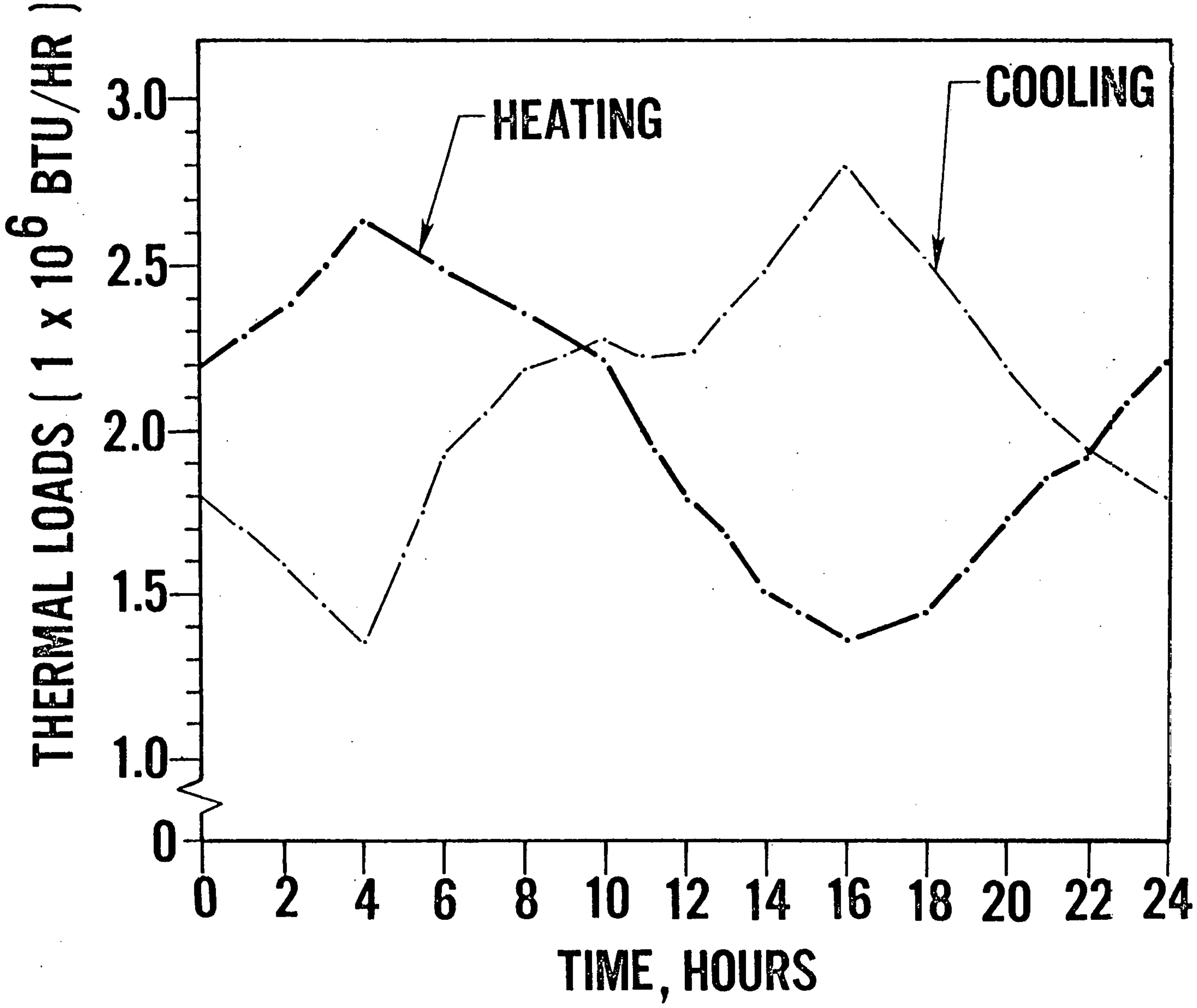

Figure 4-2. Estimated Thermal Load Profiles for Buildings 87012,13,14,15, and 16

4.2.3 Life Cycle Cost Model

During a June 2, 1977 meeting at Sandia Laboratories, it was determined that ATU would develop a commercial/industrial cost model to be used as a common basis for evaluating projected system life cycle cost for both LSE-1 and LSE-2. The necessary tasks included:

1. Review of existing models,
2. Recommendation to Sandia of an approach;
3. Presentation of the selected models, factors, and assumptions to the five contractors for LSE-1 and LSE-2 during the July mid-term reviews.

An evaluation of existing cost models was made; models developed by JPL, Atomics International, McDonnell-Douglas, the Lawrence Livermore Laboratory, National Bureau of Sandards, Mitre, and other firms were included. Financial and costing assumptions currently being used by economists were reviewed and values being used for key parameters were analyzed, e.g., fuel price escalation. Meetings were held with some of the economists developing these models, including those at the National Bureau of Standards, HEW, and ERDA, to discuss their approaches and rationales.

Development of the Model. Based on analysis of these models, a composite cost model was developed and presented to Sandia on June 21. The approach taken in this model was one of present value or discounted cash flow. This approach, while counter to the one taken by JPL and McDonnell-Douglas, was more suitable to commercial/industrial applications and more acceptable to bankers and other members of the financial community. The assumptions of the model, including the mode of depreciation, sum-of-years-digits method, were agreed upon at this meeting; additional factors such as escalation, inflation, and the discount rate were also established.

The model and sample results based on the assumed parameter values were presented to members of the Sandia staff on June 30. At this meeting, final agreement was reached on the values to be used for key parameters. Comments from that meeting were considered in revising the model for its presentation to the contractors during their midterm reviews in July. All five contractors were then sent preliminary materials on the cost benefit model, assumptions, and parameter values to be used.

During the first midterm review, which took place at Acurex/Aerotherm, it was decided that the model should be modified to provide solar systems costs rather than the cost/benefit differences between solar and conventional systems.

Presentations of the revised model were given to the other four contractors - TRW, Westinghouse, General Electric, and Stearns-Roger/McDonnell-Douglas - and discussions were held with their economists regarding the relationships, assumptions, and parametric values. These comments, none of which greatly impact the present model, were reviewed and further discussed with all five contractors. The resultant model was used as a basis for final cost evaluations.

Definition of Terms. The following terms used in the life cycle cost model require definition. The parameter values for these terms are listed in Table-4-6.

A, insurance rate. The annual rate of insurance for the solar-related equipment and property.

B_t, balance of loan at end of year. The balance on the capital cost loan or any year during the loan period.

C_{NPV}, systems costs, present value. The life cycle costs for the solar system over the period of analysis, N years, discounted at present value in 1977 dollars.

d, discount rate. The cost of capital assumed by the firm.

e_a, insurance escalation rate. The annual rate of increase in insurance costs.

e_E, electricity cost escalation rate. The annual market rate of electricity cost escalation.

e_F, fuel cost escalation rate. The annual market rate of fuel cost escalation.

e_L, land value appreciation. The annual increase in land market value.

e_{om}, operation and maintenance cost escalation rate. The annual market rate of operation and maintenance cost escalation.

e_R, replacement costs escalation rate. The escalation rate applied to equipment replacement costed with 1977 dollars.

e_{TC}, plant and equipment property tax escalation rate. The annual rate of increase in taxes on land costs.

e_{TL}, land property tax escalation rate. The annual rate of increase in taxes on land costs.

E, equity. The fractional amount of the total solar-related capital and land costs that is initially invested. The remainder of the costs are to be borrowed.

EL, electricity. The cost of annual electricity usage, based on consumption and the local utility company price structure.

F, fuel expenses. The annual fuel expenses. Nominal first year costs will be used, with escalation accounted for in the cost equation. The fuel required will be determined from the thermal calculations and the cost of this fuel will be based on the local price structure.

i, interest rate. The annual rate of interest paid on loans for capital and land costs.

I_c, capital costs. The costs, in 1977 dollars, for all solar-related initial equipment, plant, and construction. These costs will be depreciated by the sum-of-years-digits method over the period of analysis, N years.

I_L, land costs. The total cost of land, in 1977 dollars, required for the solar system. A value of $17,500 per acre is assumed.

INT_t, interst paid on loan at end of year t. The interest portion of the annual payment, M, on the loan for capital costs.

L, loan period. The number of years to repay loans for capital and land costs. Capital costs are amortized over this period, but interest only is paid on the land loan, the full principal being due at the end of the loan period.

M, annual loan payment. The annual loan payment on the amortized capital costs.

N, analysis period. The assumed number of years used to analyze the life cycle costs of the solar system and its alternatives.

OM, operation and maintenance expense. The nominal annual solar-related operation and maintenance expenses, including those for operations, labor, materials, and parts for corrective, preventative, and utility (cleaning and painting) maintenance. The nominal value, assuming normal operations and earlier year maintenance, not including experimental-related costs, will be escalated. Fuel and electricity expenses are broken out separately and are not included in this term.

R_t, replacement costs. The costs during the year, t, for replacement of plant and equipment with a life time less than the analysis period, N years. The initial costs of the equipment in 1977 dollars will be used (escalation is allowed for in the equation). These costs are to be met in the year they occur and are not to be amortized.

SV, salvage value. The value of plant and equipment, not including land, at the end of the analysis period, N years.

t, year of operation. A subscript noting the year during the analysis period.

T_c, investment tax credit. A tax credit, deductible in the first year, based on total capital costs.

T_{PC}, plant and equipment property tax rate. The annual property tax rate applied to capital cost items.

T_{PL}, land property tax rate. The annual property tax rate applied to the initial land costs.

T_R, corporate tax rate. An effective rate for federal and state corporate taxes.

Life Cycle Cost Elements. The relationship of life cycle cost elements is as follows:

Discounted Cost/Benefits = Equity - Investment Tax Credit

+ Annual Loan Payments + Net Expense & Tax Deduction on Land Loan
+ Net Expense & Tax Deduction for (Operation & Maintenance
+ Replacement + Insurance + Capital Property Tax + Land Property Tax
- Fuel Savings - Electricity Savings) - Tax Deduction on Interest
- Tax Deduction on Depreciation - Equipment Salvage Value
- Appreciated Land Value + Land Principal

Note that interest only is paid on the land purchase loan throughout the project life, with the principal payment due when the project is terminated. Detailed cost formats and assumptions for capital, operating, and maintenance costs are given in Appendix F.

Cost Model Relationships. The relationships for the cost model are given by the following equation which served as the basis for developing computer programs for calculating the yearly values:

$$\begin{aligned} CB_{NPV} = {} & E(I_c+I_L) - \frac{T_c\, I_c}{1+d} + \sum_{t=1}^{L} (1-E)\; I_c \left[\frac{i(1+i)^L}{(1+i)^L-1} \right] \frac{1}{(1+d)^t} \\ & + (1-T_R) \sum_{t=1}^{N} i(1-E)\; I_L \frac{1}{(1+d)^t} + (1-T_R) \sum_{t=1}^{N} \Big[OM(1+e_{OM})^{t-1} \\ & + R_t(1+e_R)^{t-1} + I_c\, A(1+e_A)^{t-1} + T_{PC}\, I_c\, (1+e_{TC})^{t-1} \\ & + T_{PL}\, I_L\, (1+e_{TL})^{t-1} - F(1+e_F)^{t-1} - EL(1+e_E)^{t-1} \Big] \frac{1}{(1+d)^t} \\ & - T_R \sum_{t=1}^{L} \frac{INT_t}{(1+d)^t} - T_R\, (I_c - SV)\; \frac{2}{N^2+N} \sum_{t=1}^{N} \frac{(N-t+1)}{(1+d)^t} \\ & - \frac{SV}{(1+d)^N} - \frac{I_L(1+e_L)^{N-1}}{(1+d)^N} + \frac{I_L(1-E)}{(1+d)^N} \end{aligned}$$

The term INT_t in the above equation is the interest paid on the loan at the end of year t and, thus, must be evaluated for t = 1, 2, 3 ..... L. It is given by

$$INT_t = i\ B_t$$

where i is the interest rate and B_t is the balance of the loan at end of year t. The balance at the end of the first year is given by

$$B_1 = (1-E)\,I_c$$

and for subsequent years by

$$B_t = B_{t-1} - (M-INT_{t-1})$$

in which

$$M = (1-E)I_c \ \frac{i(1+i)^L}{(1+i)^L-1}$$

Computer Programs. The life cycle cost relationships were programmed both on the HP-67 and HP-97 calculators and in IBM Fortran. Listings and calculator utilization instructions for these programs are found in Appendix G for the HP-67/97 and Appendix H for IBM Fortran.

Example Calculation. To assure uniform interpretation of the cost relationship, an example calculation was presented to the contractors. The assumed parameter values are arbitrary and do not reflect the costs of any existing or contemplated systems. Two printouts from the IBM Fortran program are provided, one displaying future costs over the 20-year life cycle (Figure 4-3), the other showing discounted costs (Figure 4-4).

The assumed values are:

I_c = \$5,000,000
I_L = \$ 87,500 (five acres)
OM = \$ 75,000
F = \$ 35,000
EL = \$ 40,000
SV = \$ 250,000
R_t = \$ 20,000
\$ 50,000
\$ 75,000

Table 4-6. Summary of Terms and Parameter Values

SYMBOL	TERM	VALUE
A	Insurance Rate (fraction)	0.1
B_t	Balance of Loan at end of year t (dollars)	-
C_{NPV}	Present value life cycle costs over N years	-
d	Discount Rate (fraction)	0.12
e_A	Insurance Escalation Rate (fraction)	0.06
e_E	Electricity Cost Escalation Rate (fraction)	0.10
e_f	Fuel Cost Escalation Rate (fraction)	0.12
e_L	Land Value Appreciation	0.06
e_{om}	Operation and Maintenance Escalation Rate (fraction)	0.06
e_R	Replacement Cost Escalation Rate (fraction)	0.06
e_{TC}	Plant & Equipment Property Tax Escalation Rate (fraction)	0.06
e_{TL}	Land Property Tax Escalation Rate (fraction)	0.06
E	Equity	0.20
EL	Electricity Expenses (Dollars/Years)	-
F	Fuel Expenses (Dollars/Year)	-
i	Interest Rate (fraction)	0.09
I_c	Capital costs (dollars)	-
I_L	Land costs (dollars)(@17,500 $/acre)	-
L	Loan Period (years)	20
INT_t	Interest paid on loan at end of year t (Dollars)	-
M	Annual Loan Payment (dollars)	-
N	Analysis Period (years)	20
OM	Operation and Maintenance expense (dollars)	-
R_t	Replacement Costs, Year t (Dollars)	-
SV	Salvage Value (Dollars)	-
t	Year of Operation	-
T_c	Investment Tax Credit (fraction)	0.20
T_{PC}	Plant & Equipment Property Tax Rate (fraction)	0.00
T_{PL}	Land Property Tax Rate (Fraction)	0.03
T_R	Corporate tax rate (fraction)	0.50

```
                          S Y S T E M   C O S T   A N A L Y S I S

                         P R E S E N T   V A L U E   C O S T S


             ANNUAL LOAN PAYMENT         OPERATE              REPLACE-                                         PROPERTY TAX         DELTA
                       INTEREST            AND       INSUR-    MENT      FUEL     ELECT.   DEPREC-                                INCOME        NET
 YEAR  PRINCIPAL  CAPITAL      LAND     MAINTAIN     ANCE      COST      COST      COST    IATION**     REAL      CAPITAL          TAX        COST *
 ----  --------   --------   --------   --------   --------  --------  --------  --------  --------   --------   --------   ------------  -----------
   0   1017500.        0.         0.         0.         0.        0.        0.        0.        0.         0.         0.             0.     1017500.
   1     71032.   321428.      5625.     66964.     44643.        0.    35714.    31250.   403912.      2344.         0.      -1253133.     -674133.
   2     69129.   281282.      5022.     63377.     42251.        0.    35077.    31250.   342604.      2218.         0.       -401540.      128066.
   3     67278.   245589.      4484.     59982.     39988.        0.    34450.    31250.   289796.      2099.         0.       -353819.      131301.
   4     65476.   213870.      4004.     56768.     37846.        0.    33835.    31250.   244372.      1987.         0.       -311966.      133069.
   5     63722.   185694.      3575.     53727.     35818.    11349.    33231.    31250.   205355.      1880.         0.       -280939.      139306.
   6     62015.   160678.      3192.     50849.     33897.        0.    32637.    31250.   171893.      1780.         0.       -243089.      133211.
   7     60354.   138479.      2850.     48125.     32083.        0.    32054.    31250.   143244.      1684.         0.       -214885.      131995.
   8     58737.   118792.      2544.     45547.     30364.        0.    31482.    31250.   118761.      1594.         0.       -190167.      130144.
   9     57164.   101344.      2272.     43107.     28738.        0.    30920.    31250.    97880.      1509.         0.       -168509.      127794.
  10     55633.    85892.      2028.     40797.     27198.    16099.    30368.    31250.    80110.      1428.         0.       -157585.      133108.
  11     54143.    72219.      1811.     38612.     25741.        0.    29825.    31250.    65024.      1351.         0.       -132917.      122035.
  12     52693.    60131.      1617.     36543.     24362.        0.    29293.    31250.    52252.      1279.         0.       -118363.      118804.
  13     51261.    49454.      1444.     34585.     23057.        0.    28770.    31250.    41470.      1210.         0.       -105620.      115431.
  14     49908.    40034.      1289.     32733.     21822.        0.    28256.    31250.    32398.      1146.         0.        -94464.      111973.
  15     48571.    31735.      1151.     30979.     20653.    13702.    27751.    31250.    24794.      1084.         0.        -91550.      115326.
  16     47270.    24431.      1028.     29319.     19546.        0.    27256.    31250.    18448.      1026.         0.        -76152.      104974.
  17     46004.    18015.       918.     27749.     18499.        0.    26769.    31250.    13177.       971.         0.        -68674.      101500.
  18     44771.    12388.       819.     26262.     17508.        0.    26291.    31250.     8824.       919.         0.        -62131.       98078.
  19     43572.     7463.       731.     24855.     16570.        0.    25821.    31250.     5252.       870.         0.        -56407.       94726.
  20     42405.     3162.       653.     23524.     15682.        0.    25360.    31250.     2345.       823.         0.        -51400.       91460.
       --------   --------   --------   --------   --------  --------  --------  --------  --------   --------   --------   ------------  -----------
 TOT.  2128645.  2172073.     47057.    834402.    556269.    41149.   605159.   624998.  2361902.     29204.         0.      -4433299.     2559558.

         *  FIRST YEAR NET COST INCLUDES EQUITY AND TAX CREDIT.

         **  METHOD OF DEPRECIATION - SUM OF YEARS
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Figure 4-3. Future Costs Over the Twenty-Year Cycle

```
                                    S Y S T E M   C O S T   A N A L Y S I S

 CAPITAL INVESTMENT = $  5000000.             ANALYSIS PERIOD =  20 YEARS               COST OF FUEL
      REAL PROPERTY = $    87500.          FIRST YEAR OPERATIONS                          DURING F RST YEAR              = $  35000.
             EQUITY = $  1017500.            AND MAINTENANCE       = $  75000.          FUEL COST RATE OF INCREASE = 12.00 PERCENT
 LOAN INTEREST RATE =  9.00 PERCENT        O AND M ESCALATION RATE =  6.00 PERCENT      COST OF ELECTRICITY
      DISCOUNT RATE = 12.00 PERCENT        FIRST YEAR INSURANCE    = $ 10.00 PER THOUSAND  DURING THE FIRST YEAR     = $  40000.
        LOAN PERIOD =  20 YEARS            INSURANCE RATE INCREASE =  6.00 PERCENT      ELECTRICITY COST RATE OF
    INCOME TAX RATE = 50.00 PERCENT                    TAX CREDIT  = 20.00 PERCENT        INCREASE                   = 10.00 PERCENT
  REAL PROPERTY TAX =  3.00 PERCENT        SYSTEM SALVAGE VALUE    = $ 250000.          CAP. PROP. TAX RATE INCR.  =  6.00 PERCENT
   CAP. PROPERTY TAX =  0.0  PERCENT                                                    REAL PROP. TAX RATE INCR.  =  6.00 PERCENT

 ANNUAL LOAN PAYMENT = $ 445856.


             ANNUAL LOAN PAYMENT         OPERATE           REPLACE-                                PROPERTY TAX         DELTA
                         INTEREST           AND     INSUR-     MENT     FUEL    ELECT.   DEPREC-                       INCOME         NET
 YEAR  PRINCIPAL  CAPITAL      LAND    MAINTAIN     ANCE      COST     COST     COST   IATION**     REAL    CAPITAL      TAX        COST *
 ----  --------   --------   --------  --------   --------  --------  -------- -------- --------  -------- -------- ----------  ----------
   0   1017500.        0.         0.        0.         0.        0.        0.       0.       0.        0.       0.         0.    1017500.
   1     79556.   360000.      6300.    75000.     50000.        0.    35000.   40000.  452381.     2625.       0.  -1403509.    -755029.
   2     86716.   352840.      6300.    79500.     53000.        0.    39200.   44000.  429762.     2782.       0.   -503692.     160646.
   3     94520.   345035.      6300.    84270.     56180.        0.    43904.   48400.  407143.     2949.       0.   -497091.     184468.
   4    103027.   336529.      6300.    89326.     59551.        0.    49172.   53240.  384524.     3126.       0.   -490884.     209387.
   5    112300.   327256.      6300.    94665.     63124.    20000.    55073.   58564.  361905.     3314.       0.   -495110.     245505.
   6    122407.   317149.      6300.   100367.     66911.        0.    61682.   64420.  339286.     3513.       0.   -479814.     262935.
   7    133423.   306132.      6200.   106368.     70926.        0.    69084.   70862.  316667.     3724.       0.   -475041.     291798.
   8    145432.   294124.      6300.   112772.     75181.        0.    77374.   77948.  294048.     3947.       0.   -470847.     322231.
   9    158520.   281035.      6300.   119538.     79692.        0.    86659.   85743.  271429.     4184.       0.   -467289.     354381.
  10    172787.   266768.      6300.   126710.     84473.    50000.    97058.   94317.  248810.     4435.       0.   -489435.     413413.
  11    188338.   251218.      6300.   134312.     89542.        0.   108704.  103749.  226190.     4701.       0.   -462358.     424506.
  12    205289.   234267.      6300.   142371.     94914.        0.   121749.  114124.  203571.     4983.       0.   -461140.     462857.
  13    223765.   215791.      6300.   150913.    100609.        0.   136359.  125536.  180952.     5282.       0.   -460871.     503684.
  14    243904.   195652.      6300.   159968.    106645.        0.   152722.  138090.  158333.     5599.       0.   -461654.     547225.
  15    265855.   173701.      6300.   169566.    113044.    75000.   171048.  151898.  135714.     5935.       0.   -501103.     631243.
  16    287782.   149774.      6300.   179740.    119827.        0.   191574.  167088.  113095.     6291.       0.   -466844.     643530.
  17    315862.   123694.      6300.   190524.    127016.        0.   214563.  183797.   90476.     6668.       0.   -471519.     696904.
  18    344290.    95266.      6300.   201955.    134637.        0.   240310.  202176.   67857.     7068.       0.   -477785.     754217.
  19    375276.    64280.      6300.   214072.    142715.        0.   269148.  222394.   45238.     7493.       0.   -485820.     815857.
  20    409051.    30505.      6300.   226917.    151278.        0.   301445.  244633.   22619.     7942.       0.   -495819.     882251.
       --------   --------   --------  --------   --------  --------  -------- -------- --------  -------- -------- ----------  ----------
 TOT.  5097587.   4721008.    125999.  2756868.   1839261.   145000.  2290975. 2521824. 4749992.    96561.       0. -10517617.    8624766.

           *  FIRST YEAR NET COST INCLUDES EQUITY AND TAX CREDIT.

           **  METHOD OF DEPRECIATION - SUM OF YEARS
```

Figure 4-4. Discounted Costs

4.3 Conceptual Design Reviews

ATU personnel attended the midterm and final design reviews of TRW, Inc., and Westinghouse Electric Corporation. These reviews provided ATU the opportunity to monitor the designs being developed by both teams and to assure that the teams were being provided adequate site-specific support.

The midterm reviews were also used to brief Westinghouse and TRW, as well as the three contractors competing on LSE-2, on the ATU Life Cycle Cost Model (see Section 4.2.3). These briefings introduced the model, explained the parameters, and provided values to be used. In addition, each contractor was provided a report on the life cycle cost model. During the final design reviews, the results of the life cycle cost analysis of each contractor were assessed.

Following the final meetings on the competitive designs, ATU reviewed the final reports (References 22 and 23) prepared by each contractor. When it was announced that Westinghouse was the selected contractor, the program planning (Section V) was updated to adapt the systems analysis, engineering test program, and various support program activities to the specific requirements of Westinghouse's design approach.

It is noted that the major differences between the Westinghouse conceptual design approach and that taken by ATU during Phase II include: the use of oil rather than water in the collector field; the use of parabolic trough collectors (which ERDA had directed ATU not to use because they were already being used on several earlier projects); and ample high-temperature storage to operate the steam turbine overnight (earlier ERDA guidance to ATU had limited the storage to one hour of operation).

V. PLANNING

V. PROGRAM PLANNING

The purpose of the program planning task is to establish the management and technical disciplines necessary to attain the development and performance objectives of the ATU/Fort Hood Solar Total Energy Military Large-Scale Experiment on schedule and within budgetary constraints. To this end, there has been an extensive program planning effort during the contract period.

The preliminary design phase initiated in December, 1976 was conducted in accordance with the management plan adopted during negotiations of Contract No. EG-77-C-04-3878 (Appendix A, Part 1). Five months into this design phase, ATU received program redirection from ERDA. This directive resulted in the termination of the preliminary design effort and required the development of a new program plan. This plan provided the foundation for ATU's provision of site coordination and technical support for the two industrial contractors selected to conduct a conceptual design competition. The new plan was designed to carry out the modified contract statement of work (Appendix A, Part 2).

The planning effort during the remainder of the contract period consisted of developing a management plan for a new preliminary design phase to follow the present contract period (Section 5.1), and long-range planning (Section 5.2) that will place the system in operation in mid-1980.

5.1 Preliminary Design Planning

The preliminary design phase has been planned to cover an eight-month period and result in a smooth transition into the definitive design phase. This detailed plan provides for the accomplishment of three major tasks:

1. Program Management and Technical Support. This task involves contract management, program plan, system and cost analyses, site specific studies, and site interface and coordination.
2. Engineering Test Program. The principal thrust of this effort is the procurement, installation, and checkout of the Collector Field Pilot Test Array (PTA). Detailed test plans will provide for testing to begin early in the definitive design phase.
3. Preliminary System Design. This task is to be performed by the designated design subcontractor and will include final adjustments to the conceptual system design, specifications for subsystems and subsystem interfacing, subsystem design, systems integration, and performance evaluation.

This basic program format will extend through the definitive design phase.

In addition, the management plan for the preliminary design phase includes a Work Breakdown Structure (WBS) to the 4th level, a detailed schedule and milestone chart, functional flow diagrams, manpower plans, and cost analysis.

5.2 Long-Range Planning

Sufficient long-range planning has been performed to establish an operational date of July, 1980 for the system.

This program plan was prepared on a WBS level I basis and includes major milestones related to the procurement, fabrication, and installation of equipment, hardware, instrumentation, and facilities. The plan provides for a ten-month definitive design phase, a sixteen-month construction phase, and a 24-month test and evaluation phase.

Detailed plans for the final three phases will be developed during the preliminary design effort. ATU will work closely with the design subcontractor to expedite completion of the system. Every effort to reduce the delay in on-line operation caused by the program redirection will be made.

REFERENCES

REFERENCES

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APPENDIX A

APPENDIX A. Part I Statement of Work, Contract No. EG-77-C-04-3878

The Contractor shall perform the tasks specified below:

1. Preliminary Design

Provide a comprehensive preliminary design of a Solar Total Energy (STE) system for the Military Large-Scale Experiment (LSE) to be located at Fort Hood, Texas.

1.1 Conceptual Design Refinement

Reconsider or modify as appropriate the conceptual design produced as Phases I and II of Contract E (40-1)-4924 with the ERDA, with respect to hardware availability, site characterization, and program direction.

1.2 Preliminary Design Requirements

Establish system operation and performance requirements.

1.3 Component and Subsystem Preliminary Design

Develop a preliminary design for each element of the system which adequately meets the requirements established in Task 1.2 and which considers the state of the technology and the expected costs as well as performance.

1.4 System Level Preliminary Design

Develop control strategies for the overall system and investigate the iterations among the parts of the system to determine whether the components designs should be modified on the basis of systems level considerations. Both costs and performance are to be considered.

1.5 Preliminary Design Documentation

Provide complete documentation of the preliminary design to establish an adequate technical basis for definitive design and construction. This documentation must include cost and performance information for the proposed system.

2. Engineering Test Program

Conduct a testing program in the vicinity of the proposed construction site to provide site-specific design information and hardware experience for project personnel.

2.1 Solar Engineering Test Module (SETM) Tests

Conduct a test program to determine collector performance characteristics, utilizing the existing 400 ft^2 test module and test loop at Fort Hood.

2.2 200 Linear Feet Array (LFA) Program

Procure, install, and test a 200 LFA (approximately 2000 ft^2), characteristic of the solar collector field subsystem.

3. Program Planning and Technical Support

Conduct management, coordinating, and support activities necessary to integrate the system preliminary design into a program which will be used as a basis for definitive design, construction, and operation of the proposed STE Military LSE at Fort Hood.

3.1 Program Management and Administrative Support

Provide management and supervision for the project by developing and maintaining a Preliminary Design Phase Management Plan, including a master task schedule, work breakdown structure charts, major milestone charts, and a cost management plan.

3.2 Long-Range Program Planning

Provide a detailed management plan for subsequent Definitive Design and Construction Phase including a procurement plan for long-lead items.

3.3 Reviews

Schedule and conduct design reviews as follows:

a. After the preparation of recommended modifications to the conceptual design.

b. After preliminary design requirements have been established and prior to initiation of the component and subsystem level design efforts.

c. After completion of the component and subsystem design tasks and prior to system level definitions/trade-off efforts.

d. Prior to final documentation of the completed preliminary design.

Conduct Program Reviews concurrently with the Preliminary Design Reviews to present the status of those activities not included in the system preliminary design. The schedules, agendas, and attendants for the reviews shall be developed by the Contractor and approved by the Government Technical Representative (GTR). These reviews shall include detailed oral presentations on the design status by the personnel involved. Accomplishments, problem areas affecting objectives, schedules, costs, and programmatic responses to the problem areas will be emphasized. Brief review reports, including a written summary of the presentations, paper reproduction of the visual aids used, and a summary narrative of discussions held during the review shall be provided within two weeks after each review.

3.4 Reports

Comply with requirements in ARTICLE III - REPORTS of this Contract EG-77-C-04-3878.

3.5 System Costs and Commercialization

Prepare a reasonable projection of the economic considerations involved in early commercial applications of similar solar total energy systems. Such projections shall address life cycle costs associated with planning, design, construction, and operation.

3.6 Characterization of the Operational Environment

Develop a system operation plan outlining thee various conditions under which the LSE is to be operated, including impacts on health, safety and environment.

3.7 Military (Fort Hood and Corps of Engineers) Interface and Coordination

Assist the ERDA as requested by the Contracting Officer to coordinate with appropriate military officials for the purpose of agreeing upon a preliminary design which will be acceptable to the military for use at Fort Hood.

3.8 Systems Analysis

Develop and maintain a systems analysis capability sufficient to verify the system design and to integrate the various activities of the project into a coherent program.

3.9 Solar Availability Studies

Determine the amount and temporal distribution of solar energy available to collectors at the Fort Hood site to the extent necessary to design and evaluate the system. This task will include both the gathering of local meterological data and the correlation of applicable data already collected, such as Weather Service data.

3.10 Energy Requirements Studies

Determine the characteristics of energy use patterns at Fort Hood to the extent necessary to specify design requirements for the system and to permit projections limited to future military use of STE systems similar to the design developed under this contract.

APPENDIX A. Part 2 Statement of Work, Modification No. A001, Contract No. EG-77-C-04-3878

The Contractor shall perform the tasks specified below:

I. Site Coordination

Assist the ERDA, as requested by the Contracting Officer, with respect to each of the following:

A. Military (Fort Hood and Corps of Engineers) Interface and Coordination to develop conceptual designs which will be acceptable to the military for use at Fort Hood;

B. Utilities Interface and Coordination - to provide coordination with utility companies with respect to conceptual designs;

C. Interface and Coordination with ERDA Design Contractors - to provide site-related information and technical data; and

D. Performance of Site-specific Studies - with respect to solar availability, energy requirements, structural layout, surface and subsurface geological and archaeological studies, and preliminary health, safety, and environmental studies.

II. Engineering Test Program

Conduct a testing program in the vicinity of the proposed Fort Hood Solar Total Energy - Large- Scale Experiment (STE-LSE) site to provide site-specific performance, operating, and maintenance experience data. This task includes:

A. Engineering Test Planning - Developing, coordinating, and maintaining an integrated engineering test plan, as approved by the Contracting Officer;

B. Solar Engineering Test Module - Conducting a test program to determine collector performance characteristics utilizing the existing ERDA 400 ft^2 collector module and test loop at Fort Hood; and

C. Collector Field Pilot Test Array Program - Determining the requirements of, and preparing plans for, the procurement, installation, and testing of a module of approximately 2000 ft^2 collecting area. The module shall be characteristic of an independent operating entity of the solar collector field subsystem.

III. Analytical Support

Assist the ERDA, as requested by the Contracting Officer, by performing site-specific design verifications, system analyses, and analytical support, including utilization of the Simulation Model to compare competing designs and determine system sensitivity to site-specific conditions. This task includes:

A. Support to the ERDA - Assisting the ERDA with site-specific system analyses and verification of designs;

B. Simulation Model - Refining the Simulation Model presently developed to include subroutines for simulation of concentrating collectors, control system variations, power cycles, and loads. Upgrading the reporting capabilities to provide improved utility and flexibility with respect to English and/or metric units of measurement.

C. Support the ERDA Design Contractors - Installing the Simulation Model, at sites approved by the Contracting Officer, for use in the development of the conceptual designs, and updating the Simulation Model with system enhancements; and

D. Costing Model - Developing and refining an approach to a solar total energy general Costing Model. This model, during the conceptual design phase, will be limited to the comparative evaluation of life-cycle costs of competing system designs.

IV. Information Dissemination and Training

Disseminate technical information relating to the proposed STE-LSE. This task will include:

A. Site Visitor Services - Providing for the reception of visitors to the Solar Engineering Test Module and the STE-LSE sites;

B. Display Models - Developing display models to demonstrate design and operating characteristics of the STE-LSE;

C. Project Information Releases - Reviewing and coordinating with the ERDA the release of technical and programmatic materials relating to the STE-LSE;

D. Technology Transfer - Attending and participating in appropriate conferences, seminars, and symposiums, as approved by the Contracting Officer; and

E. Training Requirements - Outlining educational programs, as approved by the Contracting Officer, for training technicians in the operation and maintenance of military and commercial solar total energy systems.

V. Project Direction

Provide internal management and direction for all work specified in this Appendix A-1. This task includes:

A. Reviews - Participating, as requested by the Contracting Officer, in ERDA contractor design reviews for the purpose of identifying potential site impacts;

B. Reports - Providing reports in accordance with Article III of this contract;

C. Project Management and Administration - Developing and maintaining a Management Plan, including a Master Task Schedule, Work Breakdown Structure Charts, Major Milestone Charts, and a Cost Management Plan; and

D. Long-Range Project Planning - Providing a detailed STE-LSE Site-Related Project Management Plan for subsequent preliminary design, definitive design, and construction phases.

APPENDIX B

87000 COMPLEX LOAD

ELECTRICITY - 3 PHASE KVA

BUILDING	DUTY DAY	LOAD	NBR DAYS	HOUR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
87003	BOTH	MAX	33	37	34	36	34	34	42	55	64	65	66	65	63	60	65	64	63	56	49	48	50	44	39	42	42
87003	BOTH	MIN	33	24	25	24	24	24	22	22	23	24	23	27	23	25	25	24	23	23	23	22	25	23	23	24	24
87003	BOTH	AVG	33	28	28	27	27	28	30	37	48	50	50	49	47	45	48	46	46	42	36	32	33	32	30	33	32
87003	YES	MAX	23	37	34	36	34	34	42	55	64	65	66	65	63	60	65	64	63	56	49	48	50	44	39	42	42
87003	YES	MIN	23	25	25	24	25	24	26	27	48	49	47	45	43	41	47	44	47	42	30	22	25	23	23	26	24
87003	YES	AVG	23	29	27	27	27	28	32	43	57	58	57	57	54	51	55	54	54	49	39	33	34	33	31	34	32
87003	NO	MAX	10	28	32	29.	30	31	31	27	32	42	50	47	40	44	42	34	31	31	40	37	41	42	35	39	38
87003	NO	MIN	10	24	26	24	24	25	22	22	23	24	23	27	23	25	25	24	23	23	23	23	25	25	23	24	24
87003	NO	AVG	10	26	28	26	27	28	26	25	27	32	33	33	31	32	31	28	27	26	29	29	30	30	28	31	30
87004	BOTH	MAX	30	50	49	46	47	54	78	86	90	85	86	86	78	75	79	85	83	71	71	66	58	51	51	52	49
87004	BOTH	MIN	30	31	34	31	27	27	29	29	32	33	33	34	34	34	34	34	38	36	34	31	28	28	33	33	34
87004	BOTH	AVG	30	41	42	40	39	41	50	62	66	62	60	59	58	55	54	53	52	52	50	46	42	41	41	42	41
87004	YES	MAX	20	50	49	46	47	54	78	86	90	85	86	86	78	75	79	85	83	71	71	66	58	51	51	52	49
87004	YES	MIN	20	31	36	31	27	27	29	29	50	43	46	49	38	37	41	41	40	40	41	31	28	28	33	33	34
87004	YES	AVG	20	42	42	40	39	42	55	72	76	70	67	65	64	61	61	59	57	58	55	49	43	42	42	43	42
87004	NO	MAX	10	45	45	45	45	45	51	86	90	65	84	86	72	45	45	45	49	45	42	45	45	43	50	45	43
87004	NO	MIN	10	35	34	35	35	32	34	34	32	33	33	34	34	34	34	34	38	36	34	35	32	35	35	35	35
87004	NO	AVG	10	40	40	40	40	39	41	42	44	45	46	45	44	41	40	41	41	40	39	40	40	40	40	41	40
87005	BOTH	MAX	33	14	13	14	14	13	16	30	34	32	34	32	32	32	30	31	32	27	23	16	14	14	16	14	14
87005	BOTH	MIN	33	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
87005	BOTH	AVG	33	12	12	12	12	12	12	19	23	23	23	23	23	23	22	23	22	20	15	11	12	12	12	12	12
87005	YES	MAX	23	14	13	14	14	13	16	30	34	32	34	32	32	32	30	31	32	27	23	16	14	14	16	14	14
87005	YES	MIN	23	9	9	9	9	9	9.	16	20	20	22	20	22	22	20	20	19	17	11	9	9	9	9	9	9
87005	YES	AVG	23	12	12	12	12	12	12	23	28	28	28	28	28	28	27	27	27	23	16	12	12	12	12	12	12
87005	NO	MAX	10	14	12	13	13	13	13	14	14	13	13	13	14	14	13	14	14	13	14	13	14	12	13	14	13
87005	NO	MIN	10	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
87005	NO	AVG	10	12	11	11	12	12	12	11	11	12	11	12	12	11	12	12	12	11	11	11	11	11	11	11	11

Table B-1. Hourly Electricity Demands in KVA for each Building

87000 COMPLEX LOAD

ELECTRICITY - 3 PHASE KVA

	DUTY		NBR	HOUR																							
BUILDING	DAY	LOAD	DAYS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
87006	BOTH	MAX	33	13	15	13	12	13	16	20	25	23	24	23	23	21	22	22	21	16	13	12	12	15	13	14	12
87006	BOTH	MIN	33	1	8	8	1	1	8	1	1	1	8	8	8	8	8	8	1	8	7	7	8	1	1	1	8
87006	BOTH	AVG	33	10	10	10	9	10	10	13	16	17	17	16	14	14	16	15	13	11	9	9	10	9	10	9	10
87006	YES	MAX	23	13	15	13	12	13	16	20	25	23	24	23	23	21	22	22	21	16	12	12	12	15	13	14	12
87006	YES	MIN	23	1	8	8	1	1	8	1	1	1	14	14	9	11	14	12	10	8	7	8	8	1	1	1	8
87006	YES	AVG	23	9	10	10	9	9	11	14	18	20	20	19	17	16	18	18	16	11	9	9	10	9	10	9	10
87006	NO	MAX	10	12	13	11	12	13	12	12	12	12	13	13	12	12	12	12	11	12	13	12	12	12	12	13	12
87006	NO	MIN	10	8	9	8	8	8	8	8	8	8	8	8	8	8	8	8	1	8	8	7	8	8	8	8	8
87006	NO	AVG	10	10	11	9	10	10	10	10	10	10	10	10	9	10	10	9	9	9	10	9	10	9	10	9	10
87007	BOTH	MAX	45	39	40	37	36	36	38	43	39	40	38	39	40	40	42	39	40	39	42	49	45	49	50	46	41
87007	BOTH	MIN	45	23	23	22	20	23	22	22	21	22	22	23	22	23	23	23	23	24	25	25	25	26	27	23	23
87007	BOTH	AVG	45	30	29	29	28	28	29	30	28	28	29	31	31	31	31	31	31	32	33	36	36	37	37	35	32
87007	YES	MAX	31	39	40	37	35	36	38	43	37	40	38	38	39	39	37	35	40	37	39	49	45	49	50	46	41
87007	YES	MIN	31	23	23	22	20	23	22	22	21	22	22	23	22	23	23	23	23	24	25	25	25	26	27	23	23
87007	YES	AVG	31	30	29	28	28	28	29	31	28	28	28	29	29	30	29	29	30	31	33	36	36	37	37	35	32
87007	NO	MAX	14	35	35	35	36	33	35	40	39	35	37	39	40	40	42	39	40	39	42	41	42	43	40	43	38
87007	NO	MIN	14	27	25	25	25	24	25	25	25	23	25	25	25	27	27	27	27	27	30	31	29	27	27	26	25
87007	NO	AVG	14	31	30	29	29	28	28	29	28	28	30	34	35	35	36	34	34	35	35	36	36	37	37	34	32
87008	BOTH	MAX	45	47	50	49	48	50	65	68	76	76	76	79	83	83	81	79	79	78	78	72	78	79	65	48	50
87008	BOTH	MIN	45	36	36	36	37	36	37	36	36	54	58	58	61	60	55	58	56	58	58	58	53	54	43	35	34
87008	BOTH	AVG	45	42	42	43	43	42	51	55	65	67	67	67	71	70	69	68	68	68	68	66	65	68	54	41	42
87008	YES	MAX	30	46	50	49	47	50	65	68	76	76	73	79	80	83	76	79	77	78	77	72	78	79	65	48	47
87008	YES	MIN	30	36	39	38	37	36	43	50	61	58	58	58	61	60	55	58	56	58	58	58	53	54	43	35	36
87008	YES	AVG	30	42	43	43	43	42	55	60	69	69	67	68	72	70	69	68	68	68	68	66	65	67	54	42	42
87008	NO	MAX	15	47	47	48	48	47	50	65	76	76	76	76	83	77	81	77	79	76	78	72	76	76	60	45	50
87008	NO	MIN	15	36	36	36	39	36	37	36	36	54	58	58	62	60	60	63	59	58	58	60	59	61	46	36	34
87008	NO	AVG	15	42	42	43	43	42	43	46	56	65	67	66	70	70	70	70	70	69	67	67	66	69	54	39	42

Table B-1. (cont'd)

87000 COMPLEX LOAD

ELECTRICITY - 3 PHASE KVA

	DUTY		NBR	HOUR																							
BUILDING	DAY	LOAD	DAYS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
87009	BOTH	MAX	45	34	36	34	34	36	42	48	48	52	51	49	48	49	49	49	50	45	45	43	42	39	36	37	34
87009	BOTH	MIN	45	22	23	22	22	22	23	23	23	23	23	23	23	23	23	22	22	22	22	22	22	22	22	22	22
87009	BOTH	AVG	45	28	28	27	27	27	29	36	38	38	38	38	38	37	38	37	37	36	34	33	31	30	29	29	28
87009	YES	MAX	32	34	36	34	34	36	42	48	48	52	51	49	48	49	49	49	50	45	45	43	42	39	36	37	34
87009	YES	MIN	32	22	23	22	22	22	23	28	25	27	28	28	25	28	27	27	31	27	27	27	26	25	25	25	25
87009	YES	AVG	32	28	28	28	27	28	30	39	42	42	42	42	42	41	42	41	41	40	37	35	33	31	30	30	29
87009	NO	MAX	13	32	32	32	34	30	36	38	37	33	35	34	38	37	36	36	36	36	32	35	34	32	34	33	32
87009	NO	MIN	13	23	23	23	23	23	23	23	23	23	23	23	23	23	23	22	22	22	22	22	22	22	22	22	22
87009	NO	AVG	13	27	27	26	26	26	27	29	28	28	29	29	28	27	27	28	27	27	26	27	27	27	27	27	26
87010	BOTH	MAX	47	36	36	35	35	35	67	76	76	78	76	75	78	78	79	81	81	79	79	79	82	81	76	76	58
87010	BOTH	MIN	47	1	1	1	1	1	1	1	1	1	1	17	55	56	57	56	57	49	47	37	36	7	1	1	1
87010	BOTH	AVG	47	13	14	14	14	13	22	32	46	52	56	60	64	65	67	68	68	67	68	67	65	52	25	19	16
87010	YES	MAX	34	36	36	35	35	35	67	76	76	78	76	75	76	78	79	81	81	79	79	79	82	81	76	76	58
87010	YES	MIN	34	1	1	1	1	1	1	1	20	48	32	43	55	56	57	56	59	49	49	50	43	12	1	1	1
87010	YES	AVG	34	13	13	13	13	12	24	38	57	63	63	63	64	65	69	69	69	68	68	68	67	61	27	20	16
87010	NO	MAX	13	22	22	22	22	22	22	22	22	54	65	72	78	78	71	71	71	72	76	74	74	67	36	23	22
87010	NO	MIN	13	1	1	1	1	1	1	7	1	1	1	17	56	56	58	56	57	57	47	37	36	7	1	1	1
87010	NO	AVG	13	16	16	16	16	15	15	16	15	21	36	54	64	65	64	65	66	65	66	65	62	30	19	15	14
87011	BOTH	MAX	46	31	31	32	31	38	43	47	48	45	47	50	50	45	47	47	47	48	43	39	36	32	32	30	32
87011	BOTH	MIN	46	20	20	20	20	22	21	22	22	22	22	23	22	22	22	23	22	22	22	22	20	22	20	21	20
87011	BOTH	AVG	46	25	25	24	24	25	26	35	37	37	37	37	37	36	37	36	37	36	31	28	27	26	26	25	25
87011	YES	MAX	33	31	31	32	31	38	43	47	48	45	47	50	50	45	47	47	47	48	43	39	36	32	32	30	32
87011	YES	MIN	33	20	20	20	20	22	21	31	37	35	37	36	33	33	32	32	36	36	25	23	20	22	20	21	20
87011	YES	AVG	33	26	25	25	24	25	27	39	42	41	41	41	41	40	41	40	41	41	34	29	27	26	26	26	25
87011	NO	MAX	13	28	27	27	27	29	27	30	29	31	31	31	30	32	29	30	29	27	29	28	28	30	29	27	32
87011	NO	MIN	13	22	22	21	22	22	21	22	22	22	22	23	22	22	22	23	22	22	22	22	22	22	22	22	22
87011	NO	AVG	13	24	24	24	24	24	24	25	26	26	26	26	26	26	26	26	25	25	25	25	25	25	25	25	25

Table B-1. (cont'd)

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                                                        87000 COMPLEX LOAD

                                                    ELECTRICITY - 3 PHASE KVA

                 DUTY           NBR                                  HOUR
  BUILDING       DAY    LOAD    DAYS    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24



   87012        BOTH    MAX     42     48  47  43  45  43  45  52  44  42  43  45  45  48  43  49  46  50  48  53  53  56  56  55  49
   87012        BOTH    MIN     42     30  30  30  29  29  31  31  30  29  28  29  32  32  30  31  29  31  33  33  34  36  38  36  34
   87012        BOTH    AVG     42     39  37  36  35  35  37  41  37  36  36  37  38  38  37  37  38  40  40  41  43  45  46  45  42

   87012        YES     MAX     29     48  44  43  43  42  45  52  44  42  42  43  42  43  40  43  45  50  48  49  50  53  54  55  49
   87012        YES     MIN     29     30  30  30  29  29  31  34  31  29  28  29  32  32  30  31  29  31  33  33  34  36  38  36  34
   87012        YES     AVG     29     38  36  35  35  35  37  43  38  36  36  36  37  38  36  36  37  39  40  41  42  44  46  45  41

   87012        NO      MAX     13     45  47  42  45  43  40  42  40  40  43  45  45  48  43  49  46  49  48  53  53  56  56  55  49
   87012        NO      MIN     13     32  32  31  30  31  31  31  30  31  30  32  32  32  31  31  31  33  33  35  37  40  40  39  38
   87012        NO      AVG     13     40  38  37  36  36  35  36  35  36  37  39  39  39  39  40  40  41  41  43  45  47  48  47  44




   87013        BOTH    MAX     41     42  40  35  42  32  40  46  42  42  43  43  48  53  44  40  39  41  46  50  47  53  53  50  48
   87013        BOTH    MIN     41     19  20  19  19  17  19  20  19  20  20  20  19  20  19  20  20  20  22  24  24  26  26  25  22
   87013        BOTH    AVG     41     28  26  24  24  24  25  28  25  24  26  25  27  25  26  26  27  28  30  33  35  37  37  35  32

   87013        YES     MAX     29     40  36  35  36  30  36  46  42  42  43  43  48  53  44  40  39  41  42  45  44  53  52  50  48
   87013        YES     MIN     29     19  20  19  19  17  20  23  19  20  20  20  19  20  19  20  20  20  22  24  24  26  27  25  22
   87013        YES     AVG     29     28  26  24  24  24  25  31  26  24  25  25  26  25  25  25  27  28  30  32  34  37  37  35  32

   87013        NO      MAX     12     42  40  32  42  32  40  37  29  27  43  33  32  36  36  35  34  35  46  50  47  49  53  48  45
   87013        NO      MIN     12     23  20  20  20  20  19  20  20  21  20  22  22  23  22  22  22  26  26  25  26  29  26  27  25
   87013        NO      AVG     12     27  26  24  24  23  23  23  23  24  28  28  28  29  30  28  29  29  32  34  35  38  39  36  32




   87014        BOTH    MAX     46     25  24  23  20  25  27  37  39  36  38  38  36  36  35  34  36  35  30  24  23  21  20  22  21
   87014        BOTH    MIN     46      9   9   9   9   9   9   9   9   9  11   9   9  11  13  13  13  11  11  13  13  13  13  11   9
   87014        BOTH    AVG     46     16  16  16  16  16  20  26  27  27  28  28  27  27  27  27  26  25  20  19  18  17  17  17  16

   87014        YES     MAX     29     19  19  20  20  25  27  37  39  35  38  38  36  36  35  34  36  35  30  24  23  20  20  22  20
   87014        YES     MIN     29     11  11  11  11   9  14  20  22  22  20  20  19  18  19  19  19  19  13  16  16  14  15  14  14
   87014        YES     AVG     29     16  16  16  16  17  22  31  32  32  33  33  32  31  31  31  30  29  23  20  19  17  17  17  17

   87014        NO      MAX     17     25  24  23  18  20  20  29  30  34  34  34  31  31  32  32  31  31  23  20  20  21  20  20  21
   87014        NO      MIN     17      9   9   9   9   9   9   9   9   9  11   9   9  11  13  13  13  11  11  13  13  13  13  11   9
   87014        NO      AVG     17     17  16  16  15  16  16  17  18  19  20  20  20  19  19  19  18  18  16  17  17  17  17  17  16
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Table B-1 (cont'd)

87000 COMPLEX LOAD

ELECTRICITY - 3 PHASE KVA

BUILDING	DUTY DAY	LOAD	NBR DAYS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
87015	BOTH	MAX	42	47	42	39	40	46	42	43	44	42	42	45	43	44	47	43	47	47	54	50	52	55	55	58	48
87015	BOTH	MIN	42	22	21	21	22	22	22	22	22	21	22	21	22	22	22	22	22	23	23	24	24	24	24	24	24
87015	BOTH	AVG	42	35	33	32	31	32	33	33	32	32	33	33	34	33	33	34	35	35	37	38	39	40	41	40	38
87015	YES	MAX	30	47	42	38	40	46	42	43	44	42	42	42	42	40	41	43	47	47	48	50	52	55	55	58	48
87015	YES	MIN	30	22	22	22	22	22	22	23	22	21	22	21	22	22	22	22	22	23	24	24	24	24	24	24	24
87015	YES	AVG	30	35	33	32	31	32	33	34	33	32	32	32	33	32	32	33	35	36	37	39	39	40	41	40	37
87015	NO	MAX	12	43	41	39	38	37	37	36	36	38	41	45	43	44	47	43	47	45	54	49	49	53	54	52	48
87015	NO	MIN	12	24	21	21	22	23	23	22	23	22	23	23	24	23	26	23	24	23	23	27	27	26	27	25	24
87015	NO	AVG	12	34	32	32	31	31	31	31	30	31	34	35	36	36	35	35	36	35	36	37	38	40	41	40	38
87016	BOTH	MAX	44	52	52	50	52	49	47	45	48	49	48	47	47	47	49	48	50	47	43	40	38	38	38	37	43
87016	BOTH	MIN	44	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
87016	BOTH	AVG	44	19	21	20	21	22	24	25	29	30	30	30	29	29	29	28	27	25	23	21	19	20	20	19	19
87016	YES	MAX	31	52	52	50	52	49	47	45	48	49	48	47	47	47	49	48	50	47	43	40	38	38	38	37	43
87016	YES	MIN	31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
87016	YES	AVG	31	19	21	21	22	24	26	28	33	34	34	34	33	33	33	32	31	28	25	23	20	20	21	20	19
87016	NO	MAX	13	31	31	30	30	32	32	30	31	32	32	31	31	28	28	29	31	30	30	30	30	31	29	28	29
87016	NO	MIN	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
87016	NO	AVG	13	20	21	19	19	19	20	20	20	20	20	20	21	20	20	18	18	18	18	18	18	18	18	18	18
87017	BOTH	MAX	82	108	103	110	116	125	133	140	130	133	133	121	135	130	121	121	120	123	121	120	95	93	100	105	105
87017	BOTH	MIN	82	61	61	66	63	63	63	78	75	83	75	80	90	78	83	86	81	90	93	66	63	61	63	63	63
87017	BOTH	AVG	82	77	77	78	88	94	97	112	107	108	100	102	116	112	106	104	99	113	111	101	80	77	78	78	78
87017	YES	MAX	59	108	103	110	116	125	133	140	130	130	126	111	135	130	120	116	115	123	121	120	95	93	100	105	105
87017	YES	MIN	59	61	61	66	71	73	88	106	96	98	75	80	103	108	93	86	81	96	101	80	66	61	68	66	66
87017	YES	AVG	59	77	77	78	92	100	105	121	113	111	96	100	122	121	107	102	95	114	114	108	82	78	79	80	79
87017	NO	MAX	23	95	93	93	106	110	121	120	110	133	133	121	125	125	121	121	120	116	115	105	93	93	93	83	81
87017	NO	MIN	23	63	66	66	63	63	63	78	75	83	95	93	90	78	83	100	95	90	93	66	63	63	63	63	63
87017	NO	AVG	23	79	77	76	77	77	79	88	92	100	111	108	102	90	102	110	107	110	105	82	75	76	76	74	74

Table B-1. (cont'd)

87000 COMPLEX LOAD

ELECTRICITY - 3 PHASE KVA

BUILDING	DUTY DAY	LOAD	NBR DAYS	HOUR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
87018	BOTH	MAX	28	724	719	719	719	714	719	714	719	719	739	724	739	734	739	739	734	753	753	734	729	729	729	729	729
87018	BOTH	MIN	28	671	676	680	656	671	666	661	666	671	671	666	671	676	680	685	685	685	685	690	685	685	680	676	671
87018	BOTH	AVG	28	696	694	693	692	692	692	692	694	698	703	706	709	710	714	713	715	716	716	713	710	708	705	700	698
87018	YES	MAX	20	724	719	719	719	714	719	714	719	719	739	724	739	734	739	739	734	753	753	734	729	729	729	729	729
87018	YES	MIN	20	680	680	680	656	671	666	661	666	671	676	685	676	680	695	695	695	695	695	695	695	695	695	680	680
87018	YES	AVG	20	699	696	695	691	691	691	690	693	698	705	708	710	711	717	717	719	721	720	716	712	710	707	703	700
87018	NO	MAX	8	719	719	714	710	710	710	705	710	710	714	719	724	724	724	724	729	724	719	719	714	714	719	719	710
87018	NO	MIN	8	671	676	680	680	676	680	685	680	676	671	666	671	676	680	685	685	685	685	690	685	685	680	676	671
87018	NO	AVG	8	690	689	688	694	695	695	696	696	697	699	702	705	707	707	704	704	704	705	706	704	704	700	695	691
87019	BOTH	MAX	33	24	23	23	22	23	26	37	37	39	38	39	36	36	34	34	32	32	27	24	24	23	23	23	23
87019	BOTH	MIN	33	14	14	14	14	14	15	14	14	14	16	15	15	14	15	15	15	15	15	15	15	15	15	15	15
87019	BOTH	AVG	33	20	20	19	19	20	20	27	28	29	29	29	28	27	26	26	26	25	22	21	20	20	20	20	20
87019	YES	MAX	23	24	23	23	22	23	26	37	37	39	38	39	36	36	34	34	32	32	27	23	24	23	23	22	23
87019	YES	MIN	23	14	14	14	14	14	17	25	28	28	29	26	24	24	22	20	21	21	19	17	17	17	17	17	17
87019	YES	AVG	23	20	20	20	20	20	21	30	32	33	33	33	31	30	29	29	28	27	23	21	21	20	20	20	20
87019	NO	MAX	10	22	23	23	22	22	22	22	23	22	31	38	29	33	28	28	28	27	24	24	23	22	23	23	23
87019	NO	MIN	10	16	16	14	14	14	15	14	14	14	16	15	15	14	15	15	15	15	15	15	15	15	15	15	15
87019	NO	AVG	10	20	20	19	19	18	18	19	18	19	20	21	21	21	21	20	20	20	19	19	19	19	19	19	19
87020	BOTH	MAX	33	56	52	52	50	50	59	66	51	58	59	61	60	64	63	60	60	59	61	66	69	72	72	68	66
87020	BOTH	MIN	33	40	37	36	38	38	39	37	37	37	39	37	40	41	33	38	40	38	43	40	42	46	46	48	42
87020	BOTH	AVG	33	48	45	44	43	44	47	48	44	45	45	46	48	48	47	46	47	49	52	54	55	57	58	56	51
87020	YES	MAX	23	56	52	52	50	50	59	66	51	58	52	55	53	53	53	54	52	55	59	66	69	72	72	68	66
87020	YES	MIN	23	40	37	36	38	38	41	40	37	37	39	37	40	41	33	38	40	38	43	40	42	46	46	48	42
87020	YES	AVG	23	48	44	43	43	44	48	51	44	44	43	44	46	46	44	44	46	48	51	53	54	56	57	55	50
87020	NO	MAX	10	55	52	50	50	49	50	48	50	56	59	61	60	64	63	60	60	59	61	58	64	66	68	68	62
87020	NO	MIN	10	43	42	40	39	39	39	37	39	42	44	45	47	45	46	44	45	44	47	48	49	50	48	52	48
87020	NO	AVG	10	49	47	45	43	44	43	42	44	47	49	52	54	53	53	51	52	52	53	55	57	58	59	59	53

Table B-[illegible] (cont'd)

87000 COMPLEX LOAD

ELECTRICITY - 3 PHASE KVA

BUILDING	DUTY DAY	LOAD	NBR DAYS	1	2	3	4	5	6	7	HOUR 8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
87021	BOTH	MAX	33	47	45	41	40	40	42	48	40	40	41	48	45	46	44	42	46	47	50	46	50	49	50	49	48
87021	BOTH	MIN	33	33	33	32	32	29	32	32	32	33	29	32	31	32	33	34	31	35	37	36	37	35	38	36	37
87021	BOTH	AVG	33	40	38	37	37	36	37	38	36	37	37	37	38	39	38	38	39	39	41	42	43	43	44	43	41
87021	YES	MAX	23	47	42	41	40	40	42	48	40	40	41	40	42	46	42	42	45	47	50	46	50	43	50	49	45
87021	YES	MIN	23	33	33	32	32	29	32	35	32	33	29	32	31	32	33	34	31	35	37	36	37	35	38	36	37
87021	YES	AVG	23	39	38	37	37	36	37	39	37	37	36	36	37	37	37	38	33	39	41	42	43	43	44	43	40
87021	NO	MAX	10	45	45	40	40	40	40	40	39	39	41	48	45	46	44	42	45	44	48	45	46	49	48	49	48
87021	NO	MIN	10	37	35	35	35	33	34	32	33	35	34	32	35	36	37	36	37	36	39	40	40	38	39	37	37
87021	NO	AVG	10	40	39	37	37	37	36	36	36	37	37	39	40	41	41	40	41	40	42	42	42	43	44	44	42
87022	BOTH	MAX	31	46	46	45	46	45	49	51	43	50	51	50	54	52	51	53	54	54	58	60	62	65	63	63	54
87022	BOTH	MIN	31	35	33	30	31	29	30	32	31	32	32	34	36	32	33	34	32	33	34	38	40	39	36	36	35
87022	BOTH	AVG	31	41	38	37	37	36	38	40	36	37	39	40	43	43	42	43	43	44	45	50	52	54	52	51	45
87022	YES	MAX	22	46	46	45	45	45	49	51	40	42	49	45	54	51	49	52	50	54	58	60	62	65	63	63	54
87022	YES	MIN	22	35	33	30	31	29	30	35	31	32	32	34	36	32	33	34	32	33	34	38	40	39	36	36	35
87022	YES	AVG	22	41	38	36	36	36	39	41	36	37	38	39	42	42	40	41	41	42	45	49	52	54	51	50	44
87022	NO	MAX	9	45	42	45	46	42	45	42	43	50	51	50	53	52	51	53	54	51	55	58	59	58	61	58	53
87022	NO	MIN	9	37	36	33	35	32	32	32	32	32	32	35	43	45	45	47	43	43	41	42	45	45	48	47	41
87022	NO	AVG	9	42	39	38	38	36	37	37	37	39	41	44	48	48	48	50	48	48	48	51	53	54	54	53	46

Table B-1. (cont'd)

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                                                87000 COMPLEX LOAD

                                             ELECTRICITY 3 PHASE KVA

             TOTALS FOR BUILDINGS   87012  87013  87014  87015  87016

   DUTY                                                                   HOUR
   DAY    LOAD      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24


   BOTH   MAX     214  205  190  199  195  201  223  217  211  214  218  219  228  218  214  218  220  221  217  213  223  222  222  209
   BOTH   MIN      81   81   80   80   78   82   83   81   80   82   80   83   86   85   87   85   86   90   95   96  100  102   97   90
   BOTH   AVG     137  133  128  127  129  139  153  150  149  153  153  155  153  152  152  153  153  150  152  154  159  161  156  147

   YES    MAX     206  193  186  191  192  197  223  217  211  213  213  215  219  209  208  217  220  211  238  207  219  219  222  208
   YES    MIN      83   84   83   82   78   88  101   95   93   91   91   93   93   91   93   91   94   98   98   99  101  105  100   95
   YES    AVG     136  132  128  128  132  143  167  162  158  160  160  161  159  157  157  160  160  155  155  154  158  162  157  146

   NO     MAX     186  183  166  173  164  169  174  166  171  193  188  182  187  186  188  189  190  201  232  199  210  212  203  192
   NO     MIN      89   83   82   82   84   83   83   83   84   85   87   88   90   93   90   91   94   94  131  104  109  107  103   97
   NO     AVG     138  133  128  125  125  125  127  126  130  139  142  144  143  143  140  141  141  143  149  153  160  163  158  148
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Table B-2. Hourly Electricity Demands in KVA for the five Selected Thermal Load Buildings

87000 COMPLEX LOAD

ELECTRICITY 3 PHASE KVA

TOTALS FOR BUILDINGS 87003 87004 87005 87009 87011 87014 87016 87019

DUTY DAY	LOAD	HOUR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BOTH	MAX	267	262	258	254	272	321	385	408	403	408	406	390	380	388	392	393	361	331	300	285	262	255	257	258
BOTH	MIN	130	135	130	126	128	129	129	133	135	138	141	136	139	142	141	143	139	137	135	133	133	136	136	134
BOTH	AVG	189	192	185	185	191	211	267	296	296	295	293	287	279	281	276	273	261	231	211	202	198	195	197	193
YES	MAX	261	257	255	254	272	321	385	408	403	408	406	390	380	388	392	393	361	331	299	285	261	255	256	257
YES	MIN	133	139	132	129	128	140	177	231	225	230	225	205	204	209	204	214	203	172	146	142	139	143	146	144
YES	AVG	192	191	189	187	196	225	305	342	338	335	333	325	315	319	313	309	295	252	222	209	201	199	202	196
NO	MAX	225	227	222	219	222	232	276	286	272	310	314	285	264	253	248	249	240	234	232	235	233	233	229	231
NO	MIN	139	140	136	137	135	134	134	133	135	138	141	136	139	142	141	143	139	137	140	139	142	140	139	137
NO	AVG	186	187	181	182	182	184	188	192	201	205	206	203	197	196	192	188	185	183	186	187	187	185	189	185

Table B-3. Hourly Electricity Demands in KVA for the Five Selected Thermal Load Buildings Plus the Food Service Building

87000 COMPLEX LOAD

ELECTRICITY 3 PHASE KVA

TOTALS FOR BUILDINGS 87012 87013 87014 87015 87016 87017

DUTY DAY	LOAD	HOUR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BOTH	MAX	322	308	300	315	320	334	363	347	344	347	339	354	358	339	335	338	343	342	337	308	316	322	327	314
BOTH	MIN	142	142	146	143	141	145	161	156	163	157	160	173	154	168	173	166	176	183	161	159	161	165	160	153
BOTH	AVG	214	210	206	215	223	236	265	257	257	253	255	271	265	258	256	252	266	261	253	234	236	239	234	225
YES	MAX	314	296	296	307	317	320	363	347	341	339	324	350	349	329	324	332	343	332	328	302	312	319	327	313
YES	MIN	144	145	149	153	151	176	207	191	191	166	171	196	201	184	179	172	190	199	178	165	162	173	166	161
YES	AVG	213	209	206	220	232	248	288	275	269	256	260	283	280	264	259	255	274	269	263	236	236	241	237	225
NO	MAX	281	276	259	279	274	290	294	276	304	326	309	307	312	307	309	309	306	316	307	292	303	305	286	273
NO	MIN	152	149	148	145	147	146	161	158	167	180	180	178	168	176	190	186	184	187	167	167	172	170	166	160
NO	AVG	217	210	204	202	202	204	215	218	230	250	250	246	233	245	250	248	251	248	231	228	236	239	232	222

Table B-4

Table B-4. Hourly Electricity Demands in KVA for All Headquarters and Administration/Supply Buildings

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                                        87000 COMPLEX LOAD

                                    ELECTRICITY 3 PHASE KVA

            TOTALS FOR BUILDINGS   87007  87012  87013  87015  87020  87021  87022

    DUTY                                                               HOUR
    DAY    LOAD      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24



    BOTH   MAX     325  312  292  299  292  315  349  303  314  317  331  335  347  334  326  332  337  359  374  378  399  399  389  354
    BOTH   MIN     202  197  190  191  187  195  196  192  194  192  196  202  202  198  202  197  204  217  220  226  232  235  228  217
    BOTH   AVG     261  246  239  235  235  246  258  238  239  245  249  259  258  254  255  260  267  278  294  303  313  315  305  281

    YES    MAX     323  302  291  289  289  311  349  298  306  307  306  320  325  306  309  318  331  344  365  372  395  396  389  351
    YES    MIN     202  198  191  191  187  198  212  193  194  192  196  202  202  198  202  197  204  218  220  226  232  236  228  217
    YES    AVG     259  244  235  234  235  248  270  242  238  238  241  250  250  243  246  254  263  277  292  300  311  313  303  276

    NO     MAX     310  302  283  297  276  287  285  276  285  315  321  318  330  326  321  327  322  354  354  360  374  380  373  343
    NO     MIN     223  211  205  206  202  203  199  202  206  208  214  228  231  234  230  229  232  239  243  253  255  255  253  238
    NO     AVG     263  251  242  238  235  233  234  233  242  256  271  280  281  282  278  280  280  287  293  306  317  322  313  287
```

Table B-5. Hourly Electricity Demands in KVA for All Barracks

87000 COMPLEX LOAD

ELECTRICITY 3 PHASE KVA

TOTALS FOR BUILDINGS 87006 87008 87010 87017 87018

DUTY DAY	LOAD	HOUR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BOTH	MAX	928	923	926	930	937	1000	1018	1026	1029	1048	1022	1058	1046	1042	1042	1035	1049	1044	1017	996	997	983	972	954
BOTH	MIN	770	782	791	758	772	775	777	779	810	813	829	885	878	883	893	880	890	890	858	845	808	788	776	777
BOTH	AVG	838	837	838	846	851	872	904	928	942	943	951	974	971	972	968	963	975	972	956	930	914	872	847	844
YES	MAX	927	923	926	929	937	1000	1018	1026	1026	1038	1012	1053	1046	1036	1037	1028	1049	1042	1017	996	997	983	972	951
YES	MIN	779	789	793	766	782	805	819	844	876	855	880	904	915	914	907	901	906	910	891	865	823	808	783	791
YES	AVG	840	839	839	848	854	886	923	950	960	951	958	985	983	980	974	967	982	979	967	936	925	877	854	847
NO	MAX	895	894	888	858	902	915	924	930	985	1001	1001	1022	1016	1009	1005	1010	1000	1001	982	969	962	920	883	875
NO	MIN	779	788	791	791	784	789	814	800	822	833	842	887	878	889	912	897	898	891	860	851	824	798	784	777
NO	AVG	837	835	832	840	839	842	856	869	893	923	940	950	942	953	958	956	957	953	929	917	888	859	832	831

Table B-6. Hourly Electricity Demands in KVA for Five Miscellaneous Buildings (Dispensary, Branch Exchange, Gymnasium, Food Service, and Central Energy)

```
                                                  87000 COMPLEX LOAD

                                                 ELECTRICITY 3 PHASE KVA

              TOTALS FOR BUILDINGS    87003  87004  87005  87006  87007  87008  87009  87010  87011  87012

                                      87013  87014  87015  87016  87017  87018  87019  87020  87021  87022

  DUTY                                                                HOUR
  DAY   LOAD      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24



  BOTH  MAX    1520 1497 1476 1483 1501 1636 1752 1737 1746 1773 1759 1783 1773 1764 1760 1760 1747 1734 1691 1659 1658 1637 1618 1566
  BOTH  MIN    1102 1114 1111 1075 1087 1059 1102 1104 1139 1143 1166 1223 1219 1223 1236 1220 1233 1244 1213 1204 1173 1159 1140 1128
  BOTH  AVG    1288 1275 1262 1266 1277 1329 1429 1462 1477 1483 1493 1520 1508 1507 1499 1495 1503 1481 1461 1435 1425 1382 1349 1318

  YES   MAX    1511 1482 1472 1472 1498 1632 1752 1732 1735 1753 1724 1763 1751 1730 1738 1739 1741 1717 1681 1653 1653 1634 1617 1559
  YES   MIN    1114 1126 1116 1086 1097 1144 1208 1268 1295 1277 1301 1311 1321 1321 1313 1312 1313 1300 1257 1233 1194 1187 1157 1152
  YES   AVG    1291 1274 1263 1269 1285 1359 1498 1534 1536 1524 1532 1560 1548 1542 1533 1530 1540 1508 1481 1445 1437 1389 1359 1319

  NO    MAX    1430 1423 1393 1414 1400 1434 1485 1492 1542 1626 1636 1625 1610 1588 1574 1585 1562 1589 1568 1564 1569 1533 1485 1449
  NO    MIN    1141 1139 1132 1134 1121 1126 1147 1135 1163 1179 1197 1251 1248 1265 1283 1269 1269 1267 1248 1243 1221 1193 1176 1152
  NO    AVG    1286 1273 1255 1260 1256 1259 1278 1294 1336 1384 1417 1433 1420 1431 1428 1424 1422 1423 1413 1410 1392 1366 1334 1303
```

Table B-7. Hourly Electricity Demands in KVA for all Twenty Buildings

TYPE 38: ENERGY LOAD PROCESSOR

General Description

This component processes the various components of the electrical and thermal loads in several ways. Its primary functions are:

1) scale the electrical and thermal loads,
2) assign a portion of the air conditioning load to absorption chillers, if present,
3) provide output data necessary to control the turbine.

The four raw load components (generated by another component or read by a data reader), base electric, air conditioning electric, base thermal, and space heating thermal, are first multiplied by their respective scale factors (one for electric one for thermal).

Then the scaled air conditioning electrical load is separated into A/C electric and A/C thermal loads in order to make the most of the absorption chillers which may be present.

Nothing more is done with the three components of the thermal load; they are merely passed on for further processing by a unit such as the Thermal Consumer (TYPE 33).

The two electrical loads, however, are combined into a total electric load. If the total electric load is above the "shave line," then the turbine will be ordered to operate, even if it must use the auxiliary, fossil-fueled boiler. The turbine will be told to generate enough electricity so that the electricity purchased from the power company does not exceed the shave line.

The condenser back pressure is also set low if there exists an electrical air conditioning load, otherwise it is set high to increase the thermal output from the system.

There are many circumstances under which the turbine will be asked to turn on when total electrical demand is below the shave line. Some of these are:

1) if the tank which provides the steam generator with solar-heated fluid is getting nearly full,
2) if it is late enough in the day and there is at least a one hour supply of fluid in the tank,
3) if the storage tank for the low temperature or thermal subsystem is nearly empty and there is sufficient fluid in the high-temperature tank to justify turbine turn-on.
4) if it's getting late and there is fluid in the high-temperature tank that should be used up,
5) if the turbine was running during the previous step and there is still fluid in the high-temperature tank.

In all of the above circumstances, the use of the auxiliary, fossil fueled boiler is prohibited, and an output of one kilowatt is requested from the turbine. In such a case, the turbine will generate its minimum output which is a function of the design KW and the turn-down ratio.

Nomenclature

ABSCAP	Absorption A/C tonnage
AUX	Control signal to turbine: 1 = O.K. to use auxiliary boiler 0 = do not use auxiliary boiler
F_{EL}	Electrical scale factor

F_{TH}	Thermal scale factor
KW_{AR}	Raw A/C electric load
KW_{AS}	Scaled A/C electric load (also adjusted for absorption A/C)
KW_{BR}	Raw base electric load
KW_{BS}	Scaled base electric load
KW_{S}	"Shave line" or maximum number of KW to be provided by utility company
KW_{TD}	Design KW of turbine
KW_{TOT}	Total electric demand after scaling and adjustment for absorption chillers
KW_{TR}	KW requested of the turbine
KW_{TRP}	KW requested of the turbine in previous time step
M_{THP}	Mass of fluid in high-temperature primary tank
M_{THS}	Mass of fluid in high-temperature secondary tank
M_{TLP}	Mass of fluid in low-temperature primary tank
P_{B}	Condenser back pressure
P_{BH}	High back pressure level
P_{BL}	Low back pressure level
Q_{AS}	Scaled A/C thermal load (for absorption chillers)
Q_{BS}	Scaled base thermal load
Q_{BR}	Raw base thermal load
Q_{SR}	Raw space heating thermal load
Q_{SS}	Scaled space heating thermal load
RATIO	A/C ratio (1 Centrifugal KW = X Absorption BTUs)

t_e	Earliest turbine turn-on time as pertains to reason 2 above
t_ℓ	Time for end-of-day tank run-out (reason 4 for turbine turn-on)

Mathematical Description

$$KW_{BS} = KW_{BR} F_{EL}$$

$$Q_{BS} = Q_{BR} F_{TH}$$

$$Q_{SS} = Q_{SR} F_{TH}$$

$$Q_{AS} = MIN\ (KW_{AR} F_{EL} RATI0,\ ABS_{CAP})$$

$$KW_{AS} = KW_{AR} F_{EL} - Q_{AS}/RATI0$$

$$KW_{TOT} = KW_{BS} + KW_{AS}$$

$$P_B = \begin{cases} P_{BL} \text{ if } KW_{AS} > 0 \\ P_{BH} \text{ otherwise} \end{cases}$$

$$KW_{TR} = \begin{cases} KW_{TOT} - KW_S \text{ if } KW_{TOT} > KW_S \\ 1 \quad \text{if any of the 5 conditions for the turn-on described above in general description are met} \\ 0 \quad \text{otherwise} \end{cases}$$

$$AUX = \begin{cases} 1 \quad \text{if } KW_{TOT} > KW_S \\ 0 \quad \text{otherwise} \end{cases}$$

Component Configuration

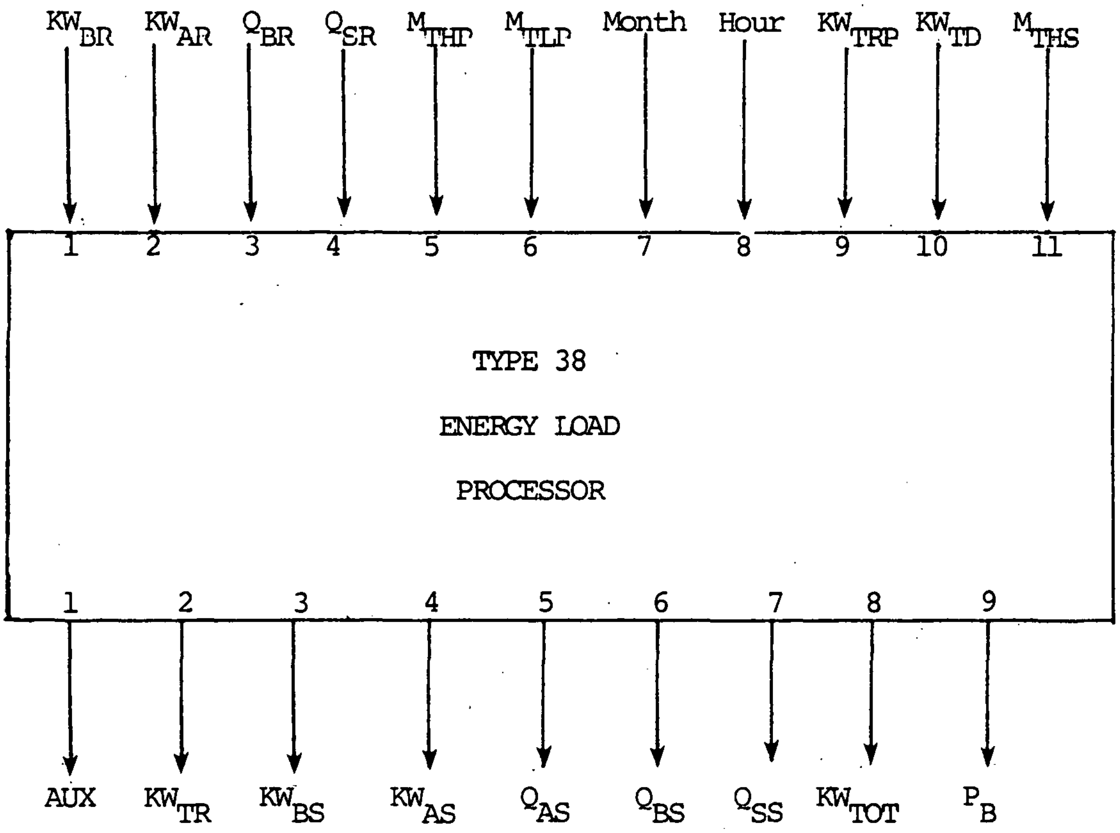
PARAMETER NO.	DESCRIPTION
1	F_{TH}, thermal scale factor
2	F_{EL}, electrical scale factor
3	RATIO, A/C Ratio
4	ABS_{CAP}, absorption A/C capacity in tons
5	t_e, early turbine turn-on time
6	t_ℓ, late turbine turn-on time
7	KW_S, shave point
8	P_{BL}, low back pressure level
9	P_{BH}, high back pressure level

INPUT NO.	DESCRIPTION
1	KW_{BR}, raw base electric load
2	KW_{AR}, raw A/C electric load
3	Q_{BR}, raw base thermal load
4	Q_{SR}, raw space heating thermal load
5	M_{THP}, mass of fluid in high-temperature primary tank
6	M_{TLP}, mass of fluid in low-temperature primary tank
7	Month (January = 1, etc.)
8	Hour of the day (24 hour clock)
9	KW_{TRP}, KW requested from turbine on previous iteration
10	KW_{TD}, design KW of turbine
11	M_{THS}, mass of fluid in high-temperature secondary tank

OUTPUT NO.	DESCRIPTION
1	AUX, Control signal to turbine 1 = O.K. to use auxiliary boiler 0 = Do not use auxiliary boiler
2	KW_{TR}, KW requested of turbine
3	KW_{BS}, scaled base electric load
4	KW_{AS}, scaled and adjusted A/C electric load
5	Q_{AS}, scaled and adjusted A/C thermal load
6	Q_{BS}, scaled base thermal load
7	Q_{SS}, scaled space heating thermal load
8	K_{TOT}, total KW demand after scaling and adjusting for absorption chillers
9	P_B, condenser back pressure

Information Flow Diagram

Inputs	11
Outputs	9
Parameters	9
Derivatives	0



Parameters

1. F_{TH}
2. F_{EL}
3. RATIØ
4. ABS_{CAP}
5. t_e
6. t_ℓ
7. KW_S
8. P_{BL}
9. P_{BH}

APPENDIX C

APPENDIX C. Modifications to the TRNSYS SYSTEM Simulation Program

The solar energy simulation system currently used by the ATU Solar Total Energy Project is based upon the Transient Simulation Program (TRNSYS) developed by the Solar Energy Laboratory, University of Wisconsin-Madison, Madison, Wisconsin under NSF and ERDA contracts. This appendix documents only the extensions and modifications to the TRNSYS system defined in the December 1976 TRNSYS Manual.

Copies of the manual may be obtained at the following address:

TRNSYS Coordinator
Solar Engineering Laboratory
1303 Engineering Research Bldg.
University of Wisconsin-Madison
1500 Johnson Drive
Madison, WI. 53706

The price of the above manual is $10.00 as of January, 1976. Inquiries regarding the modifications to and extensions of TRNSYS documented herein should be addressed to;

American Technological University
Solar Total Energy Project
Simulation Model
P. O. Box 1416
Killeen, Texas 76541

TRNSYS MODIFICATIONS

This section will outline the modifications which have been made to the TRNSYS system. A subsequent section will discuss the extensions to TRNSYS, i.e., the new subroutines which have been added.

1. Number of subroutines: The number of allowable subroutines has been increased to 50. As of this writing, there are not 50 subroutines in use.

Those which are not currently assigned are included within the system as dummy subroutines.

2. Calling Procedure: The calling procedure has been altered so that each component is called at least twice on each time step. This modification insures that each component will receive inputs relative to the time step.
3. Error Subroutine: The error handler subroutine, TYPECK, has had a number of new error conditions added.
4. Number of Outputs: The number of outpus per subroutine has been increased to 25.
5. Number of Inputs: The number of inputs per subroutine has been increased to 18.
6. Input limitation: The scanning mechanism has been altered restricing input simulation definition to columns 1-72 of the input record. Columns 73-80 may thus be used as sequence fields enabling the effective use of some test editing systems. The input data may still be coded in columns 73-80, and thus current TRNSYS data files may still be utilized.

TRNSYS EXTENSIONS

The following subroutines have been added to the TRNSYS system. The information in the TRNSYS Manual regarding general use of the subroutine applies to these new subroutines. The numbering scheme used to define the subroutines and the format of the definitions is intended to be compatible with the TRNSYS definitions.

The component subroutines discussed in this appendix are listed below:

SECTION	COMPONENT
4.28	Storage Tank
4.29	Rankine Cycle
4.30	General Focusing Collector
4.31	Cooling Tower
4.32	Unformatted Data Reader
4.33	Thermal Consumer
4.34	Continuous Controller
4.35	Steam-Generator-Turbine
4.36	Condenser
4.37	Condenser Pump
4.38	Energy Load Processor
4.39	Sheldahl SLATS^{TM} Focusing Collector

TYPE 28: STORAGE TANK

General Description

The general storage tank is distinguished from the TRNSYS TYPE 4 Stratified Fluid Storage Tank in several respects. The TYPE 28 tank is not stratified and hence there is only one temperature for the fluid. There is no optional tank heating element, and the volume of the fluid in the tank is allowed to vary. This last consideration is significant in systems employing a multitank system in which fluid flows from one tank to another.

When a mass of fluid at a given temperature is placed into the tank, it is assumed that perfect mixture is obtained, and a new temperature is computed for the entire mass of the tank according to the following formula

$$T_T = \frac{T_T \cdot V_T + T_i \cdot V_i}{V_T + V_i}$$

Environmental energy losses are calculated as a parameter times the ambient and tank temperature differential.

$$Q_{env} = Q_{Loss} \cdot (T_T - T_A)$$

Two of the tank inputs represent input and output mass flow. In general, it is the responsibility of the controller components to insure that the input and output flows do not result in tank underflow or overflow conditions. If this should occur, a warning message is printed, the excess fluid is discarded, and simulation is allowed to continue. That is, the volume of the tank is neither smaller nor greater than the tank capacity. Overflow and underflow messages are never allowed to occur on the first iteration of a timestep; this situation may occur on the first iteration because of calling sequence, and this provided one of the motives for requiring each component to be called at least twice.

Because of the mixing strategy and computation of new tank temperatures, there could potentially be convergence problems especially in systems with smaller tank and flow capacities. To avoid this problem, the input and output flows are not allowed to vary after the fifth iteration, and the input and output flows are fixed at that time to the values received on the fifth iteration. It should be noted that there has been no instance of this situation to date. This concept is similar to that employed for "sticking" the on-off differential controller (TYPE 2).

Nomenclature

Symbolic	Subroutine Mnemonic	Description
C_T	CAPTNK	Capacity of the tank
C_{tp}	SPHEAT	Specific heat of tank fluid
ρ	DENSTY	Density of tank fluid
Q_{LOSS}	ENLØSS	Environmental loss factor, e. g. $\frac{BTU}{{}^oR}$ or $\frac{KJ}{{}^oK}$
T_i	TIN	Temperature of input fluid
M_i	FLØWIN	Mass flow into tank, e.g., lbm or Kg
P_i	PRIN	Pressure of input fluid, e.g. PSIA, N/M^2
M_o	FLØWT	Output mass flow
T_A	TAMB	Ambient Temperature
V_T	VØLTNK	Tank Volume $V_T = V_T + \frac{M_i - M_o}{\rho}$
Q_{ENV}	QENV	Environmental Energy Loss $Q_{ENV} = Q_{LOSS} (T_T - T_A)$

Symbolic	Subroutine Mnemonic	Description
T_T	TTANK	Temperature of the tank
Q_T	QTANK	Energy stored in the tank $Q_T = V_T \cdot C_p \cdot T_T \cdot \rho$
Q_Δ	QDELTA	Change in energy of tank for this time step $Q_\Delta = Q_{T_i} - Q_{T_{i-1}}$
M_T		Mass of tank $M_T = V_T \cdot \rho$

Component Configuration

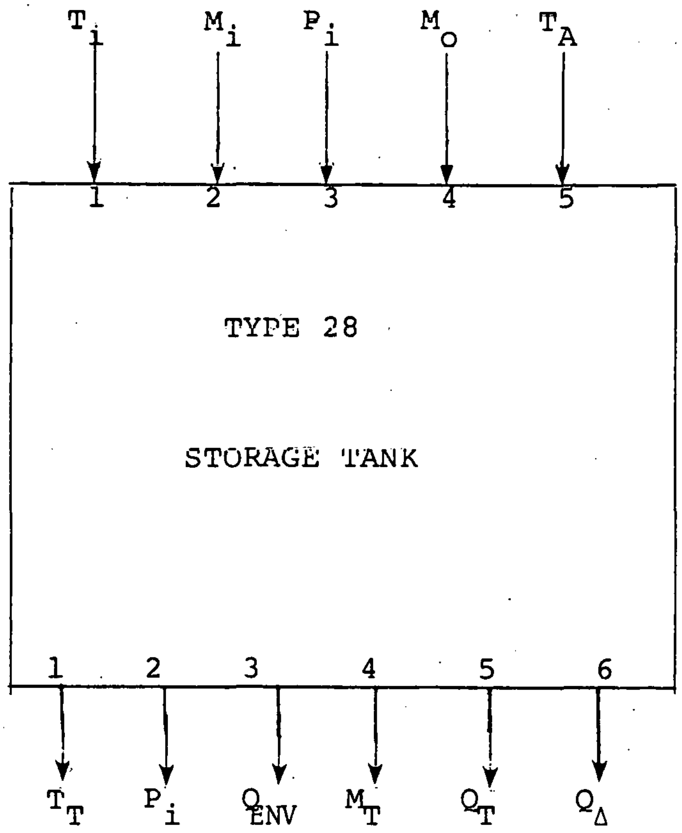
PARAMETER NO.	MNEMONIC
1	CAPTNK
2	V0TNK (May change with each timestep)
3	SPHEAT
4	DENSTY
5	TTANK (May change with each timestep)
6	ENL0SS

INPUT NO.	MNEMONIC
1	TIN
2	FL0WIN
3	PRIN
4	FL0UT
5	TAMB

OUTPUT NO.	MNEMONIC
1	TTANK
2	PRIN
3	QENV
4	VØLTNK * DENSTY (mass of tank)
5	QTANK
6	QDELTA

Information Flow Diagram

Inputs	5
Outputs	6
Parameters	6
Derivatives	0



PARAMETERS

1 C_T

2 V_T

3 C_p

4 ρ

5 T_T

6 Q_{ENV}

TYPE 29: RANKINE CYCLE

General Description

The Type 29 Rankine cycle is based upon the SOLSYS 2 Rankine cycle subroutine. The subroutine was originally designed for evaluation of various power cycle fluids and is well suited for this purpose. In its current state, it does not provide results as accurate as the TYPE 35, TYPE 36, and TYPE 37 subroutines when water is used as the cycle fluid.

The Type 29 Rankine cycle requires that the inputs be in SI units; however, the subroutine was written using English units and the SI units are converted within the subroutine. Reconversion to SI units is effected on the output side. The program could be easily modified to either allow only English units (by elimination of conversion) or to allow both modes (by use of an additional parameter and branching). The last alternative will probably be effected later.

Two constants, REIDEL and HBMS are required when using this subroutine. These constans represent the slope of the vapor pressure curve at the critical point and compressibility at the critical point respectively. Six other constants used in calculating the specific heat of the cycle fluid are also required, three each for the vapor and liquid stage. These values are given below, but are also provided below for a number of working fluids:

1. WATER (H_2O)

HMBS (BETA)	REIDEL (ALPHC)	CP0SI (Vapor)	CP1SI (Vapor)	CP2SI (Vapor)
9.096	7.402	1.78823E3	4.225E-2	1.473E-4

CPL0SI (liquid)	CPL1SI (liquid)	CPL2SI (liquid)
9.21119E3	-15.3	1.148E-2

2. Toluene ($CH_3C_6H_5$)

BETA	ALPHC	CP0SI	CP1SI	CP2SI
7.48	7.096	-2.857E2	3.046	-7.612E-4

CPL0SI	CPL1SI	CPL2SI
1.756E3	-1.955	2.208E-3

3. Chlorobenzene (C_6H_5Cl)

BETA	ALPHC	CP0SI	CP1SI	CP2SI
7.385	7.022	-2.164E2	2.412	-7.361E-4

CPL0SI	CPL1SI	CPL2SI
3.113E2	1.599	1.630E-4

4. Benzene (C_6H_6)

BETA	ALPHC	CP0SI	CP1SI	CP2SI
6.975	6.838	-4.104E2	3.182	-8.612E-4

CPL0SI	CPL1SI	CPL2SI
2.801E3	-5.435	6.000E-3

5. Thiophene (C_4H_4S)

BETA	ALPHC	CP0SI	CP1SI	CP2SI
7.701	6.761	-3.026E2	2.620	-9.478E-4

CPL0SI	CPL1SI	CPL2SI
3.968E3	-8.868	7.691E-3

6. Pyridine (C_5H_5N)

BETA	ALPHC	CP0SI	CP1SI	CP2SI
6.839	6.987	-4.874E2	3.233	-9.563E-4

CPL0SI	CPL1SI	CPL2SI
2.000E3	-2.891	3.762E-3

7. Freon 11 (CCl_3F)

BETA	ALPHC	CP0SI	CP1SI	CP2SI
6.850	6.740	2.983E2	6.846E-1	-2.932E-4

CPL0SI	CPL1SI	CPL2SI
2.169E3	-4.744	4.354E-3

The Rankine cycle can simulate supercritical and subcritical cycles with or without generation.

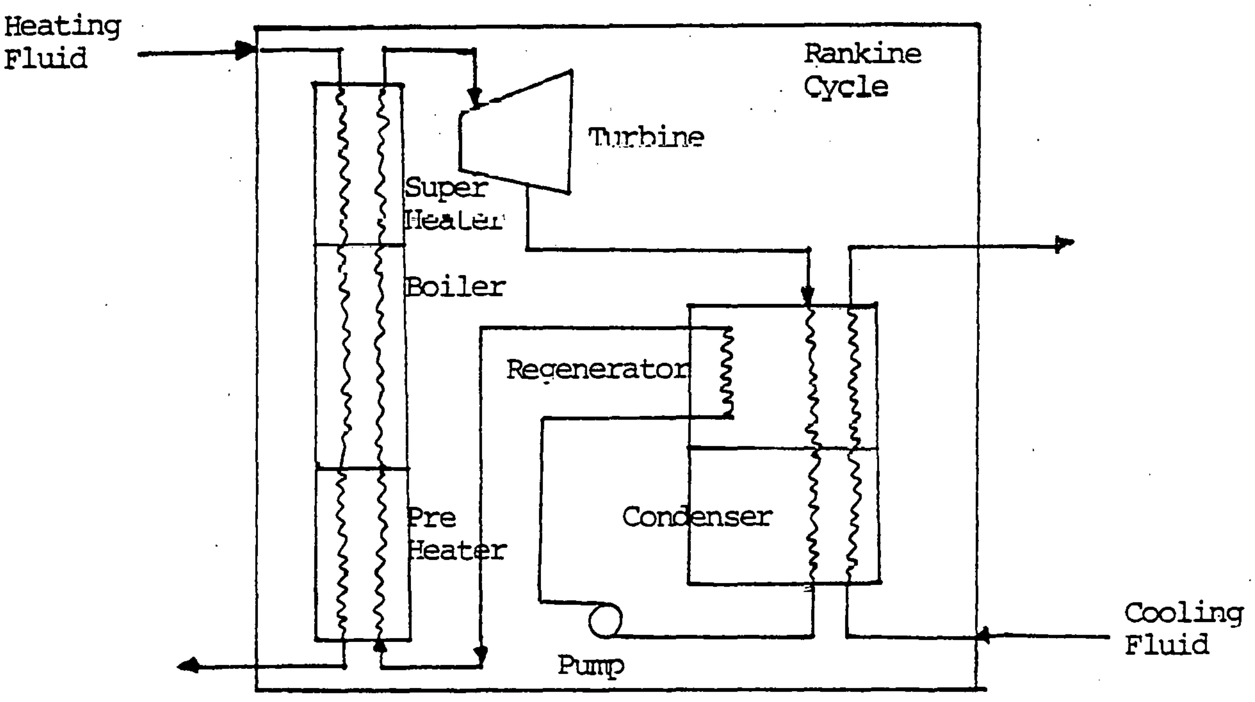
Nomenclature

Subroutine -Mnemonic	Description
DENS1	Fluid density, Boiler side (Kg/m^3)
SPHT1	Specific Heat Boiler Side (J/Kg°K)
DENS2	Fluid density, condenser side (Kg/m^3)
SPHT2	Specific heat, Boiler side (J/Kg°K)
BETA	HBMS constant
APLHC	Reidel constant
CPL0SI	Cycle liquid specific heat coefficient (J/Kg°K)
CPL1SI	Cycle liquid specific heat coefficient (J/Kg°K)
CPL2SI	Cycle liquid specific heat coefficient (J/Kg°K)
CP0SI	Cycle vapor specific heat coefficient (J/Kg°K)
CP1SI	Cycle vapor specific heat coefficient (J/Kg°K)
CP2SI	Cycle vapor specific heat coefficient (J/Kg°K)
GPGM	Cycle fluid molecular weight
TCRSI	Cycle fluid critical temperature (K)
PCRSI	Cycle fluid critical pressure (N/M^2)
TBLSI	Boiling temperature at one atmosphere (K)
ETGN	Generator efficiency
ETT	Turbine efficiency
ETR	Regenerator efficiency
ETN	Nozzle efficiency

Subroutine Mnemonic	Description
ETP	Pump efficiency
TL0WSI	Condenser temperature (K)
THIGHS	High temperature (K)
TB0UT	Boiler outlet temperature
TC0UT	Condenser outlet temperature
FBMAX	Maximum boiler flow rate (Kg/time)
FCMAX	Maximum condenser flow rate (Kg/time)
PHIGHS	High pressure if super heat cycle (N/m^2)
TBIN	Boiler inlet temperature of heating fluid (K)
FMBIN	Boiler heating fluid flow (Kg)
PBIN	Pressure at boiler inlet of heating fluid (N/m^2)
TCIN	Condenser inlet temperature of cooling fluid (K)
FMCIN	Condenser cooling fluid flow (Kg)
PCIN	Pressure at condenser inlet of cooling fluid (N/m^2)
ELDEM	Electrical demand (KW)
C0NTRL	Control function which determines if electricity is to be produced
PRMASS	Mass of fluid in primary storage tank
TB0UT	Boiler outlet temperature of heating fluid (K)
THEAT	Turbine duty (J)
TC0UT	Outlet temperature of condenser cooling fluid (K)

Subroutine Mnemonic	Description
CHEAT	Condenser duty (J)
ELECT	Electricity produced (KW)
AMD0T	Flow rate through power cycle of work fluid (Kg/hr)
DHT	Enthalpy of working fluid in turbine
DHC	Condenser enthalpy

Mathematical Description



There are four basic modes of operation for the Rankine cycle, flow driven or electricity demand driven both with or without the superheat cycle. In the electricity demand driven mode, the flow rate is adjusted to insure that the required amount of electricity is generated with the specified outlet temperature for the heating fluid. In the flow driven mode, the flow of the heating fluid through the boiler is given, and the amount of electricity is computed as a function of the outlet temperature and the flow rate.

Mode 1	Electrical demand driven, no superheater
Mode 2	Flow driven, no superheater
Mode 3	Electrical demand driven, superheater
Mode 4	Flow driven, superheater

$$\mathrm{AMDOT} = \frac{(3413)\ (\mathrm{ELDEM})}{\mathrm{ETGN}\ \left((-\mathrm{DHT})\ (\mathrm{ETT})\ -\ \frac{\mathrm{DHPW}}{\mathrm{ETP}}\right)}$$

MODE 1 & 3

$$\mathrm{FMBIN} = \frac{\mathrm{THEAT}}{(\mathrm{TBIN}-\mathrm{TBOUT})\ \ (\mathrm{SPHT1})}$$

MODE 2 & 4

$$\mathrm{THEAT} = (\mathrm{FMBIN})\ \ (\mathrm{TBIN}-\mathrm{TBOUT})\ \ (\mathrm{SPHT1})$$

$$\mathrm{ELECT} = \frac{\mathrm{THEAT}}{3.6\mathrm{E} + 06}$$

ALL MODES

$$\mathrm{CHEAT} = \left[\mathrm{DHC} + (1-\mathrm{ETR})\ \ (\mathrm{DHR})\right]\ \ \mathrm{AMDOT}$$

$$\mathrm{FMCIN} = \frac{\mathrm{CHEAT}}{(\mathrm{TCOUT}-\mathrm{TCIN})\ \ (\mathrm{SPHT2})}$$

The maximum flow rates through the boiler and condenser are not allowed to be exceeded. If the boiler flow is excessive, it is set to the maximum and the electrical production is thereby decreased. If the maximum condenser flow rate is exceeded, it is also set to the maximum and the outlet temperature is allowed to rise.

Component Configuration

PARAMETER NO.	DESCRIPTION
1	Mode 1 2 3 4 } see Mathematical Description
2	DENS1
3	SPHT1
4	DENS2
5	SPHT2

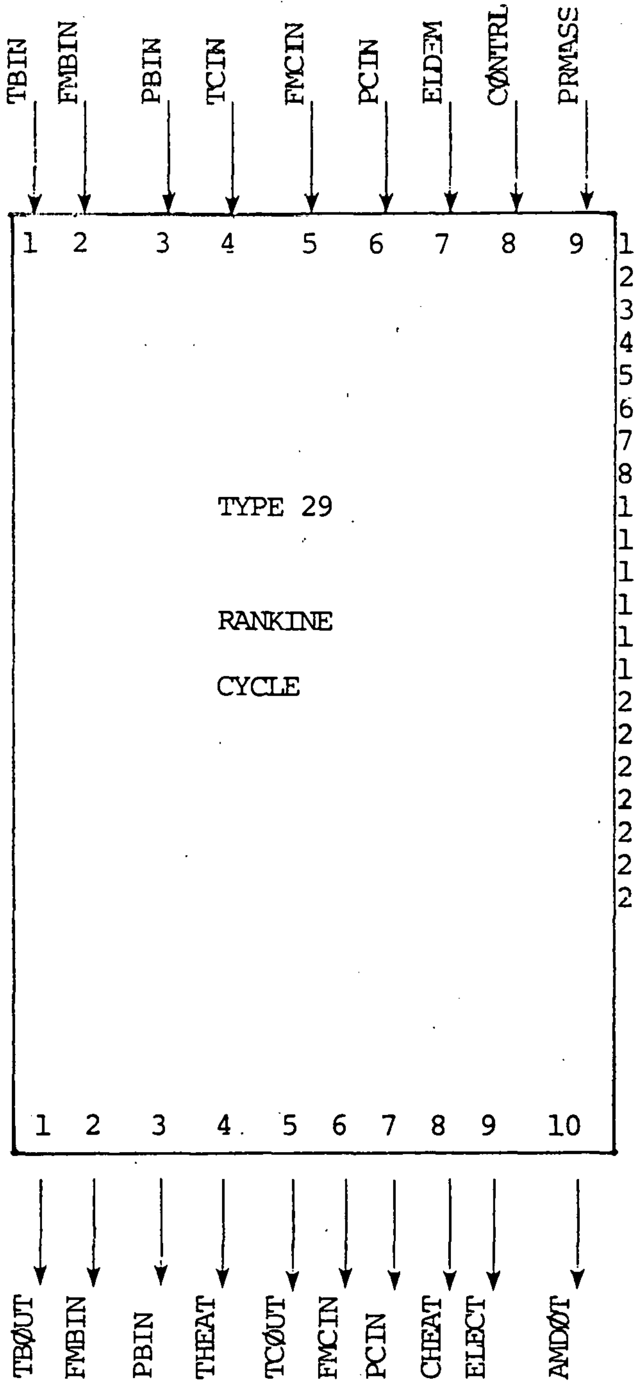
Component Configuration

PARAMETER NO.	DESCRIPTION
6	BETA
7	ALPHC
8	CPL0SI
9	CPL1SI
10	CPL2SI
11	CP0SI
12	CP1SI
13	CP2SI
14	GPGM
15	TCRSI
16	PCRSI
17	TBLSI
18	ETGN
19	ETT
20	ETR
21	ETN
22	ETP
23	TL0WSI
24	THIGHS
25	TB0UT
26	TC0UT
27	FBMAX
28	FCMAX
29	PHIGHS

INPUT NO.	DESCRIPTION
1	TBIN
2	FMBIN
3	PBIN
4	TCIN
5	FMCIN
6	PCIN
7	ELDEM
8	C0NTRL
9	PRMASS

Information Flow Diagram

Inputs	9
Outputs	10
Parameters	29
Derivatives	0



Parameters

1. MODE
2. DENS1
3. SPHT1
4. DENS2
5. SPHT2
6. BETA
7. ALPHC
8-10. CPLOSI,CPL1SI,CPL2SI
11-13. CPOSI,CP1SI,CP2SI
14. GPGM
15. TCRSI
16. PCRSI
17. TBLSI
18-22. ETGN,ETT,ETR,ETN,ETP
23. TL0WSI
24. THIGHS
25. TB0UT
26. TC0UT
27. FBMAX
28. FCMAX
29. PHIGHS

TYPE 30: GENERALIZED FOCUSING COLLECTOR

General Description

The Generalized Focusing Collector models an east-west aligned single axis tracking collector. The collector performance is given by the formula

$$Q_u = A_\alpha H_\beta R_\beta R_\varepsilon \rho \quad - U_L A_R \ (T_R - \ Ta)$$

There is presently one operational mode. In Mode 1 the fluid flow is adjusted to meet a specified (parameter) outlet temperature. It is intended to add an additional flow driven mode at a later date. The R_β factor above is calculated using the equation

$$R_\beta = \cos 15^\circ \ (\text{Hour} - 12)$$

As currenly coded the receiver loss factor $U_L A_R$ ($\bar{T}$ - TA) is a constant loss factor as given by the RTLØSS parameter.

Nomenclature

Q_u - Rate of energy gain

A_a - Unshaded projected area of the reflector system

H_β - Normal incident solar intensity

R_β - Ratio of solar intensity incident normal to the receiver aperture to that on whatever surface H_β was measured. (cosine factor).

ρ - Specular reflectance of reflector surface

γ - Fraction of reflected radiation incident on the receiver aperture

$\tau\alpha$ - Transmittance of the receiver cover and absorptance of the receiver tube.

U_L - Receiver thermal losses per unit receiver aperture area per degree temperature difference between the ambient temperature and the average of the fluid in the receiver tubes.

A_R - Area of receiver aperture

T_R - Average temperature of the fluid in the receiver tubes

Ta - Ambient temperature

Cp - Specific heat of fluid

R_ε - Receiver and loss factor

Component Configuration

Parameter Number	Symbol	Subroutine Mnemonic
1		MODE 1 meet outlet temperature 2 unassigned
2	A_a	CAREA
3	R_E	RL0SS
4	ρ	SPREFL
5	γ	GAMMA
6	τ	RETRAN
7	α	ABTUBE
8	U_L	RTL0SS
9	A_R	RAREA
10	Cp	SPHEAT
11	Mode 1 only	T0UT Required outlet temperature for Mode 1.

Input Number	Symbol	Subroutine Mnemonic
1		TIN input fluid temperature
2		FL0WIN input fluid mass flow rate
3		PRESS inlet fluid pressure

INPUT Number	Symbol	Subroutine Mnemonic
	H_β	SØLAR normal incident solar intensity
5	Ta	TAMB ambient temperature
6		HOUR hour of day value may be 0-23 or 1-24 with solar noon representing 12.

OUTPUT Number		
1		TØUT output fluid temperature
2		FLØUT output fluid flow
3		PRESS outlet fluid pressure
4	Qu	QGAIN

Mathematical Description

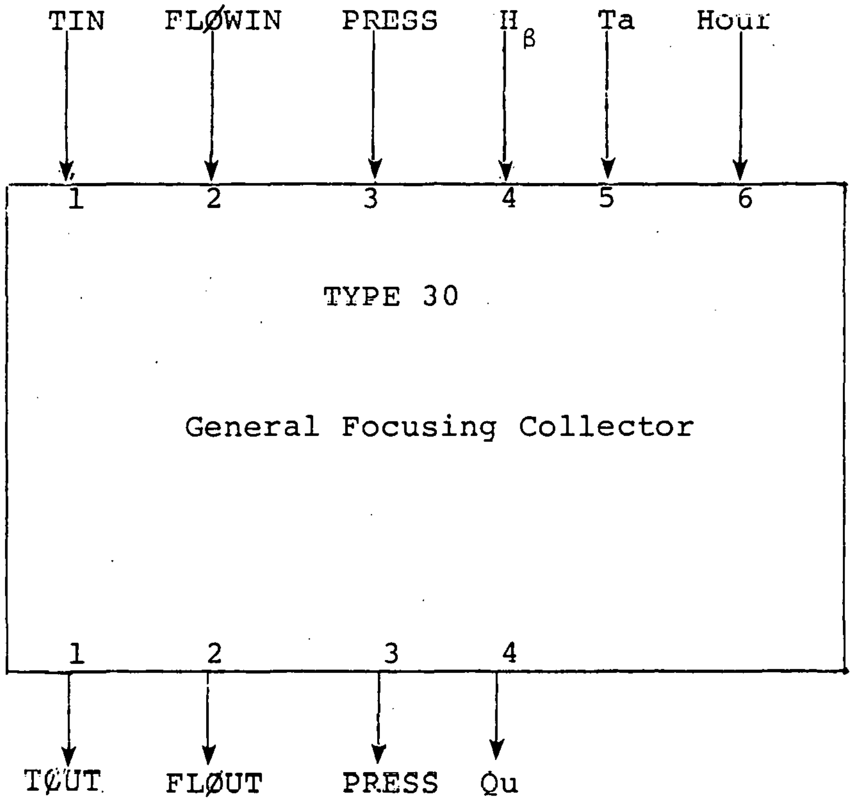
In mode 1 the output flow rate is given by

$$\text{FLØUT} = \frac{\text{Qu}}{(\text{TØUT-TIN})\ \text{Cp}}$$

If the energy gain is less than or equal to zero then the flow is zero.

Information Flow Diagram

Inputs	6
Parameters	10 or 11
Outputs	4
Derivatives	0



PARAMETERS

1. Mode
2. Aa
3. R_ε
4. ρ
5. γ
6. τ
7. α
8. UL
9. A_R
10. C_ρ
11. TØUT

(optional)

TYPE 31: COOLING TOWER

General Description

The cooling tower subroutine will accept a flow of a fluid at a given temperature and return the fluid at a specified lower temperature. If the incoming fluid temperature is already less than or equal to the specified outlet temperature, then no temperature change is effected.

Nomenclature

FLSPHT	Fluid specific heat
TØUT	Desired outlet temperature
TIN	Inlet temperature of fluid
FLOWIN	Fluid flow rate
PIN	Inlet fluid pressure
Q	Change in energy of fluid

Mathematical Description

Case I	TIN ≤ TØUT
	Q = 0
	TØUT = TIN
Case II	TIN > TØUT
	Q = (FLØWIN) (FLSPHT) (TIN-TØUT)
	TØUT = TØUT

Component Configuration

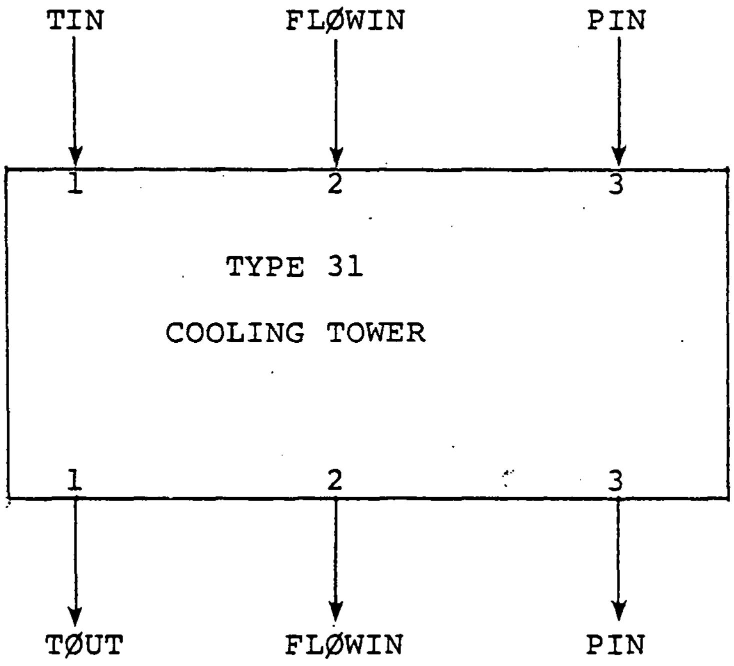
Parameter Number	
1	FLSPHT
2	TØUT

Input Number	
1	TIN
2	FL0WIN
3	PIN

Output Number	
1	T0UT
2	FL0WIN
3	PIN

Information Flow Diagram

Inputs	3
Outputs	3
Parameters	2
Derivatives	0



PARAMETERS

1. FLSPHT
2. T0UT

TYPE 32: UNFORMATTED DATA READER

General Description

The unformatted data reader may be used to read data recorded in binary form, i.e., data created with a FORTRAN unformatted write. This reader routine operates in a manner similar to the formatted data reader, TYPE 9. Any number of data readers are allowed. Scaling of input values may be accomplished in the same manner as the TYPE 9 data reader. This component may be effectively used to reduce the storage requirements of required input data. The data is accepted in both integer and real format. All integer values must precede the real values. Since the input arrays and output arrays are all real arrays, the integers are all converted to real values.

Refer to the TYPE 9 description for the operating instructions for this subroutine. All differences between the two are noted below: 1.

1. As many as five TYPE 32 subroutines may be used.
2. A maximum of 25 data values may be read and placed in the output array. These values may be all integer, all real, or any combination of integer and real values. This maximum may be increased by increasing the number of outputs per component.
3. It is possible to simulate over a period of time that which does not correspond to the beginning of the data file. To do so, one would specify the starting time for the simulation as usual. Simulation will begin at n records into the file, where n = (SIMULATION START TIME)/data time step). For instance, if one wanted to simulate for the first week in June using a data file commencing in January with hourly records, then a

```
SIMULATION 2904  3072  1
```

would skip 2904 records in the file (151 days * 24 hours/day) and terminate at time 3072 (168 hours total). Note that the divisor in the above expression is a parameter for the TYPE 32 data reader and not necessarily the simulation time step.

Nomenclature

See TYPE 9 description.

Mathematical Description

See TYPE 9 description.

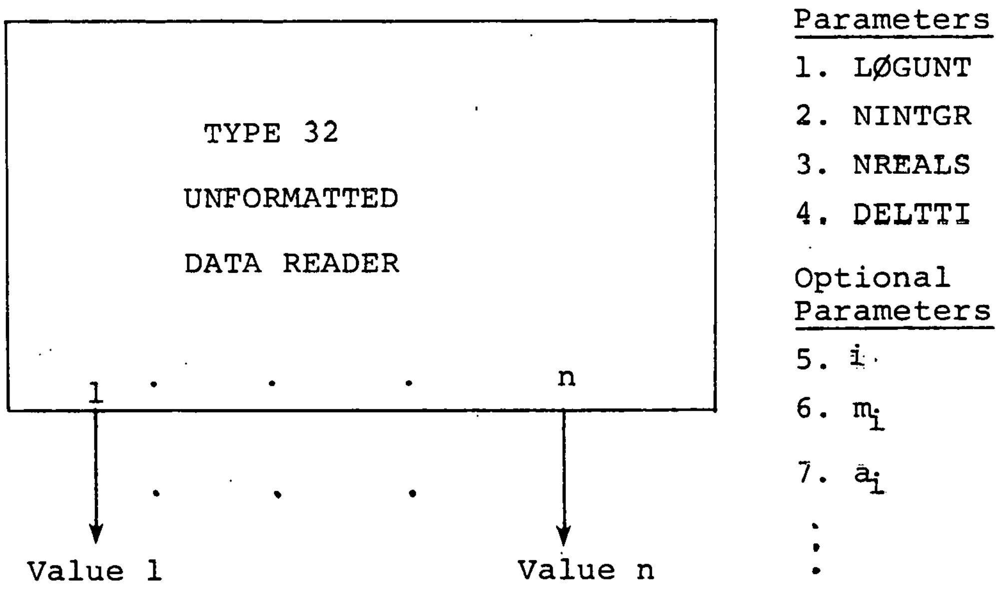
Component Configuration

PARAMETER NUMBER	DESCRIPTION
1	LOGUNT - Logical unit number
2	NINTGR - Number of integers to be read
3	NREALS - Number of real values to be read
4	DELTTI - Time interval between data records
5, 8, 11, etc.	i - Position of the value to be converted, e.g., if there are 10 integers and 15 reals, 2 is the second integer and 12 is the second real value.
6, 9, 12, etc.	M_i - Multiplication factor for value in i position.
7, 10, 13, etc.	A_i - Additive factor for value in position i.

OUTPUT Number	DESCRIPTION
1	The first converted and interpolated value
.	
.	
.	
i	The i^{th} converted and interpolated value

Information Flow Diagram

Inputs	0
Outputs	up to 25 (see general description)
Parameters	4 + 3n where n is number of values being converted
Derivatives	0



n = NINTGR + NREALS

TYPE 33: THERMAL CONSUMER

General Description

The purpose of this component subroutine is to remove heat from a fluid to satisfy thermal demands for space heating, domestic hot water, and absorption air conditioning.

Parameters specify the exit temperature for the fluid after it has been used for each of the three possible thermal applications. Inputs provide the thermal demands for space heating, domestic hot water, and absorption air conditioning. The thermal consumer is then given access to a certain mass of fluid (M_{TANK}) at a certain temperature (T_{IN}). It satisfies the thermal demands to the extent possible by removing heat from the fluid so that it leaves the thermal consumer at the proper exit temperature (specified by parameter for each application).

When operating in mode 1, the thermal consumer connects the water heating function in series with space heating and absorption air conditioning (which are connected in parallel but are normally not used concurrently). When the fluid exit temperature for space heating and absorption air conditioning are significantly higher than that of domestic hot water, more efficient use of the fluid's heat content may be realized in this mode. For example, if fluid that has been used for space heating exits at 160°F and fluid used for heating water exits at 140°F, then the space heating exit fluid can yield another 20 Btus per pound in water heating. The connections described are illustrated in Figure A-1. In that figure, fluid may follow any of the following paths: AD, AE, BD, BE, or CD.

In mode 2, space heating, absorption air conditioning, and domestic hot water are connected in parallel as shown in Figure A-2.

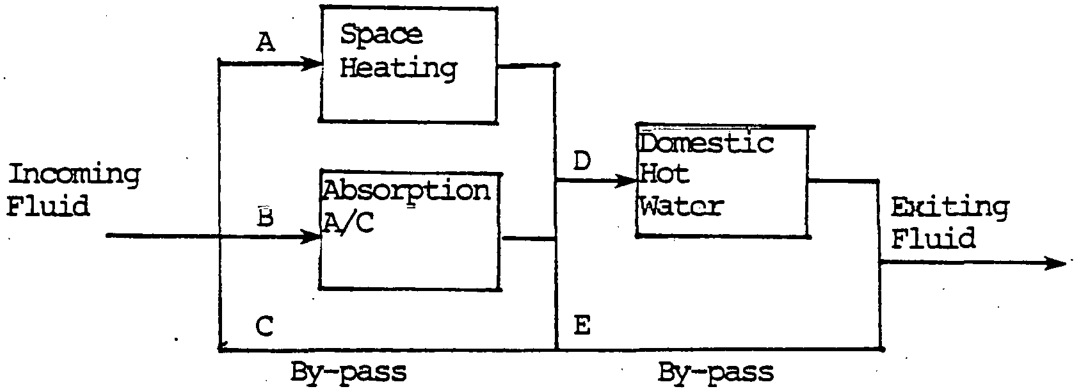


FIGURE A-1

Thermal Consumer

Mode 1 Operation

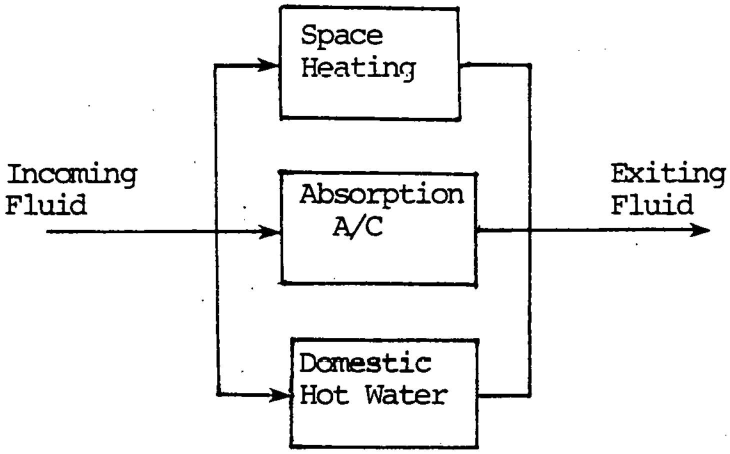


FIGURE A-2

Thermal Consumer

Mode 2 Operation

Nomenclature

T_{ESH}	Fluid exit temperature from space heating
T_{EHW}	Fluid exit temperature from domestic hot water
T_{EAC}	Fluid exit temperature from absorption air conditioning
T_{MINAC}	Minimum operating temperature for absorption air conditioning
T_{IN}	Fluid inlet temperature from upstream storage tank
T_{OUT}	Fluid outlet temperature
M_{TANK}	Mass of fluid available in upstream storage tank
M_{SH}	Mass of fluid devoted to satisfy space heating requirements

M_{AC}	Mass of fluid devoted to satisfy air conditioning
M_{HW}	Mass of fluid devoted to satisfy domestic hot water requirements (over and above M_{SH} and M_{AC})
M_{OUT}	Total mass of fluid which flows through the Thermal Consumer in a given time step.
Q_{RSH}	Heat required for space heating
Q_{RAC}	Heat required for air conditioning
Q_{RHW}	Heat required for water heating
Q_{PSH}	Heat provided for space heating
Q_{PAC}	Heat provided for air conditioning
Q_{PHW}	Heat provided for water heating
Q_R	Total heat required
Q_P	Total heat provided
Q_{AV}	Heat available for hot water from space heating and air conditioning exit fluid
C_P	Specific heat of fluid

Mathematical Description

This component provides for two modes of operation, as described above. Some computations are common to both modes, as indicated below.

Both modes:

$$M_{SH} = \mathrm{MIN}\left(\frac{Q_{RSH}}{Cp\ (T_{IN}-T_{ESH})}\ ,\ M_{TANK}\right)$$

$$M_{TANK} = M_{TANK} - M_{SH}$$

$$M_{AC} = \begin{cases} \mathrm{MIN}\left(\frac{Q_{RAC}}{Cp\ (T_{IN}-TEAC)}\ ,\ M_{TANK}\right) \text{ if } T_{IN} = T_{MAC} \\ 0 \text{ otherwise} \end{cases}$$

$$M_{TANK} = M_{TANK} - M_{AC}$$

$$Q_{PSH} = M_{SH}\, Cp\, (T_{IN} - T_{ESH})$$

$$Q_{PAC} = M_{AC}\, Cp\, (T_{IN} - T_{EAC})$$

MODE 1:

$$Q_{AV} = \mathrm{MAX}\, (M_{SH} Cp\, (T_{ESH} - T_{EHW}), 0) + \mathrm{MAX}\, (M_{AC} C_p\, (T_{EAC} - T_{EHW}), 0)$$

if $Q_{RHW} \geq Q_{AV}$

Then $M_{HW} = \mathrm{MIN}\left(\dfrac{Q_{RHW} - Q_{RV}}{Cp\, (T_{IN} - T_{EHW})}, M_{TANK}\right)$

$$T_{OUT} = T_{EHW}$$

$$Q_{PHW} = M_{HW}\, C_p\, (T_{IN} - T_{EHW}) + Q_{AV}$$

Otherwise:

$$M_{HW} = 0$$

$$Q_{PHW} = Q_{RHW}$$

$$T_{OUT} = \frac{Cp(M_{SH}\, T_{ESH} + M_{AC}\, T_{EAC}) - Q_{PHW}}{Cp\, (M_{SH} + M_{AC})}$$

MODE 2:

$$M_{HW} = \mathrm{MIN}\left(\frac{Q_{RHW}}{Cp(T_{IN} - T_{EHW})}, M_{TANK}\right)$$

$$Q_{PHW} = M_{HW}\, Cp\, (T_{IN} - T_{EHW})$$

$$T_{OUT} = \frac{M_{SH}\, T_{ESH} + M_{AC}\, T_{EAC} + M_{HW}\, T_{EHW}}{M_{SH} + M_{AC} + M_{HW}}$$

Both modes:

$$M_{OUT} = M_{SH} + M_{AC} + M_{HW}$$

$$Q_R = Q_{RSH} + Q_{RAC} + Q_{RHW}$$

$$Q_P = Q_{PSH} + Q_{PAC} + Q_{PHW}$$

Component Configuration

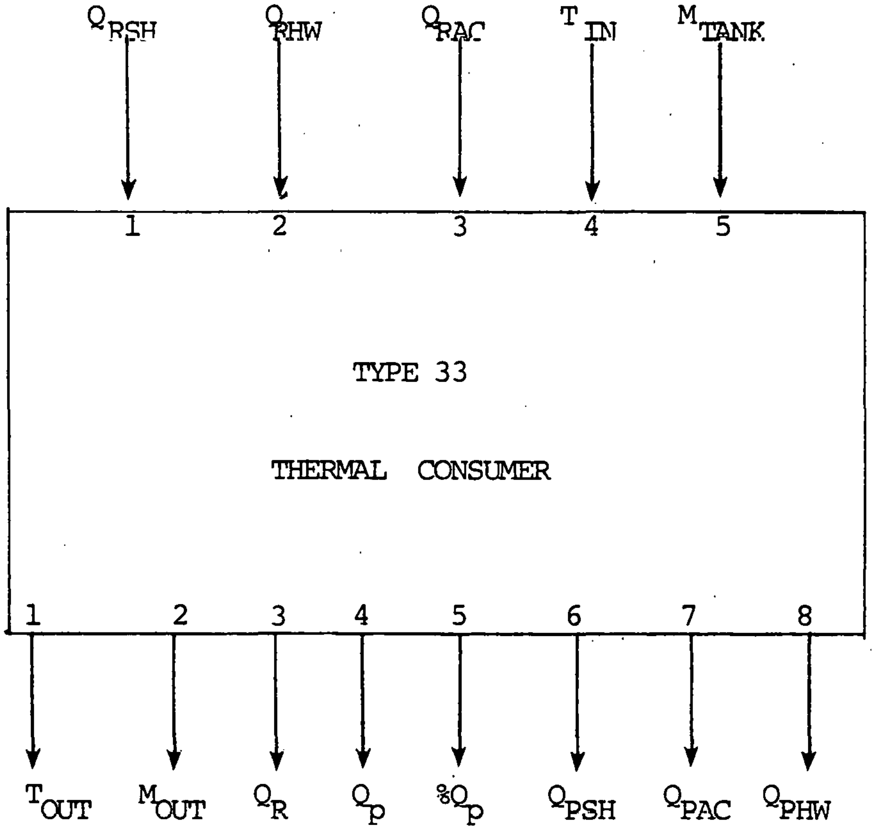
PARAMETER NO.	DESCRIPTION
1	Mode: 1 = Serial Water Heating 2 = Parallel Water Heating
2	T_{ESH}, fluid exit temperature from space heating
3	T_{EHW}, fluid exit temperature from water heating
4	T_{EAC}, fluid exit temperature from absorption air conditioning
5	T_{MINAC}, minimum operation temperature for absorption
6	Cp, specific heat of fluid

INPUT NO.	DESCRIPTION
1	Q_{RSH}, heat required for space heating
2	Q_{RHW}, heat required for domestic hot water
3	Q_{RAC}, heat required for absorption air conditioning
4	T_{IN}, temperature of fluid available for input
5	M_{TANK}, mass of fluid available for input

OUTPUT NO.	DESCRIPTION
1	T_{OUT}, temperature of outlet fluid
2	M_{OUT}, mass of fluid used
3	Q_R, total heat required
4	Q_p, total heat provided
5	% of requirements provided (100* Q_R/Q_p)
6	Q_{PSH}, heat provided for space heating
7	Q_{PAC}, heat provided for absorption air conditioning
8	Q_{PHW}, heat provided for domestic water heating

Information Flow Diagram

Inputs	5
Outputs	8
Parameters	6
Derivatives	0



Parameters

1. Mode
2. T_{ESH}
3. T_{EHW}
4. T_{EAC}
5. T_{MINAC}
6. Cp

TYPE 34: CONTINUOUS CONTROLLER

General Description

The continuous controller provides two control variables γ_1 and γ_2 such that

$$0 \leq \gamma_1 \leq 1$$

$$\gamma_2 = 1 - \gamma_1$$

These control variables are expecially useful for working with T-piece components, but its use is not limited to T-piece control.

Nomenclature

Symbolic	Description
γ_1	Control function
γ_2	Control function

Mathematical Description

$$\gamma_1 = \min \left(1, \left| \frac{XIN(1)}{XIN(2)} \right| \right)$$

$$\gamma_2 = 1-\gamma_1$$

Component Configuration

Input Number	Description
1	Numerator in evaluating control function
2	Denominator in evaluating control function

Output Number	Description
1	γ_1
2	γ_2

Example:

Suppose that a demand for 1000 kg of water were received and 750 kg was available in a primary storage tank and the remaining 250 kg was to be supplied from an auxiliary source. Then with XIN(1) = 1000 and XIN(2) = 750

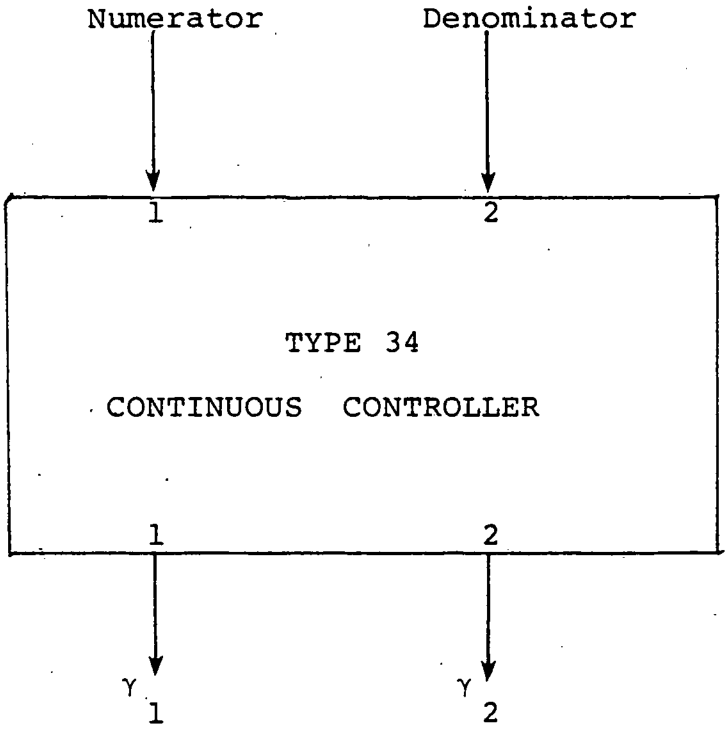
$$\gamma_1 = .75$$

$$\gamma_2 = .25$$

and these values may be used as inputs to T-piece flow diverters and mixers.

Information Flow Diagram

Inputs	2
Outputs	2
Parameters	0
Derivatives	0



TYPE 35: STEAM GENERATOR TURBINE

The steam generator and tubine component when complemented with the TYPE 36 condenser and TYPE 37 pump provides a Rankine cycle model which uses water and steam as the working fluid. This model gives more accurate results than the TYPE 29 Rankine cycle when water and steam are used.

The steam generator heats the working fluid with a heating fluid which must be water.

The steam generator-turbine produces all or part of an input electrical demand. The amount produced depends upon the maximum and minimum electrical output and an input control function. The minimum output is the product of two parameters, the design kilowatt rating (DKW) and the turn down rate (TRNDWN). The maximum generation allowed is 1.25 times the DKW. If the demand is lower than the minimum or greater than the maximum, it is set to the minimum or maximum respectively; otherwise the demand is as input. The amount of electricity actually generated then depends on a control function. If the control value is 1, then the demand is always met; this may require utilization of an auxiliary boiler for energy if there is insufficient energy in storage. The use of auxiliary energy is reflected in the output. If the control is zero, then electricity is generated only so long as energy is available from storage.

This capability allows for load following wherein the solar system must assume complete responsibility for electrical loads over a given base load (which may be zero) even though auxiliary energy sources must be used (control = 1), or allows for complete use of stored energy even though the demand is not present, e.g., to exhaust the energy in storage or to charge a low-temperature storage system via turbine exhaust.

Nomenclature

APP	Approach. The temperature difference between the boiler inlet heating fluid and the turbine inlet temperature. (°F)
TDELT	Temperature dorp of heating fluid (°F)
PDR0P1	Pressure drop of heating fluid inlet to outlet (PSIA)
PDR0P2	Pressure drop of working fluid (water-steam) from pump to turbine inlet (PSIA)
EFFG	Generator efficiency
KWL	kilowatt losses in the system (KW)
DKW	Design kilowatt load of the turbine (KW)
TRNDWN	Turndown ratio of the turbine
TBIN	Inlet temperature of heating fluid to boiler (°F)
PBIN	Heating fluid inlet pressure (PSIA)
HPUMP	Enthalpy of working fluid out of the pump ($BTU/_{1bm}$)
PPUMP	Pressure of working fluid at pump outlet (PSIA)
DEMKW	Electrical demand (KW)
PBACK	Turbine back pressure (inches of Hg)
HUEEP	Enthalpy at used energy endpoint ($BTU/_{1bm}$)
FMS	Flow of working fluid (lbm)
TEFF	Total efficiency
TSR	Theoretical Steam rate (lbm)
PRMASS	Mass of fluid in storage tank which is the source of heating fluid (lbm)

C0NTRL	Control function (1 or 0)
HTIN	Enthalpy of working fluid at turbine inlet (BTU/$_{\text{lbm}}$)
HISEN	Enthalpy of working fluid outlet from turbine (BTU/$_{\text{lbm}}$)
STRATE	Steam rate (lbm)
FRATI0	Flow ratio
FAUX	Flow through auxiliary boiler (lbm)
QAUX	Energy supplied by auxiliary system (BTU)
QB0IL	Energy supplied from solar source (BTU)
ENT	Entropy of working fluid inlet to boiler (BTU/$_{\text{lbm}^\circ\text{F}}$)

Mathematical Description

From the initial input conditions steam tables are used to calculate the HTIN, ENT, and saturation temperature at the given pressure of the working fluid at the turbine inlet. A turbine efficiency is computed based upon PTIN. The efficiency is computed by curve fitting based upon manufacturer's data for a 500 KW turbine.

The flow ratio is given by

$$\text{FRATI0} = \frac{\text{HTIN} - \text{HPUMP}}{(\text{SPHEAT})\ (\text{TDELT})},$$

The gross kilowatts produced is

$$\text{GKW} = 15. + 1.1077\ \text{XKW}$$

The 15 kilowatts is electricity required by the pump.

The available energy for electrical production is

$$\mathrm{AE} = \mathrm{HTIN} - \mathrm{HISEN}$$

The theoretical steam rate is

$$\mathrm{TSR} = \frac{3412.75}{\mathrm{AE}} \qquad \text{(kilowatt-BTU conversion)}$$

The total efficiency is calculated and allowed the true steam rate to be computed as

$$\mathrm{STRATE} = \frac{\mathrm{TSR}}{(\mathrm{TEFF})\ (\mathrm{EFFG})}$$

The flow of the working fluid is given by

$$\mathrm{FMS} = (\mathrm{STRATE})\ (\mathrm{GKW})$$

The enthalpy at the used energy end point is

$$\mathrm{HUEEP} = \mathrm{HTIN} - (\mathrm{AE})\ (\mathrm{TEFF})$$

The kiowatt losses are computed as

$$\mathrm{KWL} = \mathrm{GKW}\ (1-\mathrm{EFFG})$$

Component Configuration

PARAMETER NUMBER	
1	APP
2	TDELT
3	PDR0P1
4	PDR0P2
5	EFFG
6	DKW
7	TRNDWN

INPUT NUMBER

1	TBIN
2	PBIN
3	PPUMP
4	HPUMP
5	PBACK
6	PRMASS
7	DEMKW
8	CØNTRL

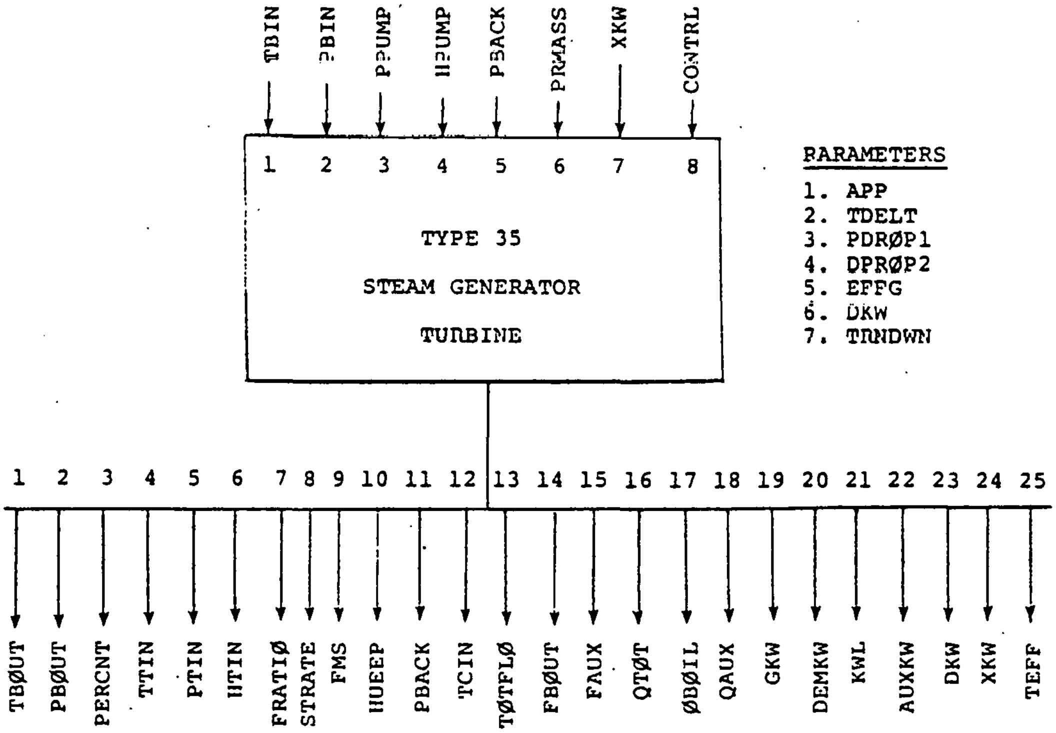
OUTPUT NUMBER

1	TBØUT	Heating fluid boiler outlet temperature
2	PBØUT	Heating fluid boiler outlet pressure
3	PERCNT	Percent of energy supplied from solar sources
4	TTIN	Inlet temperature to turbine of working fluid
5	PTIN	Inlet pressure to turbine
6	HTIN	Enthalpy at turbine inlet
7	FRATIØ	Flow ratio
8	STRATE	Steam rate
9	FMS	Mass flow through turbine
10	HUEEP	Enthalpy, used energy end point
11	PBACK	Turbine back pressure
12	TCIN	Condenser inlet temperature
13	TØTFLØ	Total mass flow (boiler plus auxiliary boiler)

OUTPUT NUMBER

14	FB0UT	Flow through the boiler from solar source
15	FAUX	Flow through auxiliary boiler
16	QT0T	Total energy supplied from boiler and auxiliary boiler
17	QB0IL	Energy provided from solar source
18	QAUX	Energy supplied from suxiliary sources
19	GKW	Gross kilowatts produced
20	DEMKW	Kilowatt demand as reflected by input (may be changed based on maximum, minimum, or avaiable energy)
21	KWL	Kilowatt losses
22	AUXKW	Auxiliary kilowatt load = 15. + 0.1077 XKW
23	DKW	Design kilowatt capacity of turbine
24	XKW	Adjusted value of output 20
25	TEFF	Total efficiency of steam generator and turbine

Information Flow Diagram



PARAMETERS

1. APP
2. TDELT
3. PDR0P1
4. DPR0P2
5. EFFG
6. DKW
7. TRNDWN

TYPE 36: CONDENSER

General Description

The condenser together with the TYPE 35 steam generator and TYPE 37 pump, model a Rankine cycle with water-steam as the working fluid. In general, this subroutine combination will provide more accurate simulation than the TYPE 29 Rankine cycle for a water-steam working fluid.

The condenser accepts input temperature, pressure, enthalpy, and flow from the turbine and computes outlet temperature, pressure, and enthalpy of the working fluid. The cooling fluid flow and temperature is computed based upon the working fluid input temperature and the terminal temperature difference parameter. The enthalpy and outlet temperature of the working fluid varies with the turbine back pressure which is an input.

Nomenclature

TTD	Terminal Temperature difference. This is the difference between the inlet temperature of the working fluid and the outlet temperature of the cooling fluid (^{o}F)
TIN	Working fluid inlet temperature (^{o}F)
PIN	Working fluid inlet pressure (PSIA)
HIN	Working fluid inlet enthalpy (BTU/lbm)
FIN	Working fluid mass flow (lbm)
TCIN	Inlet temperature of cooling fluid (^{o}F)
TOUT	Outlet temperature of working fluid (^{o}F)
HOUT	Outlet enthalpy of working fluid (BTU/lbm)
QCON	Condenser duty (BTU/hr)
TCOUT	Cooling water outlet temperature

RISE	Rise in temperature of cooling water
FCØØL	Cooling water flow (lbm)
PØUT	Outlet pressure of working fluid (psia)
FØUT	Flow of working fluid (lbm)

Mathematical Description

The outlet temperature and enthalpy of the working fluid is computed via steam table references.

QCØN = FIN (HIN-HØUT)

TCØUT = TØUT - TDD

RISE = TCØUT - TCIN

$$\mathrm{FC\O\O L} = \frac{\mathrm{QC\O N}}{\mathrm{RISE}^{*}}$$

PØUT = PIN

FØUT = FIN

*an assumed divisor is a specific heat of 1

Component Configuration

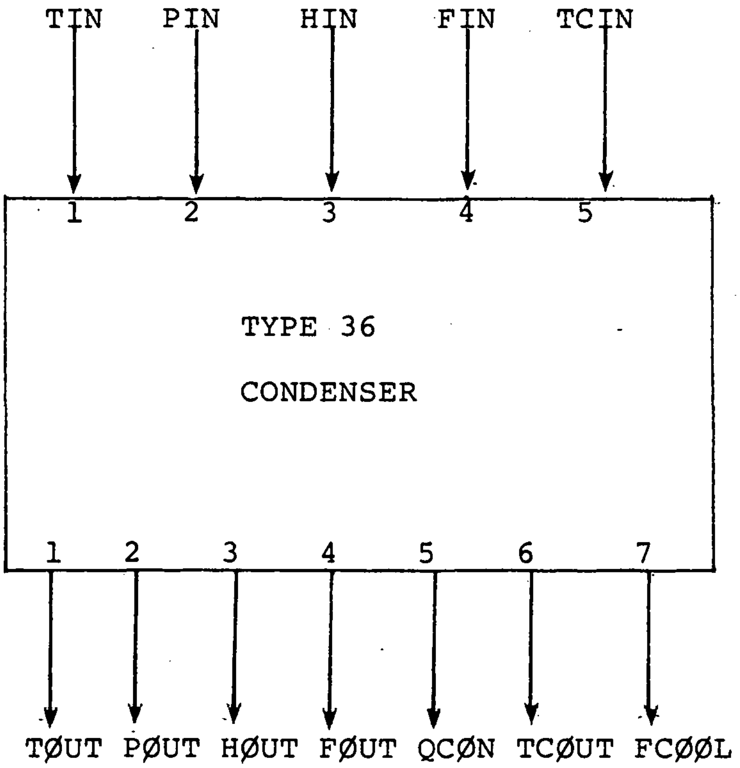
PARAMETER NO.		
1	TDD	Temperature Terminal Difference

INPUT NUMBER	
1	TIN
2	PIN
3	HIN
4	FIN
5	TCIN

OUTPUT NUMBER	
1	TØUT
2	PØUT
3	HØUT
4	FØUT
5	QCØN
6	TCØUT
7	FCØØL

Information Flow Diagram

Inputs	5
Outputs	7
Parameters	1
Derivatives	0



PARAMETERS

1. TDD

TYPE 37: CONDENSER PUMP

General Description

The condenser pump together with the TYPE 35 steam generator-turbine and TYPE 36 condenser form a Rankine cycle with water-steam as the working fluid. The pump provides the steam generator-turbine with a working fluid enthalpy and pressure.

Nomenclature

C0UPEF	Coupling efficiency
C0UPKW	Kilowatts consumed due to couple inefficiency
FIN	Inlet flow rate (lbm)
F0UT	Outlet flow (same as FIN) (lbm)
HIN	Inlet enthalpy of water (BTU/lbm)
HISEN	Enthalpy of water at outlet assuming 100% efficiency (BTU/lbm)
H0UT	Outlet enthalpy consideraing pump efficiency (BTU/lbm)
HRISE	Enthalpy change (BTU/lbm)
PIN	Inlet pressure of water (PSIA)
P0UT	Outlet water pressure (same as PUMPDP) (psia)
PUMPDP	Pump discharge pressure
PUMPEF	Pump efficiency
PUMPKW	Kilowatts consumed by the pump
SPI	Inlet entropy of water (BTU/lbm°F)
T0UT	Outlet water temperature (°F)

Mathematical Description

The HISEN, SPI, and TOUT variables are computed via stream table references. The outlet enthalpy is computed as

$$\mathrm{HOUT} = \mathrm{HIN} + \frac{(\mathrm{HISEN} - \mathrm{HIN})}{\mathrm{PUMPEF}}$$

The enthalpy rise is the difference between the inlet and outlet enthalpy

$$\mathrm{HRISE} = \mathrm{HOUT} - \mathrm{HIN}$$

The electricity consumed by the pump and coupling is given by

$$\mathrm{PUMPKW} = \frac{(\mathrm{FOUT})\ (\mathrm{HRISE})}{3417.75}\ ) \qquad \text{(3417.75 is Kilowatt-BTU)} \quad \text{(conversion factor}$$

$$\mathrm{COUPKW} = \frac{\mathrm{PUMPKW}}{\mathrm{COUPEF}}$$

Component Configuration

PARAMETER NUMBER	
1	PUMPDP
2	PUMPEF
3	COUPEF

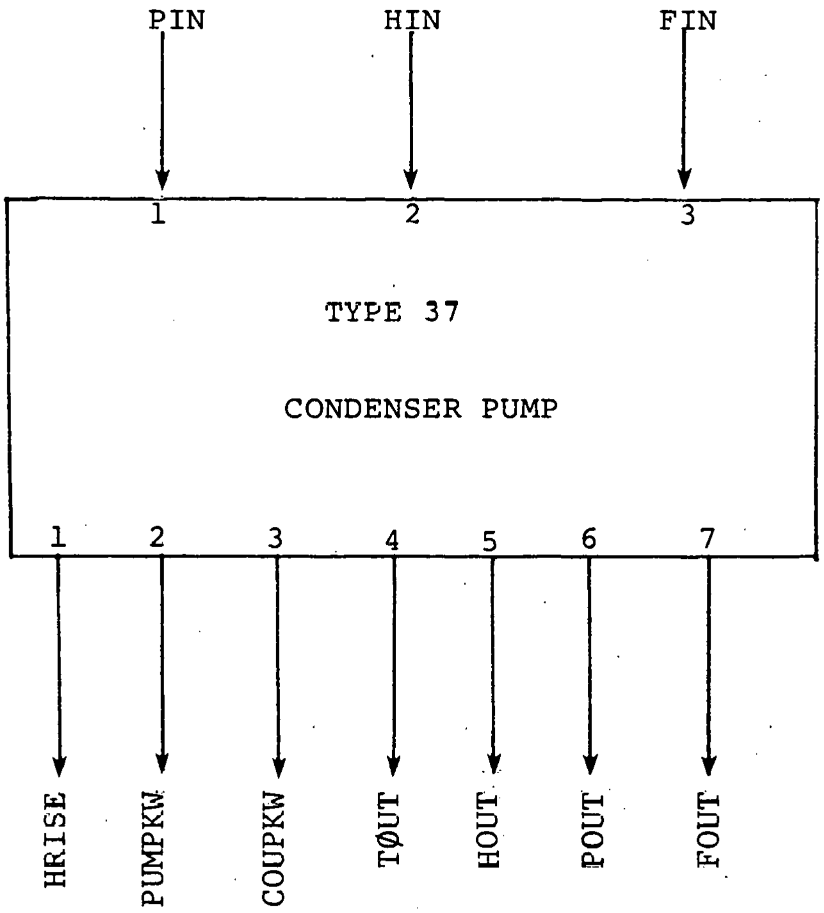
INPUT NUMBER	
1	PIN
2	HIN
3	FIN

OUTPUT NUMBER	
1	HRISE
2	PUMPKW
3	COUPKW
4	TOUT

5	H0UT
6	P0UT
7	F0UT

Information Flow Diagram

Inputs	3
Outputs	7
Parameters	3
Derivatives	0



PARAMETERS

1. PUMPDP
2. PUMPEF
3. COUPEF

APPENDIX D

APPENDIX D. Topical Outline for Technical Manual: "Solar Total Energy System Operating Plans"

I. System Description

  A. Introduction

    1. Purpose of Manual
    2. Scope
    3. Purpose of System
    4. Safety Considerations

  B. General Description

  C. System Components

    1. Solar Collector Field
    2. Power Block
      a. Vapor Generator
      b. Turbine
      c. Electrical Generator
      d. Condensor
    3. High-Temperature Storage
    4. Low-Temperature Storage
    5. Thermal Distribution
      a. Space Heating
      b. Domestic Water Heating
    6. Interfacing with 87000 Complex
      a. Electrical
      b. Cooling
      c. Space Heating
      d. Domestic Water Heating
    7. Controls

II. Start-Up Procedures

  A. Routine Weather Conditions

  B. Cloudy Conditions

  C. Restart Procedures

III. Shut-Down Procedures

- A. Routine Weather Conditions
- B. Cloudy Conditions
- C. Freezing Night
- D. Emergency Shut-Down

IV. Routine Weather Operating Procedures

- A. Start-Up
- B. Normal Operations
- C. Normal Shut-Down

V. Marginal Weather Operating Procedures

VI. Partial Shut-Down Operating Procedures

- A. Routine Maintenance of Subsystems
- B. Detection of Subsystem Faults
- C. Isolation of Subsystem Faults
- D. Subsystem Repairs

VII. Theory of Operation

- A. General System Operation
- B. Subsystems Physical Characteristics
- C. Subsystems Operation

VIII. Maintenance and Repairs

- A. Solar Collector Field
- B. Power Block
    1. Vapor Generator
    2. Turbine
    3. Electrical Generator
    4. Condensor
- C. High-Temperature Storage
- D. Low-Temperature Storage
- E. Thermal Distribution
    1. Space Heating
    2. Domestic Water Heating

APPENDIX E

Appendix E. Part I Heat-Collection Data

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/ 95	11.95	506.7	12.0	1000	6.52	80	5	180	0.63	0	91	*****	*****
77/ 95	12.12	512.8	19.7	1000	6.45	80	5	180	0.63	16	149	940	950
77/ 95	12.28	514.9	13.2	1000	6.50	80	5	180	0.63	308	100	33	34
77/ 95	12.45	515.5	12.9	1000	6.59	80	5	180	0.63	308	99	33	34
77/ 95	12.62	516.4	12.6	1000	6.61	80	5	180	0.63	307	97	32	34
77/ 95	12.78	512.2	17.0	1000	6.62	80	5	180	0.63	307	132	44	47
77/112	11.76	434.0	25.0	750	4.44	85	10	150	0.63	292	128	44	45
77/112	11.83	431.4	24.0	750	4.44	85	10	150	0.63	291	123	43	43
77/112	11.89	427.8	25.2	750	4.42	85	10	150	0.63	290	128	45	45
77/112	11.96	426.7	24.4	750	4.41	85	10	150	0.63	292	124	43	43
77/112	12.39	435.8	22.1	750	4.09	85	10	150	0.63	293	104	36	37
77/112	12.46	439.1	19.1	750	4.10	85	10	150	0.63	293	90	31	33
77/112	12.53	434.5	26.1	750	4.11	85	10	150	0.63	292	124	43	45
77/112	12.59	433.8	23.1	750	4.09	85	10	150	0.63	293	109	38	40
77/112	12.66	434.9	21.1	750	4.11	85	10	150	0.63	293	100	35	37
77/112	12.73	434.2	22.4	750	4.09	85	10	150	0.63	294	105	37	39
77/112	12.79	434.0	21.9	750	4.13	85	10	150	0.63	292	104	37	40
77/112	12.99	461.4	16.7	850	3.76	85	10	150	0.63	293	72	26	28
77/112	13.06	461.2	19.6	850	3.75	85	10	150	0.63	291	85	30	34
77/112	13.13	459.6	21.6	850	3.75	85	10	150	0.63	292	93	34	38
77/112	13.19	461.1	19.4	850	3.74	85	10	150	0.63	291	84	30	34
77/112	13.26	463.0	17.0	850	3.75	85	10	150	0.63	291	73	27	31
77/112	13.36	462.4	19.8	850	3.42	85	10	150	0.63	290	78	29	33
77/112	13.43	462.6	19.8	850	3.42	85	10	150	0.63	290	78	29	34
77/112	13.49	463.3	18.4	850	3.43	85	10	150	0.63	290	73	27	32
77/112	13.56	463.3	18.6	850	3.42	85	10	150	0.63	290	73	28	33
77/112	13.63	462.9	18.9	850	3.41	85	10	150	0.63	290	74	28	34
77/112	13.69	462.9	18.1	850	3.43	85	10	150	0.63	290	71	27	33
77/112	13.76	462.8	17.6	850	3.41	85	10	150	0.63	290	69	27	33
77/112	13.83	462.5	17.7	850	3.41	85	10	150	0.63	291	69	27	33
77/113	12.41	400.0	29.1	554	1.37	80	5	60	0.63	274	46	17	18
77/113	12.50	403.3	29.2	566	1.39	80	5	60	0.63	273	47	17	18
77/113	12.58	406.8	28.4	579	1.41	80	5	60	0.63	171	46	27	29
77/113	12.66	410.0	25.9	567	1.40	80	5	60	0.63	268	41	16	17
77/113	12.75	412.1	26.8	596	1.42	80	5	60	0.63	218	44	20	22
77/115	11.62	488.3	20.4	800	3.73	80	15	0	0.63	278	88	32	33
77/115	11.69	489.4	20.8	800	3.70	80	15	0	0.63	277	89	33	34
77/115	11.75	489.9	21.5	800	3.71	80	15	0	0.63	278	93	34	35
77/115	11.82	491.2	20.9	800	3.72	80	15	0	0.63	278	90	33	33
77/115	11.89	492.2	21.5	800	3.70	80	15	0	0.63	278	92	33	34
77/115	11.95	493.1	21.9	800	3.69	80	15	0	0.63	277	94	34	34
77/115	12.02	494.5	21.1	800	3.70	80	15	0	0.63	277	91	33	33
77/115	12.42	487.8	21.4	950	3.73	80	15	0	0.63	276	92	34	35
77/115	12.49	488.6	20.8	950	3.74	80	15	0	0.63	275	90	33	35
77/115	12.55	489.6	20.0	950	3.74	80	15	0	0.63	275	87	32	34
77/115	12.62	489.9	20.4	950	3.74	80	15	0	0.63	275	88	33	35
77/115	12.69	490.4	20.0	950	3.74	80	15	0	0.63	273	87	32	35
77/115	12.75	490.8	19.4	950	3.74	80	15	0	0.63	273	84	32	34
77/115	12.82	491.1	19.1	950	3.73	80	15	0	0.63	272	82	31	34
77/115	12.89	491.3	19.1	950	3.73	80	15	0	0.63	272	82	31	35
77/115	12.95	491.3	18.8	950	3.73	80	15	0	0.63	271	81	31	35

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/115	13.02	491.4	18.3	950	3.76	80	15	0	0.63	272	80	31	34
77/115	13.09	491.3	18.4	950	3.74	80	15	0	0.63	270	80	31	35
77/115	13.15	491.2	17.4	950	3.74	80	15	0	0.63	271	75	29	33
77/115	13.39	489.8	16.3	650	3.42	80	15	0	0.63	270	64	26	30
77/115	13.45	488.9	17.9	650	3.43	80	15	0	0.63	269	71	28	34
77/115	13.52	488.4	17.4	850	3.41	80	15	0	0.63	268	69	28	33
77/115	13.59	488.2	16.4	850	3.41	80	15	0	0.63	268	65	26	32
77/115	13.65	487.8	16.1	850	3.39	80	15	0	0.63	266	63	26	32
77/115	13.72	487.1	16.7	650	3.39	80	15	0	0.63	267	65	27	34
77/115	13.79	486.6	16.0	650	3.39	80	15	0	0.63	266	63	26	33
77/115	13.85	486.2	15.2	650	3.39	80	15	0	0.63	265	59	25	32
77/115	13.92	485.4	15.1	650	3.40	80	15	0	0.63	265	59	26	33
77/115	13.99	484.6	14.6	650	3.39	80	15	0	0.63	264	57	25	33
77/132	12.19	455.9	16.0	700	3.43	85	5	180	0.63	253	63	25	26
77/132	12.26	457.7	16.1	700	3.41	85	5	180	0.63	248	63	26	27
77/132	12.33	459.4	18.4	700	3.42	85	5	180	0.63	250	72	29	30
77/132	12.39	460.0	19.1	700	3.42	85	5	180	0.63	255	75	30	31
77/132	12.46	458.5	21.6	700	3.40	85	5	180	0.63	248	85	35	36
77/132	12.53	459.6	18.2	700	3.45	85	5	180	0.63	250	72	29	31
77/132	12.59	459.1	19.5	700	3.43	85	5	180	0.63	251	77	31	33
77/132	12.66	460.1	18.1	700	3.43	85	5	180	0.63	248	71	30	32
77/132	12.73	460.3	18.0	700	3.42	85	5	180	0.63	254	71	29	31
77/132	12.79	460.9	18.0	650	3.40	85	5	180	0.63	250	70	29	32
77/132	12.86	461.4	17.2	650	3.41	85	5	180	0.63	255	68	27	30
77/132	12.93	461.6	18.3	650	3.45	85	5	180	0.63	257	73	29	32
77/132	12.99	462.7	17.3	650	3.40	85	5	180	0.63	252	68	28	31
77/132	13.06	462.3	18.3	650	3.39	85	5	180	0.63	259	71	29	32
77/132	13.13	458.7	21.3	650	3.47	85	5	180	0.63	248	85	36	41
77/132	13.19	457.9	18.1	650	3.43	85	5	180	0.63	229	71	33	38
77/132	13.26	456.5	16.1	600	3.48	85	5	180	0.63	251	64	27	31
77/132	13.33	456.2	14.6	600	3.48	85	5	180	0.63	256	58	24	28
77/132	13.39	456.0	15.1	600	3.49	85	5	180	0.63	240	61	27	32
77/132	13.46	456.1	13.5	600	3.52	85	5	180	0.63	219	55	27	32
77/132	13.53	455.0	12.5	600	3.20	85	5	180	0.63	228	46	22	27
77/132	13.59	453.0	14.5	600	3.23	85	5	180	0.63	253	54	23	28
77/132	13.66	452.9	13.1	600	3.22	85	5	180	0.63	256	48	21	26
77/132	13.73	452.3	14.5	600	3.21	85	5	180	0.63	258	53	23	29
77/132	13.79	453.4	13.8	600	3.22	85	5	180	0.63	255	51	22	28
77/132	13.86	453.4	13.5	600	3.22	85	5	180	0.63	258	50	22	28
77/144	10.52	473.9	-1.7	700	3.77	92	8	180	0.63	237	-7	-3	*****
77/144	10.58	475.4	7.9	700	3.73	92	8	180	0.63	229	34	16	20
77/144	10.72	482.8	-1.6	700	3.76	82	8	180	0.63	231	-6	-3	*****
77/144	10.78	486.4	2.5	700	3.76	82	8	180	0.63	237	10	4	7
77/144	10.85	487.4	9.8	700	3.75	82	8	180	0.63	50	42	91	106
77/144	10.92	489.4	-1.9	700	3.80	82	8	180	0.63	0	-8	*****	*****
77/144	10.98	495.4	-8.8	700	3.81	82	8	180	0.63	237	-39	-17	*****
77/144	11.05	495.0	-1.6	700	3.80	82	8	180	0.63	152	-7	-4	*****
77/144	11.12	495.8	-6.9	700	3.82	82	8	180	0.63	0	-30	*****	*****
77/144	11.18	496.4	-9.7	700	3.86	82	8	180	0.63	0	-43	*****	*****
77/14	11.25	495.6	-7.9	700	3.82	92		180	0.63	7	-35	-462	**
77/14	11.32	495.4	-5.3	700	3.79	92		180	0.63	0	-23	*****	**

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/144	11.38	495.5	-4.9	700	3.78	82	8	180	0.63	0	-21	*****	*****
77/144	11.45	496.0	-5.6	700	3.79	82	8	180	0.63	3	-24	-645	*****
77/144	11.52	493.2	0.2	700	3.71	82	8	180	0.63	247	0	0	0
77/144	11.58	474.8	31.8	750	3.59	82	8	180	0.63	242	132	56	58
77/144	11.65	475.2	15.0	700	3.68	82	8	180	0.63	105	64	62	65
77/144	11.72	479.5	1.0	700	3.70	82	8	180	0.63	247	4	1	2
77/144	11.78	475.0	14.3	700	3.71	82	8	180	0.63	245	61	25	26
77/144	11.85	473.4	18.2	700	3.66	82	8	180	0.63	246	77	32	32
77/144	11.92	474.0	17.6	700	3.65	82	8	180	0.63	249	74	30	31
77/144	11.98	475.3	10.2	700	3.74	82	8	180	0.63	0	44	*****	*****
77/144	12.05	474.4	1.3	700	3.77	82	8	180	0.63	48	5	12	12
77/144	12.12	469.7	15.2	700	3.72	82	8	180	0.63	0	65	*****	*****
77/144	12.18	469.1	5.7	600	3.78	82	8	180	0.63	0	25	*****	*****
77/144	12.25	466.6	-1.2	600	3.76	82	8	180	0.63	10	-5	-50	*****
77/144	12.32	461.7	1.5	600	3.77	82	8	180	0.63	0	6	*****	*****
77/144	12.38	457.1	-1.6	600	3.77	82	8	180	0.63	3	-6	-181	*****
77/144	12.45	451.9	5.0	600	3.72	82	8	180	0.63	253	21	8	9
77/144	12.52	448.2	19.2	600	3.65	82	8	180	0.63	70	81	118	125
77/144	12.58	448.2	12.6	600	3.67	82	8	180	0.63	255	53	21	23
77/144	12.65	450.0	7.7	600	3.72	82	8	180	0.63	249	33	13	15
77/144	12.72	453.1	10.3	600	3.67	82	8	180	0.63	247	43	18	20
77/144	12.78	454.4	14.2	600	3.68	82	8	180	0.63	247	60	25	27
77/144	12.85	456.1	11.3	550	3.70	82	8	180	0.63	1	48	3206	3548
77/144	12.92	455.4	6.4	500	3.72	82	8	180	0.63	228	27	12	14
77/144	12.98	451.8	17.2	550	3.67	82	8	180	0.63	253	73	30	33
77/144	13.05	452.7	10.9	500	3.72	82	8	180	0.63	0	47	*****	*****
77/144	13.12	453.0	-4.7	500	3.78	82	8	180	0.63	0	-20	*****	*****
77/144	13.18	451.0	-4.8	500	3.79	82	8	180	0.63	0	-21	*****	*****
77/144	13.25	453.4	-5.3	500	3.74	82	8	180	0.63	0	-22	*****	*****
77/144	13.32	456.6	-6.3	500	3.77	82	8	180	0.63	0	-27	*****	*****
77/144	13.38	458.8	-9.9	500	3.77	82	8	180	0.63	145	-43	-32	*****
77/144	13.45	459.6	-0.4	500	3.72	82	8	180	0.63	239	-1	0	0
77/144	13.52	461.4	3.2	500	3.66	82	8	180	0.63	243	13	6	8
77/144	13.58	463.6	4.8	550	3.66	82	8	180	0.63	0	20	*****	*****
77/144	13.65	463.0	-1.3	500	3.68	82	8	180	0.63	236	-5	-2	*****
77/144	13.72	458.6	9.9	550	3.71	82	8	180	0.63	0	42	*****	*****
77/144	13.78	455.0	-0.1	500	3.77	82	8	180	0.63	239	0	0	2
77/144	13.85	452.4	10.2	500	3.72	82	8	180	0.63	233	43	21	27
77/144	13.92	453.8	7.6	500	3.71	82	8	180	0.63	235	32	16	21
77/144	13.98	454.7	7.0	500	3.70	82	8	180	0.63	229	30	15	20
77/144	14.05	454.3	7.6	500	3.71	82	8	180	0.63	227	32	16	22
77/144	14.12	454.6	4.7	500	3.72	82	8	180	0.63	229	20	10	15
77/144	14.18	454.2	3.6	500	3.75	82	8	180	0.63	0	15	*****	*****
77/144	14.25	454.6	-0.6	500	3.73	82	8	180	0.63	7	-2	-39	64
77/144	14.32	455.1	-3.5	500	3.72	82	8	180	0.63	0	-15	*****	*****
77/144	14.38	456.2	-4.7	500	3.71	82	8	180	0.63	227	-20	-10	*****
77/144	14.45	457.5	2.7	500	3.66	82	8	180	0.63	216	11	6	12
77/144	14.52	459.4	-2.3	500	3.75	82	8	180	0.63	0	-9	*****	*****
77/144	14.58	460.6	-9.2	500	3.76	82	8	180	0.63	211	-40	-24	*****
77/144	14.65	458.2	-2.8	500	3.77	82	8	180	0.63	215	-12	-7	*****
77/144	14.72	458.5	-0.4	500	3.76	82	8	180	0.63	31	-1	-7	31

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/144	14.78	458.9	-4.6	500	3.78	82	8	180	0.63	50	-20	-53	*****
77/144	14.85	459.1	-1.5	500	3.77	82	8	180	0.63	106	-6	-8	2
77/144	14.92	458.6	-1.2	500	3.78	82	8	180	0.63	2	-5	-258	215
77/145	11.03	462.6	5.0	700	6.45	82	7	165	0.63	263	37	15	17
77/145	11.18	457.8	9.9	700	6.43	82	7	165	0.63	268	73	28	31
77/145	11.27	458.3	9.0	700	6.42	82	7	165	0.63	271	66	25	27
77/145	11.35	459.0	9.8	700	6.40	82	7	165	0.63	265	72	28	30
77/145	11.43	460.2	10.0	700	6.41	82	7	165	0.63	266	74	29	30
77/145	11.52	461.7	5.3	700	6.41	82	7	165	0.63	266	39	15	16
77/145	11.60	460.6	5.1	700	6.43	82	7	165	0.63	263	37	14	15
77/145	11.68	460.6	7.1	700	6.44	82	7	165	0.63	259	52	21	21
77/145	11.77	457.9	1.5	700	6.47	82	7	165	0.63	15	11	76	81
77/145	11.85	453.8	8.9	700	6.52	82	7	165	0.63	7	67	915	929
77/145	11.93	451.4	2.8	700	6.47	82	7	165	0.63	27	20	79	80
77/145	12.02	448.9	8.9	700	6.45	82	7	165	0.63	258	66	26	26
77/145	12.10	449.0	5.2	700	6.49	82	7	165	0.63	5	39	777	787
77/145	12.18	456.6	-0.7	600	6.52	82	7	165	0.63	23	-5	-23	*****
77/145	12.27	467.9	-2.1	600	3.05	82	7	165	0.63	114	-7	-6	*****
77/145	12.35	471.2	-14.8	600	2.99	82	7	165	0.63	249	-51	-21	*****
77/145	12.43	475.8	13.6	650	2.96	82	7	165	0.63	256	46	18	19
77/145	12.52	482.2	8.8	650	3.00	82	7	165	0.63	229	30	13	14
77/145	12.60	492.5	-8.9	700	3.05	82	7	165	0.63	97	-31	-33	*****
77/145	12.68	496.5	2.6	750	2.97	82	7	165	0.63	244	9	3	4
77/145	12.77	496.1	4.8	800	2.97	82	7	165	0.63	236	16	7	8
77/145	12.85	501.5	-4.2	800	3.01	82	7	165	0.63	251	-14	-6	*****
77/145	12.93	499.2	10.5	800	2.95	82	7	165	0.63	227	36	16	19
77/145	13.02	491.2	12.0	850	2.93	82	7	165	0.63	245	40	17	20
77/145	13.10	488.3	-1.3	850	2.93	82	7	165	0.63	0	-4	*****	*****
77/145	13.18	484.0	2.5	850	2.93	82	7	165	0.63	245	8	3	5
77/145	13.27	488.0	-2.1	800	3.01	82	7	165	0.63	1	-7	-399	*****
77/145	13.35	490.7	-6.5	800	2.93	82	7	165	0.63	257	-22	-9	*****
77/145	13.43	491.9	6.7	800	2.93	82	7	165	0.63	261	22	9	12
77/145	13.52	494.3	4.7	800	3.00	82	7	165	0.63	263	16	6	9
77/145	13.60	496.2	2.7	800	2.98	82	7	165	0.63	262	9	3	6
77/145	13.68	490.5	7.6	800	2.96	82	7	165	0.63	258	26	11	15
77/145	13.77	487.6	4.9	800	2.97	82	7	165	0.63	216	16	8	13
77/145	13.85	486.8	-2.1	800	3.07	82	7	165	0.63	239	-7	-3	*****
77/145	13.93	487.7	-5.3	750	3.00	82	7	165	0.63	182	-18	-11	*****
77/145	14.02	490.4	-2.9	750	3.03	82	7	165	0.63	257	-10	-4	*****
77/145	14.10	492.6	-2.3	750	3.02	82	7	165	0.63	257	-8	-3	*****
77/145	14.18	494.3	-2.1	750	3.02	82	7	165	0.63	6	-7	-139	*****
77/145	14.27	495.0	-11.2	750	3.10	82	7	165	0.63	0	-40	*****	*****
77/145	14.35	493.6	-5.1	750	3.04	82	7	165	0.63	255	-18	-8	*****
77/145	14.43	493.8	3.9	750	2.98	82	7	165	0.63	208	13	8	15
77/145	14.52	486.7	5.6	750	2.96	82	7	165	0.63	1	19	1227	2112
77/145	14.60	476.2	4.6	750	2.97	82	7	165	0.63	2	15	853	1579
77/145	14.68	472.6	-6.7	750	2.97	82	7	165	0.63	1	-23	-2520	*****
77/145	14.77	464.6	-2.3	750	2.95	82	7	165	0.63	240	-7	-4	0
77/145	14.85	457.8	-0.8	750	2.92	82		165	0.63	142	-2	-2	
77/145	14.93	451.8	5.9	750	2.92	82		165	0.63	239	19	11	
77/145	15.02	447.9	3.4	750	2.86	82		165	0.63	245	11	6	17

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   DATE         SOLAR     INLET  TEMP.  PRESSURE  FLOW   AMBIENT  WIND    WIND   REFLEC-   DIRECT    COLLECTION       EFFICIENCY
                TIME      TEMP.  DIFF.            RATE    TEMP.   SPEED   DIR.   TIVITY  RADIATION     RATE       SINGLE    WITHOUT
(YEAR/DAY)   (DEC.HRS.)   (F)    (F)     (PSI)   (GPM)    (F)    (MPH)  (DEG.)          (BTU/HR./SQ.FT.)          MODULE    END LOSS

  77/146       11.40     507.6   14.7     900     2.35     90       8     165    0.63       229         40         18          19
  77/145       11.48     474.5   49.1     900     2.36     90       8     165    0.63       214        134         65          68
  77/146       11.56     474.1   35.3     900     2.43     90       8     165    0.63       202         99         50          53
  77/146       11.65     482.5   13.8     900     2.54     90       8     165    0.63       212         40         19          20
  77/146       11.73     486.5   10.3     900     2.54     90       8     165    0.63       206         30         15          15
  77/146       11.81     482.3   20.7     900     2.49     90       8     165    0.63       199         59         30          31
  77/146       11.90     480.1   22.4     900     2.50     90       8     165    0.63       236         65         28          28
  77/146       11.98     479.6   22.5     900     2.49     90       8     165    0.63       245         65         27          27
  77/146       12.01     479.6   23.5     900     2.48     90       8     165    0.63       243         67         28          28
  77/146       12.10     479.4   24.7     900     2.48     90       8     165    0.63       231         71         31          31
  77/146       12.18     479.0   23.1     900     2.33     90       8     165    0.63       173         62         37          37
  77/146       12.26     481.6   15.9     900     3.00     90       8     165    0.63       227         55         25          25
  77/146       12.35     480.9   16.6     900     2.67     90       8     165    0.63       239         51         22          23
  77/146       12.43     478.8   12.8     900     2.70     90       8     165    0.63        23         40        179         190
  77/146       12.51     477.1    9.0     900     2.69     90       8     165    0.63       156         28         18          20
  77/146       12.60     473.3   17.3     900     2.65     90       8     165    0.63        10         53        535         573
  77/146       12.68     471.1   13.3     900     2.33     90       8     165    0.63       243         35         15          16
  77/146       12.76     463.0   26.4     900     0.94     90       8     165    0.63       108         28         27          31
  77/146       12.85     455.4   32.4     900     0.95     90       8     165    0.63        37         35        100         112
  77/146       12.93     469.2   22.8     900     3.72     90       8     165    0.63       249         98         41          45
  77/146       13.01     469.8   12.3     900     5.73     90       8     165    0.63       244         81         35          39
  77/146       13.10     473.0   11.7     900     6.66     90       8     165    0.63       242         90         39          44
  77/146       13.18     474.6    8.0     900     6.79     90       8     165    0.63       230         62         29          33
  77/146       13.26     474.1    7.2     900     6.58     90       8     165    0.63       226         54         26          30
  77/146       13.35     467.8   11.2     900     2.69     90       8     165    0.63       237         34         16          19
  77/146       13.43     461.8   20.4     900     2.35     90       8     165    0.63       168         55         36          42
  77/146       13.51     462.2   11.2     900     2.30     90       8     165    0.63       235         29         14          17
  77/146       13.60     455.8   14.6     900     2.10     90       8     165    0.63        35         35        110         138
  77/146       13.68     447.2   15.0     900     1.02     90       8     165    0.63         4         17        455         640
  77/146       13.76     437.9   19.7     900     1.01     90       8     165    0.63       247         22         10          14
  77/146       13.85     429.0   25.9     900     1.00     90       8     165    0.63       245         29         14          18
  77/146       13.93     422.6   30.0     900     0.99     90       8     165    0.63       217         34         18          23
  77/146       14.01     418.4   33.2     900     0.99     90       8     165    0.63       241         37         18          24
  77/146       14.10     415.4   37.7     900     0.98     90       8     165    0.63       237         42         21          27
  77/146       14.18     426.6   29.1     900     2.52     90       8     165    0.63       235         84         43          54
  77/146       14.26     436.9   -0.8     900     3.04     90       8     165    0.63       239         -2         -1           1
  77/146       14.35     432.7    4.7     900     5.54     90       8     165    0.63       235         30         15          22
  77/146       14.43     431.1    3.4     900     6.84     90       8     165    0.63       241         26         13          20
  77/146       14.51     427.4    2.5     900     6.85     90       8     165    0.63        21         19        116         188
  77/147        7.93     419.3   21.7     800     6.91     90       8     210    0.63       221        173        145         249
  77/147        8.10     366.1   82.8     800     6.67     90       8     210    0.63       223        639        502         781
  77/147        8.26     414.7  -10.6     800     6.73     90       8     210    0.63       225        -82        -61       *****
  77/147        8.43     419.4   -1.5     800     6.75     90       8     210    0.63       229        -11         -8       *****
  77/147        8.60     427.9   -1.7     800     6.75     90       8     210    0.63       231        -13         -8       *****
  77/147        8.76     407.5   27.8     800     6.77     90       8     210    0.63       231        217        138         193
  77/147        8.93     444.6   -1.2     800     6.78     90       8     210    0.63       235         -9         -5       *****
  77/147        9.10     452.2   -0.4     800     6.77     90       8     210    0.63       237         -3         -1           3
  77/147        9.26     460.6    0.6     800     6.78     90       8     210    0.63       239          4          2           8
  77/147        9.43     468.3   -0.4     900     6.80     90       8     210    0.63       242         -3         -1           2
  77/147        9.60     477.1    1.1     900     6.81     90       8     210    0.63       245          8          4           9
  77/147        9.76     484.9    2.9     900     6.81     90       8     210    0.63       246         22         11          17
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DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/147	9.85	489.8	1.2	900	6.86	90	8	210	0.63	245	9	4	9
77/147	9.93	494.4	1.8	900	6.87	90	8	210	0.63	245	14	6	11
77/147	10.01	487.8	13.7	900	5.52	90	8	210	0.63	248	87	41	51
77/147	10.10	488.2	6.9	900	4.78	90	8	210	0.63	247	38	17	23
77/147	10.18	483.0	14.0	900	2.76	90	8	210	0.63	248	44	20	26
77/147	10.26	477.8	19.8	900	2.00	90	8	210	0.63	247	45	21	26
77/147	10.35	469.8	27.6	900	0.84	90	8	210	0.63	248	26	12	15
77/147	10.43	461.4	35.6	900	0.79	90	8	210	0.63	251	32	14	18
77/147	10.51	458.2	49.6	900	1.96	90	8	210	0.63	251	112	49	56
77/147	10.60	471.4	23.0	900	4.02	90	8	210	0.63	251	107	46	53
77/147	10.68	479.2	6.0	900	5.28	90	8	210	0.63	253	36	15	18
77/147	10.76	478.6	6.8	900	6.72	90	8	210	0.63	252	52	22	26
77/147	10.85	477.7	8.2	900	6.73	90	8	210	0.63	253	63	27	30
77/147	10.93	477.2	7.8	900	6.69	90	8	210	0.63	254	60	25	28
77/147	11.01	476.3	8.2	900	6.74	90	8	210	0.63	254	64	26	29
77/147	11.10	470.7	17.4	900	2.22	90	8	210	0.63	254	44	18	20
77/147	11.18	461.3	32.8	900	0.85	90	8	210	0.63	254	32	13	15
77/147	11.26	453.0	48.8	900	0.79	90	8	210	0.63	253	44	18	20
77/147	11.35	459.8	53.6	900	2.05	90	8	210	0.63	81	127	163	172
77/147	11.43	464.4	31.0	900	2.92	90	8	210	0.63	116	104	93	98
77/147	11.51	476.6	10.0	900	3.01	90	8	210	0.63	119	34	30	32
77/147	11.60	475.0	19.2	900	3.19	90	8	210	0.63	126	71	57	60
77/147	11.68	474.0	21.9	900	3.20	90	8	210	0.63	127	81	65	68
77/147	11.76	476.2	18.7	900	3.22	90	8	210	0.63	128	69	56	57
77/147	11.85	477.0	20.0	900	3.20	90	8	210	0.63	127	74	60	61
77/147	11.93	477.5	20.7	900	3.19	90	8	210	0.63	126	76	62	62
77/147	12.01	478.7	19.9	900	3.21	90	8	210	0.63	127	74	59	59
77/147	12.10	479.8	20.2	900	3.19	90	8	210	0.63	126	74	60	61
77/147	12.18	480.7	19.9	900	3.21	90	8	210	0.63	249	74	30	31
77/147	12.26	481.7	19.7	900	3.21	90	8	210	0.63	251	73	30	31
77/147	12.35	509.6	-6.1	900	3.33	90	8	210	0.63	255	-23	-9	*****
77/147	12.43	493.6	30.2	900	3.23	90	8	210	0.63	254	113	46	48
77/147	12.51	507.2	10.2	900	3.41	90	8	210	0.63	253	40	16	17
77/147	12.60	503.7	18.8	900	3.28	90	8	210	0.63	253	72	29	31
77/147	12.68	505.3	14.9	900	3.40	90	8	210	0.63	254	59	24	26
77/147	12.76	497.0	22.7	900	3.39	90	8	210	0.63	251	89	37	40
77/147	12.85	497.2	15.1	900	3.45	90	8	210	0.63	252	60	25	27
77/147	12.93	495.8	14.4	900	2.88	90	8	210	0.63	253	48	20	22
77/147	13.01	492.5	20.0	900	2.81	90	8	210	0.63	251	65	27	31
77/147	13.10	494.2	17.6	900	2.79	90	8	210	0.63	250	57	24	27
77/147	13.18	493.0	16.8	900	2.85	90	8	210	0.63	251	55	23	27
77/147	13.26	492.6	19.2	900	2.76	90	8	210	0.63	250	61	26	30
77/147	13.35	492.8	18.0	900	2.74	90	8	210	0.63	251	57	24	29
77/147	13.43	492.1	17.7	900	2.74	90	8	210	0.63	249	56	24	29
77/147	13.51	491.1	16.4	900	2.74	90	8	210	0.63	250	52	23	27
77/147	13.60	489.1	18.2	900	2.74	90	8	210	0.63	251	58	25	31
77/147	13.68	489.1	18.0	900	2.74	90	8	210	0.63	249	57	25	31
77/147	13.76	488.0	16.2	900	2.16	90	8	210	0.63	248	40	18	23
77/147	13.85	480.3	25.2	900	1.51	90	8	210	0.63	247	44	20	26
77/147	13.93	474.4	35.0	900	1.47	90	8	210	0.63	247	59	28	35
77/147	14.01	473.8	35.5	900	1.32	90	8	210	0.63	247	54	25	33

DATE	SOLAR TIME	INLET TEMP.	TEMP. DIFF.	PRESSURE	FLOW RATE	AMBIENT TEMP.	WIND SPEED	WIND DIR.	REFLEC-TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
(YEAR/DAY)	(DEC.HRS.)	(F)	(F)	(PSI)	(GPM)	(F)	(MPH)	(DEG.)		(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/147	14.10	474.2	32.5	900	1.55	90	8	210	0.63	248	58	27	36
77/147	14.18	473.8	29.6	900	1.58	90	8	210	0.63	247	54	26	34
77/147	14.26	471.5	29.4	900	1.41	90	8	210	0.63	245	48	23	32
77/147	14.35	469.3	28.8	900	1.53	90	8	210	0.63	246	51	25	34
77/147	14.43	467.8	27.1	900	1.59	90	8	210	0.63	245	49	25	35
77/147	14.51	466.0	26.1	900	1.66	90	8	210	0.63	244	50	25	36
77/157	11.54	463.2	27.6	930	2.70	90	5	0	0.65	216	86	41	43
77/157	11.62	465.9	26.5	930	2.50	90	5	0	0.65	210	76	37	39
77/157	11.70	465.2	25.1	930	2.30	90	5	0	0.65	211	66	32	33
77/157	11.79	464.0	29.3	930	2.30	90	5	0	0.65	216	78	37	38
77/157	11.87	464.3	29.7	930	2.20	90	5	0	0.65	218	75	35	36
77/157	11.95	464.2	31.1	930	1.90	90	5	0	0.65	216	68	32	32
77/157	12.04	464.2	34.2	930	1.70	90	5	0	0.65	219	67	31	31
77/158	11.12	467.1	24.1	900	2.42	95	7	30	0.65	239	67	29	32
77/158	11.20	466.9	25.3	900	2.38	95	7	30	0.65	238	69	30	33
77/158	11.28	467.0	25.9	900	2.33	95	7	30	0.65	239	69	30	32
77/158	11.37	467.2	27.4	900	2.31	95	7	30	0.65	242	73	31	33
77/158	11.45	467.6	27.8	900	2.30	95	7	30	0.65	246	74	31	33
77/158	11.53	467.9	28.2	900	2.28	95	7	30	0.65	245	74	31	32
77/158	11.62	468.8	29.3	900	2.27	95	7	30	0.65	247	77	32	33
77/158	11.70	470.6	28.3	900	2.31	95	7	30	0.65	248	75	31	32
77/158	11.78	473.4	26.8	900	2.30	95	7	30	0.65	249	71	29	30
77/158	11.87	476.0	26.5	900	2.29	95	7	30	0.65	250	70	29	29
77/158	11.95	477.1	28.6	900	2.31	95	7	30	0.65	251	76	31	31
77/158	12.03	478.6	28.9	900	2.32	95	7	30	0.65	249	77	32	32
77/158	12.12	480.0	28.0	900	2.39	95	7	30	0.65	250	77	32	32
77/158	12.20	481.1	27.9	900	2.43	95	7	30	0.65	250	78	32	33
77/158	12.28	482.2	27.5	900	2.57	95	7	30	0.65	250	82	34	34
77/158	12.37	482.6	26.7	900	2.27	95	7	30	0.65	248	70	29	30
77/158	12.45	481.6	26.8	900	2.69	95	7	30	0.65	249	83	34	36
77/158	12.53	480.2	27.0	900	2.72	95	7	30	0.65	247	85	35	37
77/158	12.62	481.0	24.8	900	2.71	95	7	30	0.65	250	78	32	34
77/158	12.70	481.8	22.4	900	2.66	95	7	30	0.65	247	69	29	31
77/158	12.78	482.0	22.3	900	2.56	95	7	30	0.65	250	66	27	30
77/158	12.87	482.6	21.1	900	2.48	95	7	30	0.65	248	60	25	28
77/158	12.95	482.1	20.6	900	2.39	95	7	30	0.65	250	57	24	27
77/158	13.03	481.1	20.0	900	2.30	95	7	30	0.65	248	53	22	25
77/158	13.12	479.6	19.4	900	2.24	95	7	30	0.65	246	50	21	25
77/159	11.02	506.8	13.9	950	5.39	95	0	0	0.65	253	87	36	40
77/159	11.10	501.9	17.0	950	4.21	95	0	0	0.65	252	83	35	38
77/159	11.18	494.1	22.1	950	3.63	95	0	0	0.65	252	93	39	42
77/159	11.27	490.8	22.4	950	3.26	95	0	0	0.65	250	85	35	38
77/159	11.35	493.0	19.8	950	2.71	95	0	0	0.65	246	62	26	28
77/159	11.40	492.2	25.8	950	2.65	95	0	0	0.65	248	79	33	35
77/159	11.48	492.2	25.8	950	2.57	95	0	0	0.65	248	77	32	34
77/159	11.57	491.3	28.6	950	2.48	95	0	0	0.65	250	82	34	35
77/159	11.65	491.3	29.2	1000	2.43	95	0	0	0.65	252	82	33	35
77/159	11.73	492.6	28.1	1000	2.41	95	0	0	0.65	250	78	32	33
77/159	11.82	493.8	28.3	1000	2.40	95	0	0	0.65	252	79	32	33
77/159	11.90	494.7	29.2	1000	2.40	95	0	0	0.65	248	81	33	34
77/159	11.98	495.4	30.1	1000	2.46	95	0	0	0.65	251	86	35	35

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/159	12.07	497.2	28.5	1000	2.56	95	0	0	0.65	249	85	35	35
77/159	12.15	498.8	27.1	1000	2.48	95	0	0	0.65	248	78	32	33
77/159	12.23	499.8	27.0	1000	2.45	95	0	0	0.65	252	77	31	32
77/159	12.32	500.3	27.9	1000	2.41	95	0	0	0.65	254	78	32	33
77/159	12.40	500.6	28.6	1000	2.41	95	0	0	0.65	251	80	33	34
77/159	12.48	501.3	27.8	1000	2.42	95	0	0	0.65	251	78	32	34
77/159	12.57	501.9	26.9	1000	2.31	95	0	0	0.65	253	72	29	31
77/159	12.65	502.3	26.1	1000	2.32	95	0	0	0.65	251	70	29	31
77/159	12.73	502.2	25.0	1000	2.20	95	0	0	0.65	248	64	27	29
77/159	12.82	501.7	23.8	1000	2.23	95	0	0	0.65	246	62	26	28
77/159	12.90	501.4	23.8	1000	2.18	95	0	0	0.65	249	60	25	28
77/159	12.98	500.0	25.8	1000	2.10	95	0	0	0.65	245	63	27	30
77/159	13.07	498.5	26.5	1000	2.03	95	0	0	0.65	246	62	27	30
77/159	13.15	497.9	24.6	1000	1.93	95	0	0	0.65	248	55	24	27
77/159	13.23	494.3	26.7	1000	1.08	95	0	0	0.65	249	33	14	17
77/159	13.32	490.6	32.7	1000	1.55	95	0	0	0.65	251	59	25	29
77/159	13.40	490.7	33.7	1000	1.65	95	0	0	0.65	242	64	29	34
77/164	10.42	387.8	4.8	611	6.40	95	6	60	0.65	15	35	257	312
77/164	10.50	385.6	11.5	611	6.36	95	6	60	0.65	265	85	35	40
77/164	10.58	387.4	9.9	611	6.35	95	6	60	0.65	264	73	30	34
77/164	10.67	388.9	8.9	611	6.38	95	6	60	0.65	243	65	29	33
77/164	10.75	389.6	4.4	611	4.94	95	6	60	0.65	10	25	264	316
77/164	10.83	386.1	18.1	611	3.77	95	6	60	0.65	263	79	32	36
77/164	10.92	385.0	20.6	611	2.89	95	6	60	0.65	260	69	28	31
77/164	11.00	384.4	22.0	561	2.35	95	6	60	0.65	250	60	25	28
77/164	11.08	385.4	27.6	561	2.20	95	6	60	0.65	265	70	28	30
77/164	11.17	385.1	28.9	561	2.12	95	6	60	0.65	265	71	28	30
77/164	11.25	386.4	32.6	561	2.08	95	6	60	0.65	265	78	31	33
77/164	11.33	389.3	27.1	561	2.00	95	6	60	0.65	183	63	36	38
77/164	11.42	390.2	21.9	561	1.87	95	6	60	0.65	266	47	18	19
77/164	11.50	392.1	35.0	561	1.86	95	6	60	0.65	266	75	29	30
77/164	11.58	391.7	38.7	561	1.87	95	6	60	0.65	264	84	32	34
77/164	11.67	392.2	40.0	561	1.94	95	6	60	0.65	264	90	35	36
77/164	11.75	395.5	37.1	561	1.94	95	6	60	0.65	266	83	32	33
77/164	11.83	400.4	31.7	561	1.91	95	6	60	0.65	266	70	27	27
77/164	11.92	404.0	30.0	611	1.90	95	6	60	0.65	15	66	452	456
77/164	12.00	405.9	24.8	611	1.86	95	6	60	0.65	268	53	20	20
77/164	12.08	402.2	39.2	611	1.83	95	6	60	0.65	263	83	32	32
77/164	12.17	397.2	47.7	611	1.92	95	6	60	0.65	268	106	40	41
77/164	12.25	392.0	48.3	611	2.10	95	6	60	0.65	269	117	45	46
77/164	12.33	390.8	42.3	611	2.26	95	6	60	0.65	270	110	42	43
77/164	12.42	389.4	37.7	561	2.28	95	6	60	0.65	108	99	95	99
77/164	12.50	388.6	26.4	561	2.15	95	6	60	0.65	265	65	25	27
77/164	12.58	387.5	32.0	561	2.09	95	6	60	0.65	270	77	30	31
77/164	12.67	387.4	34.6	561	2.06	95	6	60	0.65	269	82	32	34
77/164	12.75	387.4	32.4	561	2.03	95	6	60	0.65	270	76	29	31
77/164	12.83	386.9	33.4	511	1.99	95	6	60	0.65	270	77	30	32
77/164	12.92	387.0	34.0	511	1.97	95	6	60	0.65	272	77	30	32
77/164	13.00	386.3	34.5	511	1.97	95	6	60	0.65	267	79	31	34
77/164	13.08	386.1	32.4	511	1.94	95	6	60	0.65	270	73	28	
77/164	13.17	385.7	31.4	511	1.92	95	6	60	0.65	268	70	28	

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC- TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/164	13.25	385.6	30.9	511	1.91	95	6	60	0.65	269	68	27	31
77/164	13.33	385.4	29.7	511	1.91	95	6	60	0.65	270	65	26	30
77/164	13.42	385.4	25.3	511	1.93	95	6	60	0.65	270	56	23	26
77/164	13.50	385.3	22.7	511	1.92	95	6	60	0.65	271	50	20	24
77/164	13.58	385.1	25.9	511	1.93	95	6	60	0.65	270	58	23	28
77/164	13.67	385.0	24.7	511	1.94	95	6	60	0.65	26	55	235	281
77/164	13.75	384.9	20.1	511	1.94	95	6	60	0.65	271	45	19	23
77/164	13.83	384.9	22.6	511	1.92	95	6	60	0.65	270	50	21	26
77/164	13.92	384.9	23.7	511	1.91	95	6	60	0.65	266	52	22	28
77/164	14.00	385.0	23.3	511	1.91	95	6	60	0.65	255	51	23	29
77/164	14.08	385.0	22.7	511	1.92	95	6	60	0.65	266	50	22	28
77/164	14.17	384.8	18.8	511	1.91	95	6	60	0.65	265	41	18	24
77/164	14.25	384.1	15.2	511	1.94	95	6	60	0.65	1	34	2092	2822
77/164	14.33	382.3	13.7	511	1.94	95	6	60	0.65	1	30	2387	3305
77/179	11.84	391.3	24.4	488	2.03	95	10	210	0.65	208	57	28	29
77/179	11.92	389.7	26.1	484	1.90	95	10	210	0.65	212	57	28	28
77/179	12.00	389.1	27.2	482	1.80	95	10	210	0.65	207	56	28	28
77/179	12.09	388.8	27.0	477	1.73	95	10	210	0.65	198	54	28	28
77/179	12.17	388.1	29.5	474	1.71	95	10	210	0.65	211	58	28	29
77/179	12.25	387.4	31.3	474	1.70	95	10	210	0.65	193	61	33	33
77/179	12.34	387.9	27.8	471	1.66	95	10	210	0.65	187	53	29	30
77/179	12.42	387.9	26.5	464	1.60	95	10	210	0.65	190	49	26	28
77/179	12.50	386.5	27.2	456	1.57	95	10	210	0.65	177	49	29	30
77/179	12.59	384.7	26.6	448	1.49	95	10	210	0.65	169	46	28	30
77/179	12.67	383.1	25.2	507	1.42	95	10	210	0.65	157	41	27	29
77/179	12.75	400.9	4.4	492	1.17	95	10	210	0.65	157	5	4	5
77/179	12.84	378.7	26.0	478	1.14	95	10	210	0.65	163	34	22	24
77/179	12.92	421.5	-12.3	476	2.10	95	10	210	0.65	182	-30	-17	*****
77/179	13.00	410.4	-2.9	488	2.29	95	10	210	0.65	183	-7	-4	*****
77/179	13.09	400.8	20.0	504	2.23	95	10	210	0.65	188	51	29	32
77/179	13.25	392.7	21.5	504	2.20	95	10	210	0.65	203	54	29	33
77/179	13.34	392.1	19.4	496	2.23	95	10	210	0.65	208	50	26	30
77/179	13.42	390.7	18.8	487	2.24	95	10	210	0.65	208	48	25	30
77/179	13.50	389.3	18.1	478	2.26	95	10	210	0.65	213	47	24	29
77/179	13.59	388.3	17.6	466	2.26	95	10	210	0.65	213	46	24	28
77/179	13.67	391.0	13.7	419	2.22	95	10	210	0.65	212	35	18	23
77/179	13.75	392.5	12.6	377	2.22	95	10	210	0.65	208	32	17	22
77/179	13.84	393.2	11.7	345	2.16	95	10	210	0.65	211	29	15	20
77/179	13.92	393.9	12.2	321	2.10	95	10	210	0.65	206	29	16	21
77/179	14.00	394.7	11.2	302	2.03	95	10	210	0.65	210	26	14	19
77/179	14.09	395.4	9.5	286	2.01	95	10	210	0.65	210	22	12	17
77/179	14.17	394.4	12.7	258	2.16	95	10	210	0.65	224	31	17	22
77/179	14.25	394.6	14.5	317	2.15	95	10	210	0.65	223	36	19	26
77/179	14.34	395.7	11.7	288	2.04	95	10	210	0.65	224	27	15	21
77/179	14.42	397.3	5.6	267	2.01	95	10	210	0.65	128	13	12	21
77/179	14.50	397.0	1.2	245	1.85	95	10	210	0.65	179	2	1	6
77/180	13.00	388.5	15.0	499	2.04	97	10	180	0.65	241	35	15	17
77/180	13.09	386.1	23.4	494	1.93	97	10	180	0.65	180	52	31	34
77/180	13.17	391.4	12.2	494	1.76	97	10	180	0.65	241	24	11	13
77/180	13.25	392.1	18.5	493	1.55	97	10	180	0.65	105	33	34	40
77/180	13.34	391.3	20.0	490	1.57	97	10	180	0.65	14	36	278	328

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC- TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY	
												SINGLE MODULE	WITHOUT END LOSS
77/180	13.42	392.8	5.3	467	1.58	97	10	180	0.65	8	9	122	175
77/180	13.50	393.5	-1.6	479	1.60	97	10	180	0.65	1	-2	-207	8
77/180	13.59	390.6	-1.4	473	1.61	97	10	180	0.65	226	-2	-1	0
77/180	13.67	394.0	3.6	468	1.62	97	10	180	0.65	231	6	3	5
77/180	13.75	396.5	7.5	467	1.62	97	10	180	0.65	229	14	6	9
77/180	13.84	399.3	7.4	466	1.61	97	10	180	0.65	225	13	7	10
77/180	13.92	398.2	2.3	463	1.60	97	10	180	0.65	0	4	*****	*****
77/180	14.00	398.7	-4.6	461	1.59	97	10	180	0.65	228	-8	-4	*****
77/180	14.09	396.0	6.7	459	1.56	97	10	180	0.65	226	12	6	10
77/180	14.17	393.4	18.1	456	1.55	97	10	180	0.65	1	32	3277	4423
77/180	14.25	397.3	6.3	461	1.54	97	10	180	0.65	224	11	6	10
77/180	14.34	396.2	5.3	459	1.56	97	10	180	0.65	1	9	990	1824
77/180	14.42	396.0	-0.7	456	1.57	97	10	180	0.65	223	-1	0	2
77/180	14.50	393.5	7.7	453	1.55	97	10	180	0.65	117	13	14	25
77/180	14.59	394.5	4.8	445	1.56	97	10	180	0.65	0	8	*****	*****
77/181	12.33	400.3	20.9	600	2.18	90	10	210	0.65	245	52	22	23
77/181	12.41	407.1	4.4	598	1.89	90	10	210	0.65	237	9	4	4
77/181	12.50	404.5	12.9	550	1.70	90	10	210	0.65	1	25	1668	1794
77/181	12.58	398.9	26.9	586	1.62	90	10	210	0.65	247	50	21	22
77/181	12.66	396.4	38.1	565	1.77	90	10	210	0.65	38	78	210	223
77/181	12.75	395.8	33.9	589	1.77	90	10	210	0.65	1	69	6142	6600
77/181	12.83	397.1	24.1	592	1.62	90	10	210	0.65	249	45	19	21
77/181	12.91	400.0	26.2	590	1.60	90	10	210	0.65	245	48	21	23
77/181	13.00	399.3	33.0	590	1.58	90	10	210	0.65	244	60	26	29
77/181	13.08	398.7	32.1	590	1.58	90	10	210	0.65	57	58	109	122
77/181	13.16	398.7	22.5	589	5.70	90	10	210	0.65	239	148	66	73
77/181	13.25	399.5	18.0	583	5.77	90	10	210	0.65	242	120	53	59
77/181	13.33	399.2	17.5	579	5.80	90	10	210	0.65	243	117	52	59
77/181	13.41	397.3	25.4	571	5.58	90	10	210	0.65	235	164	76	86
77/181	13.50	394.8	20.3	563	2.92	90	10	210	0.65	129	68	58	68
77/181	13.58	394.8	3.7	553	4.02	90	10	210	0.65	173	17	11	14
77/181	13.66	393.9	-0.9	542	1.62	90	10	210	0.65	1	-1	-120	143
77/181	13.75	427.5	-37.9	540	1.72	90	10	210	0.65	11	-75	-721	*****
77/181	13.83	426.2	-38.2	534	1.71	90	10	210	0.65	1	-75	-4379	*****
77/181	13.91	423.2	-19.2	529	1.67	90	10	210	0.65	2	-37	-1808	*****
77/181	14.00	419.6	-12.4	526	1.65	90	10	210	0.65	134	-23	-20	*****
77/181	14.08	419.3	-11.2	524	1.65	90	10	210	0.65	9	-21	-277	*****
77/181	14.16	420.6	-14.6	524	1.65	90	10	210	0.65	1	-28	-2106	*****
77/181	14.25	424.3	-20.8	523	1.64	90	10	210	0.65	84	-39	-56	*****
77/181	14.33	427.2	-17.8	526	1.65	90	10	210	0.65	171	-34	-24	*****
77/181	14.41	427.8	-7.7	531	1.62	90	10	210	0.65	136	-14	-9	*****
77/181	14.50	428.1	0.6	545	1.59	90	10	210	0.65	233	1	0	4
77/181	14.58	430.3	5.8	566	1.60	90	10	210	0.65	231	10	5	11
77/181	14.66	432.4	6.1	587	1.61	90	10	210	0.65	231	11	6	12
77/181	14.75	437.6	3.3	604	1.62	90	10	210	0.65	231	6	3	9
77/181	14.83	406.6	35.1	606	1.56	90	10	210	0.65	121	63	70	98
77/181	14.91	403.8	33.1	603	1.63	90	10	210	0.65	194	62	43	62
77/181	15.00	406.8	9.1	598	1.63	90	10	210	0.65	6	17	374	694
77/182	11.80	402.1	21.8	522	2.05	95	10	210	0.65	254	51	21	21
77/182	11.88	401.1	34.2	529	2.07	95	10	210	0.65	250	82	33	34
77/182	11.96	401.4	25.1	536	2.06	95	10	210	0.65	225	60	27	[illegible]

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/182	12.05	403.6	6.9	532	1.81	95	10	210	0.65	155	14	9	9
77/182	12.13	404.2	17.1	526	1.62	95	10	210	0.65	241	32	13	13
77/182	12.21	400.1	37.0	526	1.75	95	10	210	0.65	239	75	32	33
77/182	12.30	398.9	37.0	534	1.82	95	10	210	0.65	11	78	727	747
77/182	12.38	399.5	16.5	534	1.61	95	10	210	0.65	30	30	106	111
77/182	12.46	403.6	2.9	525	1.63	95	10	210	0.65	242	5	2	2
77/182	12.55	402.9	14.4	514	1.61	95	10	210	0.65	245	26	11	12
77/182	12.63	398.0	29.5	510	1.57	95	10	210	0.65	231	53	24	25
77/182	12.71	395.2	39.2	514	1.53	95	10	210	0.65	239	69	30	32
77/182	12.80	394.8	38.9	521	1.58	95	10	210	0.65	230	71	32	35
77/182	12.88	396.9	34.5	526	1.57	95	10	210	0.65	253	62	26	28
77/182	12.96	400.9	30.4	530	1.57	95	10	210	0.65	247	55	23	26
77/182	13.05	404.6	26.7	531	1.60	95	10	210	0.65	177	49	29	33
77/182	13.13	405.9	24.6	530	1.59	95	10	210	0.65	234	45	20	23
77/182	13.21	406.5	18.8	526	1.63	95	10	210	0.65	1	35	3226	3765
77/182	13.30	406.3	10.4	520	1.63	95	10	210	0.65	208	19	10	12
77/182	13.38	405.1	8.5	509	1.64	95	10	210	0.65	2	16	744	969
77/182	13.46	402.2	2.7	498	1.63	95	10	210	0.65	0	5	*****	*****
77/182	13.55	398.7	2.9	483	1.62	95	10	210	0.65	0	5	*****	*****
77/182	13.63	394.8	2.3	473	1.60	95	10	210	0.65	1	4	302	609
77/182	13.71	390.6	9.7	463	1.59	95	10	210	0.65	221	17	9	12
77/182	13.80	386.3	14.4	456	1.60	95	10	210	0.65	0	26	*****	*****
77/182	13.88	383.4	10.4	446	1.58	95	10	210	0.65	106	19	20	28
77/182	13.96	382.7	3.9	438	1.58	95	10	210	0.65	166	7	5	8
77/183	10.91	402.2	3.1	602	6.65	97	14	180	0.65	230	23	11	13
77/183	11.08	414.7	4.9	648	6.66	97	14	180	0.65	171	37	23	26
77/183	11.24	426.9	4.0	657	6.67	97	14	180	0.65	60	30	54	60
77/183	11.41	424.3	8.7	726	6.63	97	14	180	0.65	227	66	30	32
77/183	11.58	424.7	9.6	730	6.62	97	14	180	0.65	232	73	32	34
77/183	11.74	438.9	5.8	748	6.66	97	14	180	0.65	232	44	19	20
77/183	11.91	453.1	6.4	805	6.68	97	14	180	0.65	228	49	22	22
77/183	12.08	465.9	6.6	872	6.70	97	14	180	0.65	231	51	22	23
77/183	12.24	476.8	5.9	875	6.72	97	14	180	0.65	232	45	20	21
77/183	12.33	482.1	6.0	899	6.71	97	14	180	0.65	231	46	20	21
77/183	12.41	486.9	5.9	875	6.70	97	14	180	0.65	233	45	20	21
77/183	12.49	491.4	5.1	905	6.71	97	14	180	0.65	233	39	17	18
77/183	12.58	490.2	10.5	824	6.66	97	14	180	0.65	233	81	36	38
77/183	12.66	484.7	10.0	822	5.30	97	14	180	0.65	231	61	27	29
77/183	12.74	481.9	11.3	809	4.58	97	14	180	0.65	232	60	27	29
77/183	12.83	478.7	13.6	794	3.74	97	14	180	0.65	232	59	26	29
77/183	12.91	475.7	15.5	779	3.09	97	14	180	0.65	230	55	25	28
77/183	12.99	473.1	17.0	769	2.95	97	14	180	0.65	229	58	27	30
77/183	13.08	470.8	16.5	753	2.72	97	14	180	0.65	228	52	24	27
77/183	13.16	468.4	17.4	742	2.62	97	14	180	0.65	223	52	25	29
77/183	13.24	466.4	17.1	730	2.52	97	14	180	0.65	226	50	23	27
77/183	13.33	463.9	17.4	718	2.43	97	14	180	0.65	228	49	23	27
77/183	13.41	461.7	17.9	705	2.37	97	14	180	0.65	227	49	23	28
77/183	13.49	459.7	17.4	694	2.30	97	14	180	0.65	227	46	22	27
77/183	13.58	457.3	18.0	683	2.25	97	14	180	0.65	225	47	23	28
77/183	13.66	455.2	16.8	673	2.21	97	14	180	0.65	223	43	21	26
77/183	13.74	452.1	18.3	662	2.18	97	14	180	0.65	229	46	22	28

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLECTIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/183	13.83	450.3	17.9	653	2.14	97	14	180	0.65	224	44	22	28
77/183	13.91	447.7	18.0	643	2.12	97	14	180	0.65	225	44	22	28
77/183	13.99	445.0	18.4	634	2.08	97	14	180	0.65	223	44	23	29
77/183	14.08	442.6	17.9	624	2.04	97	14	180	0.65	224	42	22	29
77/183	14.16	439.4	18.7	614	2.03	97	14	180	0.65	224	44	23	31
77/183	14.24	436.5	18.3	604	1.99	97	14	180	0.65	224	42	22	30
77/183	14.33	433.3	18.4	594	1.96	97	14	180	0.65	221	41	23	31
77/183	14.41	430.4	17.7	584	1.92	97	14	180	0.65	216	39	22	31
77/183	14.49	426.8	17.9	574	1.85	97	14	180	0.65	219	38	22	31
77/183	14.58	423.0	18.4	563	1.75	97	14	180	0.65	216	37	22	31
77/183	14.66	420.4	17.8	554	1.71	97	14	180	0.65	217	35	21	30
77/183	14.74	417.9	16.6	545	1.71	97	14	180	0.65	216	32	20	30
77/183	14.83	414.8	16.6	538	1.70	97	14	180	0.65	216	32	20	31
77/183	14.91	412.0	16.0	531	1.72	97	14	180	0.65	214	31	20	31
77/183	14.99	409.5	15.0	525	1.72	97	14	180	0.65	211	29	19	31
77/183	15.08	406.3	14.6	519	1.71	97	14	180	0.65	212	29	19	31
77/186	11.87	430.0	17.1	737	2.84	95	8	180	0.65	15	56	374	380
77/186	11.92	429.6	13.7	731	2.51	95	8	180	0.65	264	39	15	15
77/186	11.97	427.5	20.9	728	2.44	95	8	180	0.65	259	59	23	23
77/186	12.02	427.3	23.2	717	2.31	95	8	180	0.65	1	62	3226	3231
77/186	12.07	428.3	7.6	707	2.12	95	8	180	0.65	5	18	373	377
77/186	12.12	424.5	4.3	702	2.00	95	8	180	0.65	2	9	370	382
77/186	12.17	417.2	14.4	695	1.90	95	8	180	0.65	252	31	13	13
77/186	12.22	413.5	21.0	666	1.55	95	8	180	0.65	81	37	48	49
77/186	12.27	412.2	18.0	677	1.38	95	8	180	0.65	0	28	*****	*****
77/186	12.32	411.1	17.3	671	1.35	95	8	180	0.65	257	27	10	11
77/186	12.37	408.6	18.0	665	1.37	95	8	180	0.65	8	28	355	374
77/186	12.42	406.4	18.5	657	1.36	95	8	180	0.65	1	29	1908	2020
77/186	12.47	428.2	-8.4	657	1.47	95	8	180	0.65	1	-14	-937	*****
77/186	12.52	448.5	-44.3	660	1.49	95	8	180	0.65	260	-76	-30	*****
77/186	12.57	447.7	-30.3	667	1.46	95	8	180	0.65	258	-51	-20	*****
77/186	12.62	425.5	8.0	662	1.36	95	8	180	0.65	252	12	5	6
77/186	12.67	402.8	53.3	657	1.27	95	8	180	0.65	12	78	667	710
77/186	12.72	407.8	54.6	647	1.78	95	8	180	0.65	1	112	7432	7903
77/186	12.77	410.1	34.0	645	1.58	95	8	180	0.65	15	62	433	468
77/186	12.82	411.4	11.9	649	1.38	95	8	180	0.65	258	19	7	8
77/186	12.87	410.4	12.8	648	1.37	95	8	180	0.65	252	20	8	9
77/186	12.92	405.6	20.9	639	1.37	95	8	180	0.65	1	33	2956	3327
77/186	12.97	402.4	20.7	631	1.36	95	8	180	0.65	225	32	15	17
77/186	13.02	402.7	16.5	628	1.38	95	8	180	0.65	55	26	51	59
77/186	13.07	402.2	14.0	624	1.37	95	8	180	0.65	249	22	9	11
77/186	13.12	399.3	13.4	619	1.36	95	8	180	0.65	254	21	8	10
77/186	13.17	396.0	15.5	615	1.36	95	8	180	0.65	7	24	369	438
77/186	13.22	393.6	21.4	612	1.33	95	8	180	0.65	257	33	13	16
77/186	13.27	392.5	22.4	608	1.34	95	8	180	0.65	1	34	1906	2235
77/186	13.32	392.5	20.4	603	1.35	95	8	180	0.65	260	32	13	15
77/186	13.37	392.8	18.4	601	1.27	95	8	180	0.65	262	27	11	13
77/186	13.42	392.3	19.5	597	1.35	95	8	180	0.65	2	30	1209	1463
77/186	13.47	397.6	13.7	596	1.46	95	8	180	0.65	0	23	*****	*****
77/186	13.52	435.8	-32.1	596	1.45	95	8	180	0.65	0	-54	*****	*****
77/186	13.57	438.9	-45.3	596	1.47	95	8	180	0.65	251	-77	-34	*****

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77/186	13.62	435.4	-43.6	594	1.46	95	8	180	0.65	7	-73	-1096	*****
77/186	13.67	429.7	-23.9	594	1.37	95	8	180	0.65	257	-38	-16	*****
77/186	13.72	397.2	28.3	587	1.29	95	8	180	0.65	260	42	18	22
77/186	13.77	386.3	52.0	583	1.25	95	8	180	0.65	256	75	33	39
77/186	13.82	395.6	50.8	578	1.74	95	8	180	0.65	13	102	894	1061
77/186	13.87	393.2	44.2	577	1.84	95	8	180	0.65	218	94	49	59
77/186	13.92	396.1	22.8	576	1.54	95	8	180	0.65	250	40	18	23
77/186	13.97	396.2	19.2	574	1.34	95	8	180	0.65	254	29	13	18
77/185	14.02	393.6	23.1	571	1.33	95	8	180	0.65	257	35	16	21
77/186	14.07	392.3	27.0	568	1.33	95	8	180	0.65	253	41	19	25
77/186	14.12	392.1	30.3	565	1.32	95	8	180	0.65	256	46	21	27
77/186	14.17	392.4	31.4	562	1.31	95	8	180	0.65	258	47	22	28
77/186	14.22	393.7	26.0	554	1.35	95	8	180	0.65	0	40	*****	*****
77/186	14.27	394.5	17.0	547	1.33	95	8	180	0.65	251	26	12	17
77/186	14.32	394.2	11.4	545	1.34	95	8	180	0.65	254	17	8	13
77/186	14.37	391.9	14.2	542	1.32	95	8	180	0.65	256	21	10	15
77/186	14.42	388.5	23.6	540	1.32	95	8	180	0.65	253	36	17	24
77/186	14.47	386.7	29.6	537	1.31	95	8	180	0.65	255	45	22	30
77/186	14.52	388.5	28.7	533	1.30	95	8	180	0.65	227	43	24	33
77/186	14.57	391.6	23.2	529	1.33	95	8	180	0.65	1	35	2302	3286
77/186	14.62	393.5	16.9	526	1.32	95	8	180	0.65	255	25	13	19
77/186	14.67	393.0	13.2	523	1.34	95	8	180	0.65	255	20	10	16
77/186	14.72	390.2	16.0	522	1.33	95	8	180	0.65	255	24	12	19
77/186	14.77	387.5	23.3	521	1.31	95	8	180	0.65	255	35	18	27
77/186	14.82	386.4	27.2	518	1.31	95	8	180	0.65	256	41	21	31
77/186	14.87	387.8	26.2	516	1.30	95	8	180	0.65	256	39	20	30
77/186	14.92	390.0	22.8	514	1.32	95	8	180	0.65	254	35	18	28
77/186	14.97	391.3	20.0	512	1.32	95	8	180	0.65	252	30	16	26
77/186	15.02	391.4	18.5	510	1.32	95	8	180	0.65	252	28	15	25
77/186	15.07	390.6	19.0	509	1.32	95	8	180	0.65	254	29	16	26
77/186	15.12	389.5	20.1	506	1.31	95	8	180	0.65	249	30	17	28
77/186	15.15	388.7	20.5	503	1.30	95	8	180	0.65	250	31	17	28
77/187	10.12	478.8	8.3	848	1.36	95	8	180	0.65	252	13	6	9
77/187	10.20	487.2	1.7	871	1.39	95	8	180	0.65	255	2	1	3
77/187	10.28	492.4	6.8	894	1.36	95	8	180	0.65	252	10	4	7
77/187	10.37	494.5	13.4	924	1.36	95	8	180	0.65	254	21	9	12
77/187	10.45	496.5	18.4	958	1.31	95	8	180	0.65	256	28	12	15
77/187	10.53	466.3	53.8	976	1.34	95	8	180	0.65	258	83	35	41
77/187	10.62	450.6	69.9	980	1.84	95	8	180	0.65	257	149	63	71
77/187	10.70	467.6	27.5	968	2.05	95	8	180	0.65	260	65	27	31
77/187	10.78	468.9	16.0	960	1.95	95	8	180	0.65	260	36	15	17
77/187	10.87	462.6	31.5	945	1.95	95	8	180	0.65	260	71	29	33
77/187	10.95	466.1	27.8	931	1.91	95	8	180	0.65	257	61	25	28
77/187	11.03	466.8	27.2	922	1.90	95	8	180	0.65	261	60	24	27
77/187	11.12	468.2	28.6	914	1.84	95	8	180	0.65	193	61	33	36
77/187	11.20	471.2	25.3	906	1.80	95	8	180	0.65	256	52	21	23
77/187	11.28	470.8	26.9	895	1.57	95	8	180	0.65	256	49	20	21
77/187	11.37	470.5	29.7	896	1.62	95	8	180	0.65	261	55	22	24
77/187	11.45	471.9	34.2	896	1.70	95	8	180	0.65	263	67	26	28
77/187	11.53	470.5	37.4	899	1.73	95	8	180	0.65	260	75	30	31
77/187	11.62	471.5	37.5	905	1.84	95	8	180	0.65	260	80	31	33

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										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/187	11.70	474.0	33.8	911	1.95	95	8	180	0.65	259	76	30	31
77/187	11.78	476.7	31.1	914	2.02	95	8	180	0.65	260	73	29	29
77/187	11.87	477.4	32.7	920	2.06	95	8	180	0.65	261	78	30	31
77/187	11.95	479.7	31.8	923	2.16	95	8	180	0.65	262	80	31	31
77/187	12.03	481.0	31.1	927	2.25	95	8	180	0.65	262	81	32	32
77/187	12.12	483.8	29.1	934	2.33	95	8	180	0.65	261	79	31	31
77/187	12.20	485.3	28.2	937	2.39	95	8	180	0.65	260	78	31	31
77/187	12.28	486.2	27.7	939	2.44	95	8	180	0.65	261	78	31	32
77/187	12.37	487.3	25.7	936	2.40	95	8	180	0.65	255	71	29	30
77/187	12.45	486.0	17.2	925	2.21	95	8	180	0.65	260	44	17	18
77/187	12.53	480.9	30.7	924	2.14	95	8	180	0.65	260	76	30	32
77/187	12.62	467.5	44.4	917	2.64	95	8	180	0.65	262	136	54	57
77/187	12.70	460.8	30.7	882	3.08	95	8	180	0.65	31	109	370	394
77/187	12.78	460.6	13.8	870	2.40	95	8	180	0.65	256	38	15	17
77/187	12.87	458.4	19.1	857	2.22	95	8	180	0.65	257	49	20	22
77/187	12.95	455.7	19.7	840	2.10	95	8	180	0.65	258	47	19	21
77/187	13.03	455.1	19.7	829	1.98	95	8	180	0.65	257	45	18	21
77/187	13.12	452.6	15.3	826	1.43	95	8	180	0.65	9	25	285	341
77/187	13.20	446.5	10.9	794	1.41	95	8	180	0.65	101	17	19	24
77/187	13.28	437.1	27.4	787	1.38	95	8	180	0.65	257	43	18	21
77/187	13.37	435.2	35.2	778	1.35	95	8	180	0.65	255	55	23	27
77/187	13.45	440.1	30.9	769	1.37	95	8	180	0.65	251	49	21	25
77/187	13.53	442.8	24.2	760	1.39	95	8	180	0.65	58	39	74	90
77/187	13.62	441.7	25.5	752	1.39	95	8	180	0.65	254	41	18	22
77/187	13.70	438.8	21.3	743	1.38	95	8	180	0.65	122	34	31	39
77/187	13.78	435.3	19.0	732	1.38	95	8	180	0.65	251	30	13	17
77/187	13.87	431.3	21.6	725	1.39	95	8	180	0.65	250	34	16	20
77/187	13.95	428.4	30.2	719	1.36	95	8	180	0.65	249	47	22	28
77/187	14.03	430.4	29.0	713	1.33	95	8	180	0.65	249	44	21	27
77/187	14.12	433.1	20.4	701	1.37	95	8	180	0.65	1	32	3232	4407
77/187	14.20	431.8	5.7	690	1.39	95	8	180	0.65	230	9	4	8
77/187	14.28	421.7	6.5	680	1.40	95	8	180	0.65	1	10	1078	1950
77/187	14.37	411.2	16.2	673	1.38	95	8	180	0.65	7	25	424	619
77/187	14.45	407.5	14.6	662	1.39	95	8	180	0.65	0	23	*****	*****
77/187	14.53	404.5	2.9	653	1.40	95	8	180	0.65	52	4	11	31
77/187	14.62	395.3	2.1	645	1.39	95	8	180	0.65	22	3	19	64
77/188	9.06	420.9	12.1	740	5.20	92	8	202	0.65	250	72	39	56
77/188	9.15	418.5	9.1	724	3.47	92	8	202	0.65	249	36	19	29
77/188	9.23	416.0	11.5	715	2.51	92	8	202	0.65	252	33	17	26
77/188	9.31	413.2	14.1	706	2.22	92	8	202	0.65	253	36	18	27
77/188	9.40	411.6	15.4	657	2.05	92	8	202	0.65	253	36	18	26
77/188	9.48	410.4	17.3	689	1.89	92	8	202	0.65	254	37	18	26
77/188	9.56	408.3	20.5	681	1.37	92	8	202	0.65	256	32	15	22
77/188	9.65	405.7	26.2	674	1.36	92	8	202	0.65	256	41	19	26
77/188	9.73	406.7	27.7	668	1.35	92	8	202	0.65	256	43	20	27
77/188	9.81	409.0	25.7	664	1.34	92	8	202	0.65	257	40	18	24
77/188	9.90	410.3	25.8	660	1.34	92	8	202	0.65	257	40	18	24
77/188	9.98	410.8	28.1	658	1.36	92	8	202	0.65	260	44	20	25
77/188	10.06	412.5	29.3	656	1.33	92	8	202	0.65	259	45	20	25
77/188	10.15	414.7	29.5	654	1.33	92	8	202	0.65	258	45	20	25
77/188	10.23	416.7	29.2	652	1.32	92	8	202	0.65	260	44	19	

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC- TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/188	10.31	418.7	30.5	650	1.31	92	8	202	0.65	258	46	20	24
77/188	10.40	420.7	32.0	648	1.32	92	8	202	0.65	141	49	38	46
77/188	10.48	423.2	28.2	642	1.32	92	8	202	0.65	19	43	241	290
77/188	10.56	424.1	17.4	629	1.34	92	8	202	0.65	0	27	*****	*****
77/188	10.65	419.5	8.6	623	1.34	92	8	202	0.65	259	13	5	7
77/188	10.73	410.5	21.0	620	1.35	92	8	202	0.65	260	32	13	16
77/188	10.81	406.7	33.2	618	1.31	92	8	202	0.65	261	50	20	23
77/188	10.90	411.3	33.9	616	1.32	92	8	202	0.65	2	51	2334	2635
77/188	10.98	416.1	22.6	607	1.34	92	8	202	0.65	3	35	1178	1344
77/188	11.06	416.2	14.5	603	1.36	92	8	202	0.65	0	22	*****	*****
77/188	11.15	410.6	12.0	593	1.35	92	8	202	0.65	7	18	263	305
77/188	11.23	404.3	13.2	590	1.34	92	8	202	0.65	256	20	8	9
77/188	11.31	398.6	29.1	587	1.31	92	8	202	0.65	260	44	17	19
77/188	11.40	400.1	37.4	589	1.27	92	8	202	0.65	261	55	22	23
77/188	11.48	407.7	35.8	591	1.30	92	8	202	0.65	261	54	21	22
77/188	11.56	414.7	34.8	591	1.29	92	8	202	0.65	16	52	324	339
77/188	11.65	419.5	22.5	582	1.32	92	8	202	0.65	3	34	1124	1176
77/188	11.73	419.7	14.2	577	1.35	92	8	202	0.65	256	22	8	9
77/188	11.81	413.9	18.9	570	1.33	92	8	202	0.65	238	29	12	12
77/188	11.90	410.7	32.6	573	1.30	92	8	202	0.65	262	49	19	19
77/188	11.98	413.0	43.8	579	0.97	92	8	202	0.65	264	48	19	19
77/188	12.06	417.3	50.7	590	0.80	92	8	202	0.65	252	47	19	19
77/188	12.15	422.5	43.2	581	0.83	92	8	202	0.65	262	41	16	16
77/188	12.23	424.0	43.3	590	0.69	92	8	202	0.65	265	34	13	13
77/188	12.73	412.7	11.9	604	1.97	92	8	202	0.65	187	27	15	16
77/188	12.81	408.4	27.5	600	1.95	92	8	202	0.65	258	62	25	27
77/188	12.90	415.5	23.4	594	1.95	92	8	202	0.65	255	52	21	24
77/188	12.98	417.8	16.4	585	1.45	92	8	202	0.65	1	27	2462	2838
77/188	13.06	411.9	13.8	577	1.41	92	8	202	0.65	255	22	9	11
77/188	13.15	405.5	25.5	573	1.38	92	8	202	0.65	257	40	17	19
77/188	13.23	404.1	36.6	569	1.35	92	8	202	0.65	254	57	24	27
77/188	13.31	410.3	22.8	559	1.38	92	8	202	0.65	175	36	22	26
77/188	13.40	410.8	8.2	554	1.41	92	8	202	0.65	227	13	6	8
77/188	13.48	402.1	18.5	547	1.39	92	8	202	0.65	68	29	48	58
77/188	13.56	397.3	21.8	541	1.38	92	8	202	0.65	144	35	27	32
77/188	13.65	397.4	16.5	535	1.39	92	8	202	0.65	171	26	17	22
77/188	13.73	394.5	15.7	531	1.39	92	8	202	0.65	243	25	11	15
77/188	13.81	391.0	25.8	527	1.37	92	8	202	0.65	244	41	19	23
77/188	13.90	392.1	28.4	523	1.37	92	8	202	0.65	242	45	21	26
77/188	13.98	396.3	23.2	518	1.39	92	8	202	0.65	245	37	17	22
77/188	14.06	397.5	21.4	515	1.39	92	8	202	0.65	244	34	16	22
77/188	14.15	397.2	24.8	511	1.37	92	8	202	0.65	245	39	19	25
77/188	14.23	398.6	25.6	507	1.39	92	8	202	0.65	245	41	20	27
77/188	14.31	400.7	23.3	504	1.38	92	8	202	0.65	243	37	18	25
77/188	14.40	401.3	22.4	499	1.39	92	8	202	0.65	241	36	18	25
77/188	14.48	401.2	22.4	495	1.37	92	8	202	0.65	239	35	18	26
77/188	14.56	401.1	21.6	491	1.37	92	8	202	0.65	237	34	18	26
77/188	14.65	400.7	21.5	486	1.37	92	8	202	0.65	233	34	18	27
77/188	14.73	399.9	20.8	482	1.36	92	8	202	0.65	235	32	18	27
77/188	14.81	399.1	20.3	476	1.35	92	8	202	0.65	232	31	18	27
77/188	14.90	398.1	19.6	472	1.36	92	8	202	0.65	226	31	18	28

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY	
												SINGLE MODULE	WITHOUT END LOSS
77/193	11.75	399.5	18.3	628	3.41	98	12	180	0.83	256	72	29	29
77/193	11.84	396.2	26.1	637	3.40	98	12	180	0.83	253	102	41	42
77/193	11.92	398.7	23.6	646	3.26	98	12	180	0.83	254	89	36	36
77/193	12.00	400.5	24.6	655	3.23	98	12	180	0.83	253	92	37	37
77/193	12.09	402.7	24.6	663	3.22	98	12	180	0.83	253	91	37	37
77/193	12.17	404.9	24.2	669	3.01	98	12	180	0.83	255	84	34	34
77/193	12.25	406.6	25.6	672	2.90	98	12	180	0.83	254	86	34	35
77/193	12.34	408.7	25.8	677	2.79	98	12	180	0.83	254	83	33	35
77/193	12.42	410.3	26.7	682	2.73	98	12	180	0.83	254	84	34	35
77/193	12.50	412.1	26.5	686	2.65	98	12	180	0.83	253	81	33	35
77/193	12.59	413.6	26.6	690	2.54	98	12	180	0.83	253	78	32	33
77/193	12.67	414.7	27.4	692	2.45	98	12	180	0.83	253	77	32	34
77/193	12.75	415.8	27.6	695	2.39	98	12	180	0.83	248	76	32	34
77/193	12.84	416.7	27.4	695	2.35	98	12	180	0.83	249	74	31	34
77/193	12.92	417.1	27.6	693	2.31	98	12	180	0.83	249	73	31	34
77/193	13.00	417.9	27.1	691	2.23	98	12	180	0.83	247	70	30	33
77/193	13.09	418.3	26.9	688	2.19	98	12	180	0.83	246	68	29	33
77/193	13.17	418.5	27.3	682	2.14	98	12	180	0.83	246	67	29	33
77/193	13.25	418.5	27.3	676	2.08	98	12	180	0.83	246	65	28	32
77/193	13.34	418.7	26.8	670	2.05	98	12	180	0.83	246	63	28	32
77/193	13.42	418.3	27.3	662	2.01	98	12	180	0.83	245	63	28	32
77/193	13.50	418.0	26.9	654	1.97	98	12	180	0.83	246	61	27	32
77/193	13.59	418.0	26.1	648	1.89	98	12	180	0.83	245	57	25	30
77/193	13.67	417.6	26.1	640	1.82	98	12	180	0.83	244	55	25	30
77/193	13.75	415.9	27.2	632	1.57	98	12	180	0.83	242	49	23	28
77/193	13.84	413.9	30.0	623	1.48	98	12	180	0.83	245	51	24	29
77/193	13.92	412.7	31.8	617	1.45	98	12	180	0.83	247	53	25	31
77/193	14.00	413.0	31.1	612	1.42	98	12	180	0.83	247	51	24	30
77/193	14.09	413.0	30.4	608	1.32	98	12	180	0.83	244	46	22	29
77/193	14.17	412.0	31.2	602	1.32	98	12	180	0.83	242	47	23	30
77/193	14.25	412.7	29.7	596	1.34	98	12	180	0.83	245	46	22	30
77/193	14.34	413.2	26.7	590	1.35	98	12	180	0.83	245	41	20	28
77/193	14.42	412.5	26.5	584	1.36	98	12	180	0.83	237	41	21	30
77/193	14.50	411.0	26.0	577	1.36	98	12	180	0.83	239	41	21	30
77/193	14.59	409.1	25.8	570	1.35	98	12	180	0.83	235	40	22	31
77/193	14.67	407.6	24.7	563	1.36	98	12	180	0.83	235	39	21	31
77/193	14.67	407.6	24.7	563	1.36	98	12	180	0.83	235	39	21	31
77/193	14.84	403.7	17.5	545	1.37	98	12	180	0.83	228	27	16	25
77/193	14.92	400.1	10.0	547	1.39	98	12	180	0.83	231	16	9	17
77/199	11.26	427.0	15.6	654	2.92	98	8	135	0.83	266	52	20	22
77/199	11.34	431.9	19.2	694	2.89	98	8	135	0.83	271	64	24	26
77/199	11.43	437.9	21.4	734	2.91	98	8	135	0.83	268	72	27	29
77/199	11.51	433.8	20.6	754	2.88	98	8	135	0.83	270	68	26	27
77/199	11.59	426.6	36.5	766	2.82	98	8	135	0.83	215	119	57	59
77/199	11.68	430.9	19.6	775	2.86	98	8	135	0.83	238	64	28	29
77/199	11.76	430.6	29.7	776	2.82	98	8	135	0.83	273	97	36	37
77/199	11.84	435.3	15.1	766	2.89	98	8	135	0.83	137	50	37	38
77/199	11.93	430.4	18.9	752	2.93	98	8	135	0.83	0	64	*****	*****
77/199	12.01	428.1	10.7	740	2.90	98	8	135	0.83	7	35	517	517
77/199	12.09	426.5	7.9	718	2.92	98	8	135	0.83	11	26	230	233
77/199	12.18	421.6	21.3	711	2.82	98	8	135	0.83	272	69	26	26

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   DATE        SOLAR      INLET  TEMP.  PRESSURE  FLOW   AMBIENT  WIND   WIND   REFLEC-   DIRECT    COLLECTION     EFFICIENCY
               TIME       TEMP.  DIFF.            RATE    TEMP.   SPEED  DIR.   TIVITY   RADIATION    RATE     SINGLE    WITHOUT
(YEAR/DAY) (DEC.HRS.)     (F)    (F)      (PSI)   (GPM)   (F)     (MPH)  (DEG.)         (BTU/HR./SQ.FT.)       MODULE    END LOSS

  77/199      12.26      428.6   24.0     707     2.85     98       8     135    0.83      273        79        29         30
  77/199      12.34      431.1   24.8     708     2.86     98       8     135    0.83      272        82        31         32
  77/199      12.43      432.6   26.4     714     2.82     98       8     135    0.83      274        86        32         33
  77/199      12.51      435.3   26.1     721     2.81     98       8     135    0.83      276        84        31         33
  77/199      12.59      438.1   24.5     723     2.84     98       8     135    0.83      231        80        36         38
  77/199      12.68      441.2   18.5     717     2.90     98       8     135    0.83       56        62       114        123
  77/199      12.76      435.2   11.5     708     2.86     98       8     135    0.83      274        38        14         16
  77/199      12.84      434.2   17.2     694     2.84     98       8     135    0.83      274        56        21         23
  77/199      12.93      431.2   19.8     689     2.84     98       8     135    0.83      272        65        25         27
  77/199      13.01      434.8   21.3     685     2.85     98       8     135    0.83      273        70        27         30
  77/199      13.09      436.1   17.0     677     2.88     98       8     135    0.83      268        56        22         25
  77/199      13.18      434.0   21.6     675     2.82     98       8     135    0.83      271        70        27         31
  77/199      13.26      436.5   20.8     673     2.84     98       8     135    0.83      272        68        27         30
  77/199      13.34      437.7   17.7     668     2.88     98       8     135    0.83      271        59        23         27
  77/199      13.43      434.2   12.7     659     2.88     98       8     135    0.83      270        42        17         20
  77/199      13.51      431.1   16.2     649     2.91     98       8     135    0.83        0        54     *****      *****
  77/199      13.59      427.1   15.2     646     2.87     98       8     135    0.83      271        50        20         24
  77/199      13.68      429.6   18.6     640     2.84     98       8     135    0.83      272        61        25         30
  77/199      13.76      430.6   16.9     635     2.84     98       8     135    0.83      270        55        23         28
  77/199      13.84      429.6   15.1     629     2.86     98       8     135    0.83      272        50        21         26
  77/199      13.93      428.8   14.1     619     2.89     98       8     135    0.83       21        47       254        323
  77/199      14.01      424.4    3.6     605     2.93     98       8     135    0.83      104        12        13         22
  77/199      14.09      413.3    5.3     590     2.94     98       8     135    0.83        5        18       384        572
  77/199      14.18      417.3   -9.7     578     2.94     98       8     135    0.83        8       -33      -453      *****
  77/199      14.26      423.9   -3.3     581     2.87     98       8     135    0.83      267       -10        -4      *****
  77/199      14.34      437.5   -1.8     583     2.84     98       8     135    0.83      264        -5        -2      *****
  77/199      14.43      427.4   20.1     575     2.79     98       8     135    0.83      264        65        30         40
  77/199      14.51      425.8   17.0     570     2.85     98       8     135    0.83      266        56        26         36
  77/199      14.59      423.5   13.7     562     2.88     98       8     135    0.83       34        45       171        242
  77/199      14.68      419.4   10.6     556     2.89     98       8     135    0.83      259        35        17         26
  77/199      14.76      421.5    9.0     550     2.92     98       8     135    0.83      258        30        15         24
  77/199      14.84      422.7    0.6     543     2.93     98       8     135    0.83      252         2         1          6
  77/200      11.29      395.3   14.3     595     1.98     98       5     180    0.83        0        32     *****      *****
  77/200      11.37      392.8   17.7     593     1.49     98       5     180    0.83      254        30        12         13
  77/200      11.46      391.0   33.8     589     1.54     98       5     180    0.83        1        60      5269       5561
  77/200      11.54      413.1    0.7     575     1.47     98       5     180    0.83        4         1        28         52
  77/200      11.62      419.2  -11.3     589     1.47     98       5     180    0.83      249       -19        -8      *****
  77/200      11.71      403.4   35.2     596     1.35     98       5     180    0.83      246        55        23         23
  77/200      11.79      398.9   51.9     593     1.89     98       5     180    0.83      254       113        46         46
  77/200      11.87      405.6   24.3     613     1.86     98       5     180    0.83       14        52       367        372
  77/200      11.96      403.6   24.3     616     1.57     98       5     180    0.83      251        44        18         18
  77/200      12.04      402.3   39.0     613     1.90     98       5     180    0.83      251        86        35         35
  77/200      12.12      407.4   38.7     632     1.97     98       5     180    0.83      250        88        36         36
  77/200      12.21      411.8   34.1     644     2.02     98       5     180    0.83      253        79        32         33
  77/200      12.29      415.0   34.5     654     2.08     98       5     180    0.83      250        83        34         35
  77/200      12.37      417.9   31.0     655     2.12     98       5     180    0.83        2        76      3301       3420
  77/200      12.46      419.0   21.9     658     2.05     98       5     180    0.83      175        52        30         32
  77/200      12.54      417.8   33.6     662     2.03     98       5     180    0.83      247        79        33         34
  77/200      12.62      422.1   33.4     670     2.07     98       5     180    0.83      252        80        33         35
  77/200      12.71      425.2   31.0     679     2.10     98       5     180    0.83      246        75        32         34
  77/200      12.79      426.8   30.5     684     2.12     98       5     180    0.83      250        74        31         33
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DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/200	12.87	427.8	29.9	689	2.12	98	5	180	0.83	245	73	31	34
77/200	12.96	429.0	28.6	692	2.08	98	5	180	0.83	245	68	29	32
77/200	13.04	429.4	27.1	688	2.08	98	5	180	0.83	103	65	67	74
77/200	13.12	429.3	16.9	671	1.98	98	5	180	0.83	234	38	17	20
77/200	13.21	425.1	17.6	661	1.46	98	5	180	0.83	245	29	13	15
77/200	13.29	419.9	31.8	657	1.47	98	5	180	0.83	241	54	24	28
77/200	13.37	422.9	34.0	653	1.73	98	5	180	0.83	245	68	30	35
77/200	13.46	425.1	27.0	649	1.45	98	5	180	0.83	245	45	20	24
77/200	13.54	423.5	28.4	639	1.39	98	5	180	0.83	1	45	4262	5131
77/200	13.62	422.4	18.7	619	1.37	98	5	180	0.83	239	29	13	17
77/200	13.79	414.2	30.1	612	1.34	98	5	180	0.83	237	46	22	27
77/200	13.87	416.1	32.3	607	1.33	98	5	180	0.83	229	49	24	31
77/200	13.96	422.2	16.8	590	1.36	98	5	180	0.83	237	26	13	17
77/200	14.04	420.1	12.0	585	1.37	98	5	180	0.83	236	19	9	13
77/200	14.12	412.9	17.5	569	1.37	98	5	180	0.83	223	27	14	20
77/200	14.21	409.8	16.9	564	1.36	98	5	180	0.83	235	26	13	19
77/200	14.29	407.2	18.1	552	1.35	98	5	180	0.83	0	28	*****	*****
77/200	14.37	405.2	8.0	539	1.38	98	5	180	0.83	1	12	1330	2280
77/200	14.46	399.7	4.3	534	1.35	98	5	180	0.83	225	6	3	8
77/200	14.54	390.0	21.1	530	1.33	98	5	180	0.83	230	32	18	25
77/200	14.62	389.3	27.1	525	1.30	98	5	180	0.83	225	41	23	33
77/200	14.71	394.5	19.8	520	1.33	98	5	180	0.83	227	30	17	26
77/200	14.79	390.5	17.4	510	1.35	98	5	180	0.83	4	27	833	1302
77/201	9.82	355.4	24.2	454	3.25	94	8	180	0.83	245	91	44	55
77/201	9.91	356.4	16.7	457	2.65	94	8	180	0.83	243	51	25	31
77/201	9.99	353.1	18.3	455	2.35	94	8	180	0.83	244	50	24	30
77/201	10.07	352.2	20.1	455	2.18	94	8	180	0.83	249	51	23	29
77/201	10.16	353.0	21.8	455	2.08	94	8	180	0.83	249	53	24	29
77/201	10.24	354.8	22.7	456	2.00	94	8	180	0.83	251	53	23	28
77/201	10.32	356.4	24.5	458	1.94	94	8	180	0.83	250	55	24	29
77/201	10.41	357.8	26.1	460	1.85	94	8	180	0.83	251	56	25	29
77/201	10.49	358.3	28.9	463	1.68	94	8	180	0.83	247	56	25	29
77/201	10.57	358.7	31.9	466	1.66	94	8	180	0.83	251	61	26	31
77/201	10.66	360.3	32.4	469	1.69	94	8	180	0.83	250	63	27	31
77/201	10.74	361.1	30.8	470	1.57	94	8	180	0.83	199	56	30	34
77/201	10.82	360.6	24.8	464	1.41	94	8	180	0.83	250	40	17	20
77/201	10.91	359.4	23.4	462	1.39	94	8	180	0.83	251	38	16	18
77/201	10.99	358.5	36.1	462	1.37	94	8	180	0.83	255	57	24	26
77/201	11.07	360.5	43.1	464	1.55	94	8	180	0.83	242	77	33	36
77/201	11.16	367.5	32.9	468	1.67	94	8	180	0.83	236	64	28	30
77/201	11.24	369.0	28.3	474	1.56	94	8	180	0.83	253	51	21	23
77/201	11.32	370.3	39.4	477	1.91	94	8	180	0.83	255	87	35	37
77/201	11.41	375.1	36.0	488	1.95	94	8	180	0.83	256	81	33	34
77/201	11.49	377.9	33.6	495	1.99	94	8	180	0.83	251	77	32	33
77/201	11.57	380.4	34.9	501	2.02	94	8	180	0.83	257	82	32	34
77/201	11.92	374.5	10.4	469	1.43	94	8	180	0.83	253	17	7	7
77/201	11.96	372.7	13.1	470	1.43	94	8	180	0.83	232	21	9	9
77/201	12.04	368.1	36.9	472	1.37	94	8	180	0.83	254	58	23	23
77/201	12.12	373.0	49.6	475	1.78	94	8	180	0.83	253	102	41	[illegible]
77/201	12.21	384.0	37.1	487	1.92	94	[illegible]	180	0.83	253	82	33	[illegible]
77/201	12.29	383.9	32.3	459	1.95	94	[illegible]	180	0.83	254	73	29	[illegible]

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/201	12.37	390.7	37.2	510	1.99	94	8	180	0.83	255	86	34	35
77/201	12.46	393.9	34.4	519	2.02	94	8	180	0.83	88	80	94	98
77/201	12.54	396.1	25.5	526	2.03	94	8	180	0.83	256	60	24	25
77/201	12.62	396.6	32.8	529	2.01	94	8	180	0.83	256	76	31	32
77/201	12.71	400.1	31.5	534	2.03	94	8	180	0.83	257	74	30	32
77/201	12.79	402.9	28.1	536	2.03	94	8	180	0.83	156	66	44	48
77/201	12.87	404.3	24.0	539	1.97	94	8	180	0.83	251	54	22	25
77/201	12.96	403.9	23.4	527	1.91	94	8	180	0.83	2	51	2303	2557
77/201	13.04	402.3	17.2	526	1.42	94	8	180	0.83	253	28	11	13
77/201	13.12	397.7	35.6	524	1.39	94	8	180	0.83	254	57	24	27
77/201	13.21	401.7	38.5	527	1.82	94	8	180	0.83	255	81	34	38
77/201	13.29	406.8	27.7	535	1.72	94	8	180	0.83	257	55	23	26
77/201	13.37	406.2	30.0	538	1.59	94	8	180	0.83	252	55	24	27
77/201	13.46	406.5	33.8	538	1.77	94	8	180	0.83	54	69	141	164
77/201	13.54	406.9	22.5	536	1.40	94	8	180	0.83	252	36	16	19
77/201	13.62	404.7	26.4	534	1.40	94	8	180	0.83	251	42	19	23
77/201	13.71	402.7	31.4	524	1.38	94	8	180	0.83	242	50	23	28
77/201	13.79	403.1	26.8	521	1.37	94	8	180	0.83	243	42	20	24
77/201	13.87	402.7	23.5	508	1.40	94	8	180	0.83	2	38	1582	2021
77/201	13.96	401.3	8.7	495	1.40	94	8	180	0.83	67	14	24	37
77/201	14.04	395.8	7.3	487	1.41	94	8	180	0.83	21	11	65	105
77/201	14.12	387.0	10.4	477	1.40	94	8	180	0.83	6	16	298	446
77/202	11.21	448.5	11.3	622	2.56	98	8	225	0.83	260	33	13	15
77/202	11.29	427.8	38.8	642	3.18	98	8	225	0.83	262	142	56	60
77/202	11.38	427.6	24.9	660	2.69	98	8	225	0.83	260	77	30	32
77/202	11.46	443.4	14.9	669	2.41	98	8	225	0.83	266	41	16	17
77/202	11.54	437.9	23.0	673	2.26	98	8	225	0.83	263	60	23	24
77/202	11.63	435.1	40.0	680	2.39	98	8	225	0.83	260	110	43	45
77/202	11.71	439.5	30.0	692	2.41	98	8	225	0.83	9	83	945	971
77/202	11.79	439.1	27.4	697	2.36	98	8	225	0.83	33	74	231	235
77/202	11.88	438.3	18.4	688	2.22	98	8	225	0.83	262	47	18	18
77/202	11.96	434.3	18.7	667	2.10	98	8	225	0.83	193	45	24	24
77/202	12.04	431.5	26.4	663	2.01	98	8	225	0.83	157	61	40	40
77/202	12.13	431.8	22.6	650	1.88	98	8	225	0.83	262	49	19	19
77/202	12.21	429.9	18.6	631	1.44	98	8	225	0.83	0	31	*****	*****
77/202	12.29	424.9	12.1	616	1.43	98	8	225	0.83	213	20	9	10
77/202	12.38	435.7	-5.3	609	1.51	98	8	225	0.83	28	-9	-33	*****
77/202	12.46	445.9	-16.2	613	1.51	98	8	225	0.83	262	-28	-11	*****
77/202	12.54	423.4	25.3	622	1.43	98	8	225	0.83	260	42	16	17
77/202	12.63	428.1	42.9	624	1.38	98	8	225	0.83	260	68	27	29
77/202	12.71	445.4	28.3	625	1.35	98	8	225	0.83	216	44	21	23
77/202	12.79	426.5	51.2	635	1.32	98	8	225	0.83	258	78	31	34
77/202	12.88	418.1	48.8	619	1.77	98	8	225	0.83	0	100	*****	*****
77/202	12.96	427.6	10.0	607	1.44	98	8	225	0.83	222	16	14	17
77/202	13.04	423.2	8.9	600	1.44	98	8	225	0.83	79	14	19	24
77/202	13.13	412.9	32.0	601	1.38	98	8	225	0.83	256	51	21	24
77/202	13.21	415.8	38.5	595	1.36	98	8	225	0.83	221	60	29	33
77/202	13.29	424.5	23.5	581	1.39	98	8	225	0.83	1	37	2586	3059
77/202	13.38	425.2	13.9	574	1.39	98	8	225	0.83	254	22	9	12
77/202	13.46	419.1	28.7	574	1.32	98	8	225	0.83	257	44	18	22
77/202	13.54	418.7	38.4	573	1.26	98	8	225	0.83	255	56	24	28

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77/202	13.63	422.2	34.7	568	1.30	98	8	225	0.83	253	52	23	27
77/202	13.71	407.6	43.1	550	1.16	98	8	225	0.83	244	58	26	32
77/202	13.79	410.9	30.5	538	1.36	98	8	225	0.83	251	48	21	26
77/202	13.88	415.6	16.9	531	1.38	98	8	225	0.83	1	27	1569	2098
77/202	13.96	412.5	19.9	527	1.32	98	8	225	0.83	253	30	14	18
77/202	14.04	409.6	28.3	524	1.29	98	8	225	0.83	251	42	19	25
77/202	14.13	411.4	26.5	513	1.19	98	8	225	0.83	39	36	109	147
77/202	14.21	410.1	19.3	507	1.36	98	8	225	0.83	253	30	14	20
77/202	14.29	408.5	22.8	504	1.36	98	8	225	0.83	244	36	18	24
77/202	14.38	406.7	24.6	495	1.32	98	8	225	0.83	0	37	*****	*****
77/202	14.46	406.7	17.8	488	1.37	98	8	225	0.83	241	28	14	21
77/202	14.54	404.9	15.8	479	1.37	98	8	225	0.83	206	25	15	23
77/202	14.63	401.3	12.3	470	1.39	98	8	225	0.83	242	19	10	17
77/202	14.71	396.7	13.3	467	1.37	98	8	225	0.83	240	21	11	18
77/202	14.79	392.1	22.2	460	1.38	98	8	225	0.83	0	35	*****	*****
77/206	10.37	374.2	14.6	439	3.50	100	7	180	0.83	242	59	27	32
77/206	10.46	373.2	18.3	446	2.77	100	7	180	0.83	244	59	26	31
77/205	10.54	373.8	20.1	452	2.44	100	7	180	0.83	245	57	25	29
77/206	10.62	374.9	22.7	458	2.28	100	7	180	0.83	243	60	27	31
77/206	10.71	376.5	24.4	463	2.19	100	7	180	0.83	223	62	30	34
77/206	10.79	378.0	23.4	469	2.11	100	7	180	0.83	241	57	25	28
77/206	10.87	378.6	26.2	473	2.07	100	7	180	0.83	247	63	27	30
77/206	10.96	380.3	29.2	479	2.06	100	7	180	0.83	249	70	29	32
77/206	11.04	383.1	29.8	488	2.09	100	7	180	0.83	247	72	30	33
77/206	11.12	385.5	29.4	494	2.10	100	7	180	0.83	247	71	30	33
77/205	11.21	387.7	29.6	502	2.10	100	7	180	0.83	248	72	30	32
77/206	11.29	390.5	31.3	512	2.14	100	7	180	0.83	248	77	32	34
77/206	11.37	394.2	31.3	525	2.18	100	7	180	0.83	249	79	33	35
77/206	11.46	397.7	31.0	538	2.20	100	7	180	0.83	251	79	32	34
77/206	11.54	400.3	31.4	549	2.24	100	7	180	0.83	251	81	33	35
77/206	11.62	403.6	31.5	560	2.32	100	7	180	0.83	250	84	34	36
77/206	11.71	407.1	30.1	572	2.33	100	7	180	0.83	250	81	33	34
77/206	11.79	410.3	30.0	585	2.44	100	7	180	0.83	249	84	34	35
77/206	11.87	414.1	29.1	599	2.44	100	7	180	0.83	250	82	33	34
77/206	11.96	417.1	29.2	612	2.46	100	7	180	0.83	252	83	33	34
77/206	12.04	419.9	28.9	623	2.51	100	7	180	0.83	251	84	34	34
77/206	12.12	422.8	28.4	635	2.54	100	7	180	0.83	252	83	34	34
77/206	12.21	425.7	28.0	647	2.57	100	7	180	0.83	252	83	34	34
77/206	12.29	428.4	27.5	658	2.51	100	7	180	0.83	251	80	32	33
77/206	12.37	430.9	27.6	670	2.51	100	7	180	0.83	249	80	33	34
77/206	12.46	433.1	27.6	679	2.47	100	7	180	0.83	248	79	32	34
77/206	12.54	435.1	27.2	690	2.45	100	7	180	0.83	249	77	32	33
77/206	12.62	436.9	26.9	699	2.40	100	7	180	0.83	249	74	31	33
77/206	12.71	438.0	27.2	705	2.36	100	7	180	0.83	249	74	31	33
77/206	12.79	439.5	26.1	710	2.28	100	7	180	0.83	246	69	29	31
77/206	12.87	440.3	25.6	713	2.21	100	7	180	0.83	247	65	27	30
77/205	12.96	440.7	25.2	715	2.12	100	7	180	0.83	245	61	26	29
77/206	13.04	441.1	24.6	715	2.05	100	7	180	0.83	247	58	25	28
77/206	13.12	440.8	24.9	712	2.00	100	7	180	0.83	244	57	25	28
77/206	13.21	441.1	25.0	710	1.96	100		180	0.83	243	56	25	8
77/206	13.29	441.4	24.4	708	1.89	100		180	0.83	243	53	23	7

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77/206	13.37	440.7	25.4	705	1.87	100	7	180	0.83	243	55	24	28
77/206	13.46	440.5	24.9	701	1.88	100	7	180	0.83	242	54	24	29
77/206	13.54	439.7	24.6	695	1.84	100	7	180	0.83	241	52	24	28
77/206	13.62	438.9	24.6	691	1.81	100	7	180	0.83	243	51	23	28
77/206	13.71	438.5	24.4	686	1.73	100	7	180	0.83	242	48	22	27
77/206	13.79	436.9	26.1	682	1.50	100	7	180	0.83	241	45	21	26
77/206	13.87	435.1	28.8	679	1.42	100	7	180	0.83	240	47	22	28
77/206	13.96	434.7	29.3	675	1.43	100	7	180	0.83	240	48	23	29
77/206	14.04	434.0	28.8	671	1.37	100	7	180	0.83	239	45	22	29
77/206	14.12	432.7	28.7	665	1.31	100	7	180	0.83	239	43	21	28
77/206	14.21	430.9	29.6	660	1.26	100	7	180	0.83	237	43	21	29
77/206	14.29	430.1	29.1	655	1.27	100	7	180	0.83	230	42	22	30
77/206	14.37	429.4	27.0	647	1.28	100	7	180	0.83	227	40	21	30
77/206	14.46	427.8	25.6	640	1.28	100	7	180	0.83	229	38	20	29
77/206	14.54	425.8	25.0	632	1.27	100	7	180	0.83	214	36	21	31
77/206	14.62	424.2	23.8	625	1.27	100	7	180	0.83	218	35	20	30
77/215	8.73	282.4	6.9	154	1.13	90	2	180	0.83	243	9	5	12
77/215	8.89	289.8	13.7	171	1.14	90	2	180	0.83	247	18	10	18
77/215	9.06	310.6	4.1	187	1.19	90	2	180	0.83	248	5	3	7
77/215	9.23	330.7	1.2	347	1.18	90	2	180	0.83	249	1	0	4
77/215	9.39	326.0	27.7	371	1.15	90	2	180	0.83	249	37	19	27
77/215	9.48	326.0	35.8	385	1.17	90	2	180	0.83	253	49	24	33
77/215	9.56	353.7	11.5	402	1.21	90	2	180	0.83	243	16	8	13
77/215	9.64	360.9	0.8	414	1.18	90	2	180	0.83	226	1	0	3
77/215	9.73	322.9	49.0	418	1.13	90	2	180	0.83	209	65	37	48
77/215	9.81	325.0	55.6	442	1.79	90	2	180	0.83	251	116	55	68
77/215	9.89	334.1	23.9	456	1.80	90	2	180	0.83	255	50	23	29
77/215	9.98	339.8	17.8	450	1.55	90	2	180	0.83	258	32	14	19
77/215	10.06	343.3	21.9	448	1.23	90	2	180	0.83	258	31	14	18
77/215	10.14	341.7	33.9	452	1.23	90	2	180	0.83	258	48	21	26
77/215	10.23	342.3	42.0	469	1.73	90	2	180	0.83	259	84	37	44
77/215	10.31	343.7	37.1	485	1.78	90	2	180	0.83	259	77	33	39
77/215	10.39	347.2	31.4	490	1.79	90	2	180	0.83	258	65	28	33
77/215	10.48	355.3	24.7	492	1.75	90	2	180	0.83	257	50	21	25
77/215	10.56	358.3	26.8	496	1.69	90	2	180	0.83	264	52	21	25
77/215	10.64	358.8	34.7	505	1.76	90	2	180	0.83	262	71	29	33
77/215	10.73	359.8	27.7	512	1.73	90	2	180	0.83	237	55	25	29
77/215	10.81	360.1	18.5	503	1.23	90	2	180	0.83	253	26	11	13
77/215	10.89	360.8	31.2	503	1.21	90	2	180	0.83	258	44	18	20
77/215	10.98	362.4	44.3	514	1.73	90	2	180	0.83	210	89	44	49
77/215	11.06	363.9	35.8	532	1.79	90	2	180	0.83	253	74	31	33
77/215	11.14	365.6	27.3	533	1.76	90	2	180	0.83	247	56	23	25
77/215	11.23	373.3	31.0	538	1.78	90	2	180	0.83	248	64	27	29
77/215	11.31	375.4	34.1	548	1.82	90	2	180	0.83	250	72	30	32
77/215	11.39	375.9	41.9	562	1.89	90	2	180	0.83	259	92	36	38
77/215	11.48	379.7	40.4	582	2.01	90	2	180	0.83	260	94	37	39
77/215	11.56	385.0	35.9	595	2.10	90	2	180	0.83	254	87	35	36
77/215	11.64	391.7	29.9	601	2.09	90	2	180	0.83	233	72	31	33
77/215	11.73	396.3	29.8	608	2.08	90	2	180	0.83	253	71	29	29
77/215	11.81	398.4	35.7	621	2.16	90	2	180	0.83	263	89	34	35
77/215	11.89	401.2	37.6	640	2.37	90	2	180	0.83	266	103	39	40

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/215	11.98	406.6	33.5	656	2.53	90	2	180	0.83	266	98	37	37
77/215	12.06	414.0	29.0	667	2.50	90	2	180	0.83	261	84	32	33
77/215	12.14	418.2	30.9	678	2.57	90	2	180	0.83	256	92	36	37
77/215	12.23	421.6	30.4	690	2.67	90	2	180	0.83	251	94	38	39
77/215	12.31	426.7	26.7	700	2.61	90	2	180	0.83	251	80	32	33
77/215	12.39	429.7	28.2	711	2.60	90	2	180	0.83	253	84	34	35
77/215	12.48	432.1	28.8	723	2.65	90	2	180	0.83	254	88	35	37
77/215	12.56	434.7	26.9	733	2.58	90	2	180	0.83	245	80	33	35
77/215	12.64	437.2	26.8	740	2.48	90	2	180	0.83	255	77	31	33
77/215	12.73	437.9	15.8	737	2.21	90	2	180	0.83	3	40	1060	1160
77/215	12.81	437.5	-2.4	722	1.90	90	2	180	0.83	24	-5	-22	*****
77/215	12.89	431.5	9.8	710	1.35	90	2	180	0.83	255	15	6	7
77/215	12.98	424.2	36.0	699	1.29	90	2	180	0.83	237	53	23	26
77/215	13.06	421.1	44.8	702	1.76	90	2	180	0.83	253	91	38	42
77/215	13.14	422.3	36.5	713	1.82	90	2	180	0.83	252	77	32	36
77/215	13.23	424.1	28.8	712	1.81	90	2	180	0.83	115	60	56	64
77/215	13.31	429.3	18.4	705	1.32	90	2	180	0.83	231	28	13	15
77/215	13.39	428.1	24.4	697	1.30	90	2	180	0.83	226	36	17	21
77/215	13.48	424.1	34.1	689	1.27	90	2	180	0.83	202	50	27	32
77/215	13.56	421.8	37.0	686	1.26	90	2	180	0.83	238	54	25	30
77/215	13.64	421.4	37.2	685	1.38	90	2	180	0.83	246	59	27	32
77/215	13.73	422.0	29.9	677	1.30	90	2	180	0.83	74	45	68	84
77/215	13.81	422.0	11.8	667	1.31	90	2	180	0.83	247	17	8	11
77/215	13.89	423.1	8.8	659	1.31	90	2	180	0.83	245	13	6	9
77/215	13.98	420.1	24.6	649	1.26	90	2	180	0.83	240	36	17	22
77/215	14.06	414.8	36.3	642	1.24	90	2	180	0.83	241	52	25	32
77/215	14.14	411.7	40.2	640	1.24	90	2	180	0.83	244	57	28	36
77/215	14.23	411.0	38.1	638	1.24	90	2	180	0.83	247	54	26	35
77/215	14.31	411.5	33.8	635	1.23	90	2	180	0.83	243	48	24	32
77/215	14.39	412.6	29.7	630	1.25	90	2	180	0.83	239	43	22	30
77/215	14.48	415.1	25.5	625	1.25	90	2	180	0.83	235	37	19	28
77/215	14.56	414.8	24.7	619	1.24	90	2	180	0.83	237	35	19	27
77/215	14.64	413.9	25.4	613	1.26	90	2	180	0.83	233	37	20	30
77/215	14.73	411.7	26.7	605	1.26	90	2	180	0.83	229	39	22	33
77/215	14.81	410.9	22.4	595	1.26	90	2	180	0.83	0	32	*****	*****
77/215	14.89	409.7	11.8	583	1.26	90	2	180	0.83	225	17	10	19
77/217	9.50	386.9	37.1	510	1.58	90	8	210	0.81	248	68	34	46
77/217	9.55	390.9	32.0	506	1.54	90	8	210	0.81	249	57	28	38
77/217	9.63	395.2	16.8	501	1.63	90	8	210	0.81	250	31	15	22
77/217	9.71	390.0	24.2	497	1.56	90	8	210	0.81	253	43	21	28
77/217	9.80	388.8	28.6	493	1.60	90	8	210	0.81	251	53	25	33
77/217	9.88	391.6	24.7	490	1.54	90	8	210	0.81	251	44	20	27
77/217	9.96	391.8	24.9	488	1.54	90	8	210	0.81	253	44	20	26
77/217	10.05	391.9	28.2	487	1.55	90	8	210	0.81	253	50	23	29
77/217	10.13	393.8	29.7	561	1.52	90	8	210	0.81	254	52	23	29
77/217	10.21	396.5	28.9	558	1.53	90	8	210	0.81	252	51	23	28
77/217	10.30	397.7	23.8	552	1.55	90	8	210	0.81	251	42	19	23
77/217	10.38	397.2	19.4	552	1.55	90	8	210	0.81	254	34	15	19
77/217	10.46	392.8	31.0	548	1.56	90	8	210	0.81	253	56	24	29
77/217	10.55	396.1	29.2	547	1.54	90		210	0.81	257	52	22	5
77/217	10.63	398.7	29.3	543	1.54	90		210	0.81	259	52	21	5

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE	EFFICIENCY SINGLE MODULE	WITHOUT END LOSS
77/217	10.71	400.9	30.1	543	1.51	90	8	210	0.81	258	52	22	25
77/217	10.80	403.3	31.2	541	1.52	90	8	210	0.81	257	55	22	26
77/217	10.88	406.5	26.8	539	1.54	90	8	210	0.81	105	47	48	55
77/217	10.96	405.1	19.6	530	1.58	90	8	210	0.81	162	36	23	26
77/217	11.05	401.8	16.1	527	1.55	90	8	210	0.81	259	29	11	13
77/217	11.13	403.9	18.0	522	1.54	90	8	210	0.81	261	32	12	14
77/217	11.21	406.1	25.1	523	1.50	90	8	210	0.81	258	43	17	19
77/217	11.30	402.3	36.3	523	1.50	90	8	210	0.81	260	63	25	27
77/217	11.38	409.1	35.7	524	1.51	90	8	210	0.81	259	62	25	26
77/217	11.46	394.1	58.2	524	1.50	90	8	210	0.81	260	101	40	42
77/217	11.55	389.7	68.4	524	1.52	90	8	210	0.81	261	120	47	49
77/217	11.63	405.4	57.7	525	1.50	90	8	210	0.81	262	100	39	40
77/217	11.71	399.9	70.0	528	1.49	90	8	210	0.81	262	121	47	48
77/217	11.80	416.4	59.8	550	1.20	90	8	210	0.81	264	83	32	32
77/217	11.88	427.0	57.9	655	1.82	90	8	210	0.81	260	122	48	48
77/217	11.96	452.9	29.7	652	1.88	90	8	210	0.81	146	64	45	45
77/217	12.05	454.4	27.9	651	1.85	90	8	210	0.81	259	59	23	23
77/217	12.13	454.5	37.3	754	1.87	90	8	210	0.81	193	81	42	43
77/217	12.21	460.5	28.2	744	1.89	90	8	210	0.81	259	61	24	25
77/217	12.30	458.5	26.4	729	1.86	90	8	210	0.81	0	57	*****	*****
77/217	12.38	452.1	18.2	721	1.34	90	8	210	0.81	259	28	11	11
77/217	12.46	442.5	42.9	721	1.77	90	8	210	0.81	258	88	35	36
77/217	12.55	452.8	38.4	714	1.86	90	8	210	0.81	259	82	33	34
77/217	12.63	459.4	19.7	709	1.57	90	8	210	0.81	258	35	14	15
77/217	12.71	451.2	35.4	705	1.81	90	8	210	0.81	259	74	29	32
77/217	12.80	455.0	32.3	697	1.82	90	8	210	0.81	256	68	27	30
77/217	12.88	457.2	23.0	688	1.38	90	8	210	0.81	46	36	83	94
77/217	12.96	446.2	24.3	576	1.35	90	8	210	0.81	256	38	15	17
77/217	13.05	439.3	27.3	564	1.36	90	8	210	0.81	0	43	*****	*****
77/217	13.13	432.3	29.8	655	1.35	90	8	210	0.81	10	46	464	532
77/217	13.21	429.8	26.5	648	1.34	90	8	210	0.81	237	41	18	21
77/217	13.30	425.2	32.5	641	1.34	90	8	210	0.81	196	50	27	32
77/217	13.38	423.7	33.2	637	1.33	90	8	210	0.81	255	51	21	25
77/217	13.46	424.2	33.3	631	1.34	90	8	210	0.81	122	51	46	55
77/217	13.55	424.1	28.8	625	1.34	90	8	210	0.81	256	44	19	23
77/217	13.63	422.9	29.0	619	1.35	90	8	210	0.81	79	45	64	78
77/217	13.71	420.8	29.7	614	1.33	90	8	210	0.81	254	45	20	25
77/217	13.80	419.6	31.9	610	1.34	90	8	210	0.81	255	49	22	27
77/217	13.88	418.3	34.3	605	1.32	90	8	210	0.81	254	52	23	29
77/217	13.96	419.4	32.8	601	1.34	90	8	210	0.81	255	51	23	29
77/217	14.05	420.4	30.8	597	1.33	90	8	210	0.81	253	47	22	28
77/217	14.13	420.3	30.4	593	1.35	90	8	210	0.81	38	47	147	194
77/217	14.21	417.5	24.0	588	1.36	90	8	210	0.81	253	37	18	24
77/217	14.30	414.6	20.4	579	1.36	90	8	210	0.81	248	32	15	22
77/217	14.38	408.5	29.2	573	1.33	90	8	210	0.81	249	45	22	30
77/217	14.46	406.7	30.4	569	1.34	90	8	210	0.81	247	47	24	33
77/217	14.55	406.6	26.3	564	1.34	90	8	210	0.81	246	40	21	30
77/217	14.63	404.7	23.9	559	1.34	90	8	210	0.81	246	37	19	28
77/217	14.71	401.6	25.7	554	1.35	90	8	210	0.81	33	40	159	236
77/217	14.80	397.7	19.6	544	1.37	90	8	210	0.81	0	31	*****	*****
77/217	14.88	392.5	9.7	538	1.38	90	8	210	0.81	244	15	8	16

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												SINGLE MODULE	WITHOUT END LOSS
77/221	9.05	342.6	15.1	380	2.28	93	7	180	0.81	249	40	22	34
77/221	9.14	339.8	14.9	374	2.03	93	7	180	0.81	251	35	19	29
77/221	9.22	337.1	19.9	368	1.92	93	7	180	0.81	249	44	24	34
77/221	9.30	337.9	18.3	364	1.65	93	7	180	0.81	255	35	18	26
77/221	9.39	335.2	24.1	359	1.34	93	7	180	0.81	256	37	19	27
77/221	9.47	334.5	29.4	354	1.34	93	7	180	0.81	260	46	22	30
77/221	9.55	337.2	29.1	350	1.33	93	7	180	0.81	261	45	21	29
77/221	9.64	340.2	27.4	346	1.34	93	7	180	0.81	261	43	20	27
77/221	9.72	341.8	28.2	343	1.34	93	7	180	0.81	259	44	20	27
77/221	9.80	343.1	27.6	339	1.34	93	7	180	0.81	261	43	19	26
77/221	9.89	325.1	45.3	335	1.33	93	7	180	0.81	262	70	31	39
77/221	9.97	345.3	31.0	334	1.33	93	7	180	0.81	263	48	21	27
77/221	10.05	347.5	34.8	333	1.31	93	7	180	0.81	264	53	23	29
77/221	10.14	352.7	34.4	331	1.33	93	7	180	0.81	260	53	23	29
77/221	10.22	357.4	32.3	331	1.32	93	7	180	0.81	264	49	21	26
77/221	10.30	360.8	32.0	329	1.33	93	7	180	0.81	235	49	23	28
77/221	10.39	363.1	30.6	326	1.34	93	7	180	0.81	27	47	197	237
77/221	10.47	364.5	25.6	322	1.34	93	7	180	0.81	262	40	16	20
77/221	10.55	364.5	25.4	318	1.35	93	7	180	0.81	0	40	*****	*****
77/221	10.64	362.2	26.8	314	1.34	93	7	180	0.81	264	41	17	20
77/221	10.72	363.1	31.4	313	1.33	93	7	180	0.81	257	48	20	23
77/221	10.80	364.4	44.0	311	1.32	93	7	180	0.81	264	67	27	30
77/221	10.89	372.8	41.1	362	1.33	93	7	180	0.81	81	63	82	92
77/221	10.97	378.9	31.7	433	1.32	93	7	180	0.81	261	48	19	22
77/221	11.05	381.6	30.1	431	1.33	93	7	180	0.81	24	46	202	225
77/221	11.14	379.4	33.6	426	1.30	93	7	180	0.81	264	50	20	22
77/221	11.22	382.2	35.1	422	1.31	93	7	180	0.81	135	53	41	44
77/221	11.30	383.9	42.4	419	1.30	93	7	180	0.81	228	64	29	31
77/221	11.39	389.3	40.8	416	1.30	93	7	180	0.81	268	61	23	25
77/221	11.47	395.5	39.7	415	1.32	93	7	180	0.81	253	60	24	26
77/221	11.55	398.7	39.4	410	1.32	93	7	180	0.81	41	60	150	157
77/221	11.64	400.9	28.8	513	1.32	93	7	180	0.81	0	44	*****	*****
77/221	11.72	398.7	21.0	505	1.31	93	7	180	0.81	264	32	12	12
77/221	11.80	393.5	25.8	497	1.32	93	7	180	0.81	0	39	*****	*****
77/221	11.89	387.9	28.4	490	1.31	93	7	180	0.81	34	43	129	131
77/221	11.97	387.0	25.0	484	1.32	93	7	180	0.81	267	38	14	14
77/221	12.05	384.9	32.4	480	1.31	93	7	180	0.81	147	49	34	34
77/221	12.14	384.3	28.3	472	1.31	93	7	180	0.81	126	43	34	35
77/221	12.22	383.2	16.4	465	1.33	93	7	180	0.81	75	25	34	35
77/221	12.30	377.4	30.3	461	1.31	93	7	180	0.81	50	46	93	96
77/221	12.39	374.1	34.6	453	1.31	93	7	180	0.81	35	52	153	159
77/221	12.47	377.4	14.2	446	1.33	93	7	180	0.81	122	22	18	19
77/221	12.55	372.7	14.3	440	1.33	93	7	180	0.81	0	22	*****	*****
77/221	12.64	363.3	24.3	435	1.31	93	7	180	0.81	18	37	210	227
77/221	12.72	361.8	30.8	432	1.31	93	7	180	0.81	13	47	351	380
77/221	12.80	363.5	33.2	428	1.30	93	7	180	0.81	253	50	20	22
77/221	12.89	368.3	32.3	425	1.29	93	7	180	0.81	260	48	19	21
77/221	12.97	370.3	25.4	418	1.32	93	7	180	0.81	0	39	*****	*****
77/221	13.05	368.5	8.5	410	1.33	93	7	180	0.81	213	13	6	8
77/221	13.14	360.2	9.1	404	1.34	93	-	180	0.81	0	14	*****	*
77/221	13.22	349.1	16.2	398	1.34	93		180	0.81	103	25	26	

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77/221	13.30	345.2	24.3	396	1.30	93	7	180	0.81	260	37	15	17
77/221	13.39	345.8	33.8	394	1.29	93	7	180	0.81	0	51	*****	*****
77/221	13.47	350.5	23.4	368	1.32	93	7	180	0.81	253	36	15	18
77/221	13.55	353.2	15.8	385	1.34	93	7	180	0.81	0	24	*****	*****
77/221	13.64	347.5	16.7	379	1.33	93	7	180	0.81	19	26	152	192
77/221	13.72	344.0	12.9	373	1.32	93	7	180	0.81	0	19	*****	*****
77/221	13.80	339.4	15.9	370	1.32	93	7	180	0.81	202	24	13	17
77/221	13.89	335.6	29.4	368	1.30	93	7	180	0.81	220	44	23	29
77/221	13.97	338.4	34.1	366	1.31	93	7	180	0.81	251	52	24	30
77/221	14.05	345.4	29.7	364	1.30	93	7	180	0.81	253	45	21	26
77/221	14.14	349.6	23.0	359	1.33	93	7	180	0.81	0	35	*****	*****
77/221	14.22	348.8	11.4	353	1.34	93	7	180	0.81	15	17	139	208
77/221	14.30	343.8	9.5	350	1.33	93	7	180	0.81	125	14	14	22
77/221	14.39	335.2	17.7	345	1.33	93	7	180	0.81	0	27	*****	*****
77/229	11.90	418.9	12.9	584	6.53	96	5	180	0.79	265	97	37	37
77/229	11.99	420.6	16.8	591	4.94	96	5	180	0.79	264	96	37	37
77/229	12.07	423.3	18.1	740	6.28	96	5	180	0.79	262	131	51	51
77/229	12.15	425.1	21.3	747	3.96	96	5	180	0.79	264	97	37	38
77/229	12.24	426.9	22.6	755	3.59	96	5	180	0.79	263	93	36	37
77/229	12.32	429.0	24.0	761	3.29	96	5	180	0.79	264	91	35	36
77/229	12.40	430.4	25.7	768	3.16	96	5	180	0.79	262	94	36	38
77/229	12.49	432.7	25.3	769	2.98	96	5	180	0.79	264	87	33	35
77/229	12.57	432.8	28.2	756	2.97	96	5	180	0.79	264	97	37	39
77/229	12.65	431.5	29.2	738	3.01	96	5	180	0.79	263	101	39	42
77/229	12.74	430.9	27.6	725	2.98	96	5	180	0.79	264	95	37	40
77/229	12.82	430.3	27.0	712	2.89	96	5	180	0.79	264	90	35	38
77/229	12.90	429.6	26.7	702	2.79	96	5	180	0.79	264	86	34	37
77/229	12.99	429.1	26.4	695	2.65	96	5	180	0.79	261	81	32	35
77/229	13.07	428.2	27.2	689	2.57	96	5	180	0.79	262	81	32	36
77/229	13.15	427.9	27.3	684	2.53	96	5	180	0.79	261	80	32	36
77/229	13.24	427.8	26.6	680	2.44	96	5	180	0.79	261	75	30	35
77/229	13.32	427.1	26.5	675	2.36	96	5	180	0.79	248	72	31	36
77/229	13.40	426.7	24.7	671	2.28	96	5	180	0.79	234	65	30	35
77/229	13.49	426.5	23.8	670	2.19	96	5	180	0.79	242	60	27	32
77/229	13.57	426.8	23.9	667	2.04	96	5	180	0.79	252	56	24	29
77/229	13.65	425.7	26.4	663	1.95	96	5	180	0.79	248	59	26	32
77/229	13.74	424.9	27.2	661	1.90	96	5	180	0.79	250	59	27	33
77/229	13.82	424.7	27.0	658	1.83	96	5	180	0.79	252	57	25	32
77/229	13.90	424.6	27.3	656	1.77	96	5	180	0.79	251	56	25	32
77/229	13.99	423.8	28.2	653	1.44	96	5	180	0.79	243	47	22	29
77/229	14.07	421.1	31.9	649	1.28	96	5	180	0.79	274	47	20	26
77/229	14.15	419.8	34.4	645	1.27	96	5	180	0.79	242	50	25	33
77/229	14.24	419.0	34.0	641	1.23	96	5	180	0.79	241	48	24	32
77/229	14.32	417.6	33.0	635	1.27	96	5	180	0.79	245	48	24	33
77/229	14.40	416.6	31.7	628	1.27	96	5	180	0.79	240	46	24	33
77/229	14.49	416.2	29.9	620	1.28	96	5	180	0.79	233	44	24	34
77/229	14.57	416.2	26.9	612	1.28	96	5	180	0.79	233	40	22	32
77/229	14.65	415.5	25.2	604	1.29	96	5	180	0.79	230	37	21	32
77/229	14.74	414.2	24.6	596	1.26	96	5	180	0.79	236	36	20	31
77/231	8.11	408.1	6.8	582	3.36	95	8	270	0.79	202	26	24	59
77/231	8.45	393.2	4.2	547	3.40	95	8	270	0.79	200	16	13	32

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLECTIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/231	8.78	379.9	9.8	517	2.00	95	8	270	0.79	210	22	16	30
77/231	9.11	369.4	14.8	490	1.28	95	8	270	0.79	117	22	25	44
77/231	9.25	366.3	12.8	480	1.29	95	8	270	0.79	42	19	60	103
77/231	9.33	364.7	10.2	474	1.26	95	8	270	0.79	103	15	19	33
77/231	9.41	374.5	-3.4	471	3.03	95	8	270	0.79	107	-12	-14	*****
77/231	9.50	381.1	-10.6	467	2.10	95	8	270	0.79	219	-25	-15	*****
77/231	9.58	380.2	9.0	465	1.94	95	8	270	0.79	216	20	11	18
77/231	9.66	379.6	14.5	465	1.89	95	8	270	0.79	200	31	19	27
77/231	9.75	380.5	12.5	465	1.80	95	8	270	0.79	204	26	15	22
77/231	9.83	387.0	7.5	465	1.28	95	8	270	0.79	217	11	6	10
77/231	9.91	393.1	5.2	468	1.29	95	8	270	0.79	219	7	4	7
77/231	10.00	395.4	11.3	473	1.29	95	8	270	0.79	217	16	9	13
77/231	10.08	396.4	17.3	481	1.30	95	8	270	0.79	213	26	14	19
77/231	10.16	397.1	21.1	617	1.31	95	8	270	0.79	224	32	16	21
77/231	10.25	397.8	21.3	624	1.30	95	8	270	0.79	227	32	15	20
77/231	10.33	399.2	20.0	636	1.31	95	8	270	0.79	172	30	19	25
77/231	10.41	402.8	18.4	642	1.33	95	8	270	0.79	220	28	14	18
77/231	10.50	406.9	17.4	651	1.34	95	8	270	0.79	232	27	12	16
77/231	10.58	410.9	21.2	664	1.31	95	8	270	0.79	225	32	15	19
77/231	10.66	413.3	26.2	680	1.33	95	8	270	0.79	222	40	19	23
77/231	10.75	415.1	30.8	699	1.29	95	8	270	0.79	208	46	23	27
77/231	10.83	416.9	32.8	722	1.31	95	8	270	0.79	195	49	27	31
77/231	10.91	419.9	28.9	741	1.32	95	8	270	0.79	192	44	24	27
77/231	11.00	423.2	22.0	749	1.33	95	8	270	0.79	155	33	23	26
77/231	11.08	427.7	13.4	750	1.35	95	8	270	0.79	0	21	*****	*****
77/231	11.16	432.1	-1.4	739	1.37	95	8	270	0.79	0	-2	*****	*****
77/231	11.25	435.9	-12.1	735	1.37	95	8	270	0.79	134	-19	-14	*****
77/231	11.33	436.6	-2.4	730	1.36	95	8	270	0.79	130	-3	-3	*****
77/231	11.41	433.5	12.4	726	1.35	95	8	270	0.79	124	19	16	17
77/231	11.50	432.3	18.0	728	1.33	95	8	270	0.79	115	27	24	26
77/231	11.58	431.6	15.3	730	1.34	95	8	270	0.79	89	23	27	29
77/231	11.66	431.9	6.9	733	1.35	95	8	270	0.79	107	10	10	11
77/231	11.75	433.4	5.7	734	1.35	95	8	270	0.79	121	8	7	8
77/231	11.83	436.3	6.5	730	1.25	95	8	270	0.79	62	9	15	16
77/231	11.91	437.2	1.8	723	1.34	95	8	270	0.79	123	2	2	2
77/231	12.00	437.3	2.8	721	1.33	95	8	270	0.79	121	4	3	3
77/231	12.08	437.2	11.4	721	1.33	95	8	270	0.79	148	17	12	12
77/231	12.16	436.9	18.0	725	1.31	95	8	270	0.79	138	27	20	20
77/231	12.25	436.5	20.1	734	1.32	95	8	270	0.79	136	30	23	23
77/231	12.33	436.5	20.7	746	1.32	95	8	270	0.79	153	31	21	22
77/231	12.41	437.7	21.3	757	1.30	95	8	270	0.79	154	32	21	22
77/231	12.50	439.8	20.3	766	1.33	95	8	270	0.79	147	31	21	23
77/231	12.58	442.2	11.6	765	1.31	95	8	270	0.79	125	17	14	16
77/231	12.66	445.2	3.4	767	1.35	95	8	270	0.79	144	5	3	5
77/231	12.75	447.1	7.2	765	1.35	95	8	270	0.79	147	11	7	9
77/231	12.83	447.5	12.3	762	1.33	95	8	270	0.79	134	18	14	17
77/231	12.91	447.1	14.8	763	1.31	95	8	270	0.79	155	22	15	17
77/231	13.00	446.9	15.8	767	1.34	95	8	270	0.79	149	24	17	20
77/231	13.08	447.4	15.3	773	1.33	95	8	270	0.79	147	23	17	20
77/231	13.16	448.5	13.3	778	1.33	95	8	270	0.79	136	20	15	
77/231	13.25	450.1	10.8	779	1.33	95	8	270	0.79	126	16	14	

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/237	10.61	413.7	39.4	694	1.21	90	5	270	0.79	245	55	24	28
77/237	10.77	416.4	44.1	718	1.70	90	5	270	0.79	243	86	38	43
77/237	10.94	422.3	30.6	730	1.74	90	5	270	0.79	247	61	26	29
77/237	11.11	426.9	34.1	736	1.71	90	5	270	0.79	241	67	29	32
77/237	11.27	427.0	37.1	757	1.82	90	5	270	0.79	245	78	32	35
77/237	11.44	433.5	32.8	772	1.90	90	5	270	0.79	248	72	29	31
77/237	11.61	436.9	36.3	795	2.04	90	5	270	0.79	246	85	35	36
77/237	11.77	442.3	32.0	813	2.15	90	5	270	0.79	243	79	33	34
77/237	11.94	446.3	32.8	807	2.17	90	5	270	0.79	243	82	34	34
77/237	12.11	441.4	39.9	738	2.66	90	5	270	0.79	247	123	50	51
77/237	12.27	429.7	27.3	689	3.30	90	5	270	0.79	247	104	42	44
77/237	12.44	427.6	22.9	721	2.87	90	5	270	0.79	243	76	32	33
77/237	12.61	432.1	29.0	725	2.33	90	5	270	0.79	236	78	34	36
77/237	12.77	433.7	27.6	740	2.23	90	5	270	0.79	239	71	30	33
77/237	12.94	435.6	26.8	743	2.10	90	5	270	0.79	234	65	29	32
77/237	13.11	434.8	2.1	708	1.55	90	5	270	0.79	15	3	25	47
77/237	13.19	430.1	0.0	672	1.30	90	5	270	0.79	226	0	0	1
77/237	13.27	430.8	6.5	653	1.29	90	5	270	0.79	217	9	4	6
77/237	13.36	418.7	29.6	651	1.21	90	5	270	0.79	230	41	19	23
77/237	13.44	413.7	40.6	659	1.20	90	5	270	0.79	226	56	27	32
77/237	13.52	411.9	43.5	668	1.19	90	5	270	0.79	229	60	28	34
77/237	13.61	411.2	40.6	673	1.43	90	5	270	0.79	228	67	32	39
77/237	13.69	414.4	30.9	670	1.39	90	5	270	0.79	224	49	24	30
77/237	13.77	429.0	9.3	661	1.37	90	5	270	0.79	225	14	7	11
77/237	13.86	422.7	14.6	645	1.25	90	5	270	0.79	228	21	10	14
77/237	13.94	414.2	32.1	637	1.21	90	5	270	0.79	225	45	23	29
77/237	14.02	410.5	42.1	638	1.21	90	5	270	0.79	219	59	31	40
77/237	14.11	408.5	37.8	641	1.20	90	5	270	0.79	222	52	28	36
77/237	14.19	407.9	33.0	636	1.21	90	5	270	0.79	224	46	24	33
77/237	14.27	408.3	28.7	627	1.22	90	5	270	0.79	227	40	21	30
77/237	14.36	409.1	24.1	616	1.21	90	5	270	0.79	227	33	18	26
77/237	14.44	407.8	21.0	604	1.23	90	5	270	0.79	182	30	20	30
77/237	14.52	405.7	17.7	591	1.23	90	5	270	0.79	190	25	17	26
77/237	14.61	403.7	12.2	576	1.22	90	5	270	0.79	222	17	10	17
77/237	14.69	401.1	10.6	558	1.22	90	5	270	0.79	1	15	1252	2333
77/238	9.10	449.5	0.6	633	1.22	90	12	225	0.79	234	0	0	7
77/238	9.27	449.0	7.3	666	1.20	90	12	225	0.79	232	10	5	13
77/238	9.44	433.9	26.7	685	1.14	90	12	225	0.79	237	35	19	29
77/238	9.60	424.6	32.7	689	1.12	90	12	225	0.79	240	42	22	31
77/238	9.77	419.7	30.9	682	1.11	90	12	225	0.79	240	39	20	27
77/238	9.94	420.1	17.2	668	1.10	90	12	225	0.79	242	21	10	15
77/238	10.10	423.5	25.7	661	1.09	90	12	225	0.79	244	32	15	20
77/238	10.27	424.5	32.0	665	1.08	90	12	225	0.79	245	40	18	23
77/239	10.44	427.8	30.5	680	1.08	90	12	225	0.79	247	38	17	21
77/238	10.60	411.0	53.2	691	1.04	90	12	225	0.79	250	64	27	32
77/238	10.77	415.8	45.9	715	1.42	90	12	225	0.79	247	75	32	37
77/238	10.94	423.4	31.2	706	1.50	90	12	225	0.79	250	54	22	25
77/238	11.10	423.7	40.4	716	1.47	90	12	225	0.79	252	68	28	31
77/238	11.27	428.1	37.3	738	1.80	90	12	225	0.79	253	77	31	34
77/233	11.44	433.9	34.7	752	1.91	90	12	225	0.79	249	76	31	33
77/238	11.60	438.7	34.5	769	2.24	90	12	225	0.79	252	89	36	37

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/238	11.77	449.8	30.6	752	2.09	90	12	225	0.79	252	74	29	30
77/238	11.94	441.1	48.0	739	2.23	90	12	225	0.79	251	124	50	50
77/238	12.10	427.4	30.0	710	3.35	90	12	225	0.79	249	116	47	47
77/238	12.27	437.7	30.0	696	2.49	90	12	225	0.79	251	86	35	36
77/238	12.44	436.7	32.0	681	2.47	90	12	225	0.79	249	91	37	39
77/238	12.60	436.8	29.6	665	2.40	90	12	225	0.79	249	82	34	36
77/238	12.77	436.6	29.5	650	2.30	90	12	225	0.79	250	78	32	35
77/238	12.94	434.7	30.6	635	2.25	90	12	225	0.79	245	79	34	37
77/238	13.10	429.7	29.6	619	2.27	90	12	225	0.79	249	77	33	37
77/238	13.27	429.4	28.6	605	2.11	90	12	225	0.79	247	70	30	34
77/238	13.44	428.2	27.5	591	2.00	90	12	225	0.79	246	63	28	33
77/238	13.60	428.5	25.7	578	1.89	90	12	225	0.79	243	56	25	31
77/238	13.77	427.2	25.3	565	1.73	90	12	225	0.79	243	50	23	29
77/238	13.94	423.8	30.2	554	1.33	90	12	225	0.79	238	46	22	29
77/238	14.10	423.6	30.7	544	1.32	90	12	225	0.79	237	47	23	31
77/238	14.27	423.7	32.0	533	1.33	90	12	225	0.79	234	49	25	35
77/243	12.05	476.9	32.3	939	2.58	91	8	135	0.79	268	96	36	36
77/243	12.13	489.7	5.7	949	2.28	91	8	135	0.79	22	15	68	71
77/243	12.21	501.8	-17.3	941	1.68	91	8	135	0.79	268	-33	-12	*****
77/243	12.30	508.0	0.2	966	1.28	91	8	135	0.79	269	0	0	0
77/243	12.38	498.2	31.6	961	1.57	91	8	135	0.79	0	58	*****	*****
77/243	12.46	504.3	8.8	942	1.43	91	8	135	0.79	265	14	5	6
77/243	12.55	505.4	0.7	962	1.42	91	8	135	0.79	17	1	6	16
77/243	12.63	503.1	18.0	971	1.33	91	8	135	0.79	272	28	10	11
77/243	12.71	496.7	27.6	959	1.28	91	8	135	0.79	264	41	16	17
77/243	12.80	488.5	36.7	978	1.15	91	8	135	0.79	258	49	19	21
77/243	12.88	487.5	40.1	973	1.05	91	8	135	0.79	0	49	*****	*****
77/243	12.96	489.3	32.6	923	1.51	91	8	135	0.79	260	57	23	26
77/243	13.05	475.6	34.5	874	2.14	91	8	135	0.79	4	86	2071	2316
77/243	13.13	482.5	0.0	846	2.44	91	8	135	0.79	268	0	0	1
77/243	13.21	479.7	18.8	832	2.37	91	8	135	0.79	268	51	20	24
77/243	13.30	473.1	30.3	826	2.27	91	8	135	0.79	268	80	32	36
77/243	13.38	472.7	24.1	798	2.35	91	8	135	0.79	137	65	52	61
77/243	13.46	474.7	0.8	771	2.49	91	8	135	0.79	257	2	0	3
77/243	13.55	470.7	14.7	758	2.43	91	8	135	0.79	265	41	17	21
77/243	13.63	463.7	27.4	748	2.33	91	8	135	0.79	133	74	61	74
77/243	13.71	462.9	7.1	721	2.49	91	8	135	0.79	0	20	*****	*****
77/243	13.80	465.1	-9.8	696	2.01	91	8	135	0.79	0	-22	*****	*****
77/243	13.88	452.8	6.1	672	1.99	91	8	135	0.79	192	14	8	13
77/243	13.96	445.9	11.0	656	1.98	91	8	135	0.79	254	25	11	16
77/243	14.05	441.1	17.9	646	1.96	91	8	135	0.79	252	40	18	25
77/243	14.13	437.3	24.0	632	1.90	91	8	135	0.79	4	52	1322	1757
77/243	14.21	435.7	17.6	611	1.89	91	8	135	0.79	255	38	18	25
77/243	14.30	433.1	11.4	594	1.94	91	8	135	0.79	1	25	1978	3008
77/258	10.54	200.5	56.3	100	0.95	93	8	180	0.76	262	64	26	30
77/258	10.71	214.4	56.0	107	0.97	93	8	180	0.76	263	64	26	29
77/258	12.37	336.1	57.7	270	1.09	93	8	180	0.76	269	73	27	28
77/258	12.54	343.1	62.9	301	1.07	93	8	180	0.76	265	78	30	31
77/258	12.71	347.5	63.4	329	1.09	93	8	180	0.76	194	80	42	45
77/258	12.87	359.5	51.5	348	1.11	93	8	180	0.76	262	66	26	28
77/258	13.04	368.8	51.0	361	1.09	93	8	180	0.76	265	64	25	28

DATE	SOLAR TIME	INLET TEMP.	TEMP. DIFF.	PRESSURE	FLOW RATE	AMBIENT TEMP.	WIND SPEED	WIND DIR.	REFLEC-TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
(YEAR/DAY)	(DEC.HRS.)	(F)	(F)	(PSI)	(GPM)	(F)	(MPH)	(DEG.)		(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/258	13.21	373.7	52.0	381	1.09	93	8	180	0.76	266	66	26	30
77/258	13.37	378.1	50.3	397	1.10	93	8	180	0.76	263	64	26	30
77/258	13.54	384.7	43.2	406	1.12	93	8	180	0.76	259	56	23	28
77/258	13.71	387.6	42.3	409	1.12	93	8	180	0.76	261	55	23	29
77/258	13.87	390.9	40.8	414	1.12	93	8	180	0.76	262	53	23	29
77/258	14.04	392.9	35.2	414	1.16	93	8	180	0.76	0	47	*****	*****
77/258	14.21	395.9	1.0	403	1.18	93	8	180	0.76	260	1	0	3
77/258	14.37	389.4	32.4	393	1.13	93	8	180	0.76	257	42	20	28
77/258	14.54	383.5	37.0	387	1.11	93	8	180	0.76	3	47	1935	2772
77/258	14.71	384.1	2.8	371	1.18	93	8	180	0.76	141	3	3	12
77/258	14.87	382.3	8.8	357	1.17	93	8	180	0.76	251	12	6	14
77/258	15.04	372.5	27.8	344	1.14	93	8	180	0.76	245	37	21	36
77/258	15.21	369.5	21.0	329	1.16	93	8	180	0.76	238	28	18	33
77/271	11.27	403.5	20.7	464	4.40	94	5	180	0.74	267	105	40	43
77/271	11.43	408.9	18.3	495	3.24	94	5	180	0.74	267	68	26	27
77/271	11.60	413.0	23.8	533	3.13	94	5	180	0.74	268	86	32	34
77/271	11.77	419.1	29.6	565	3.12	94	5	180	0.74	268	106	40	41
77/271	11.93	429.8	25.3	570	3.05	94	5	180	0.74	267	89	33	34
77/271	12.10	420.3	29.4	521	4.13	94	5	180	0.74	267	140	53	53
77/271	12.27	407.0	24.8	481	4.70	94	5	180	0.74	266	135	51	52
77/271	12.43	403.3	21.0	466	4.51	94	5	180	0.74	266	109	41	43
77/271	12.60	405.8	20.6	465	3.91	94	5	180	0.74	266	93	35	37
77/271	12.77	406.5	22.6	467	3.71	94	5	180	0.74	265	97	37	40
77/271	12.93	407.8	24.1	469	3.51	94	5	180	0.74	263	98	38	42
77/271	13.10	408.0	24.7	461	3.33	94	5	180	0.74	263	95	38	42
77/271	13.27	405.9	23.6	455	3.38	94	5	180	0.74	262	92	37	42
77/271	13.43	405.2	23.2	453	3.24	94	5	180	0.74	262	87	36	41
77/271	13.60	404.5	23.0	449	2.96	94	5	180	0.74	260	78	33	39
77/271	13.77	403.9	23.8	447	2.71	94	5	180	0.74	259	74	32	39
77/271	13.93	403.5	23.4	535	2.56	94	5	180	0.74	258	69	31	33
77/271	14.10	402.0	22.5	526	2.30	94	5	180	0.74	255	62	28	37
77/271	14.27	401.2	21.5	520	2.21	94	5	180	0.74	251	55	26	35
77/271	14.43	400.3	21.2	518	2.09	94	5	180	0.74	252	51	25	35
77/271	14.60	399.4	19.8	511	1.90	94	5	180	0.74	250	43	22	33
77/271	14.77	397.9	19.4	511	1.80	94	5	180	0.74	246	40	22	33
77/271	14.93	396.5	16.2	502	1.27	94	5	180	0.74	242	23	13	24
77/271	15.10	393.1	19.7	491	1.24	94	5	180	0.74	237	28	17	31
77/271	15.27	390.3	17.3	481	1.23	94	5	180	0.74	234	24	16	31
77/271	15.43	387.9	11.1	465	1.23	94	5	180	0.74	227	15	11	27
77/271	15.60	394.0	10.6	448	1.20	94	5	180	0.74	227	14	11	29
77/272	10.29	415.9	10.6	447	3.16	95	8	202	0.74	267	38	16	20
77/272	10.46	433.7	13.0	574	2.25	95	8	202	0.74	268	33	13	17
77/272	10.63	446.1	19.1	647	2.07	95	8	202	0.74	268	45	18	22
77/272	10.79	459.9	19.7	723	1.96	95	8	202	0.74	270	44	17	20
77/272	10.96	454.1	35.6	782	2.20	95	8	202	0.74	271	90	35	39
77/272	11.13	455.7	22.1	787	2.58	95	8	202	0.74	272	66	25	27
77/272	11.29	457.7	29.5	774	2.77	95	8	202	0.74	272	94	35	38
77/272	11.46	462.2	23.7	774	3.01	95	8	202	0.74	274	82	30	32
77/272	11.63	463.0	25.2	768	3.22	95	8	202	0.74	273	94	34	36
77/272	11.79	463.6	24.7	765	3.45	95	8	202	0.74	274	98	36	37
77/272	11.96	464.3	23.9	756	3.68	95	8	202	0.74	275	101	37	37

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLECTIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/272	12.13	464.7	23.3	749	3.76	95	8	202	0.74	273	101	37	38
77/272	12.29	465.3	22.4	740	3.71	95	8	202	0.74	274	96	35	36
77/272	12.46	465.1	22.5	734	3.73	95	8	202	0.74	273	97	36	38
77/272	12.63	465.1	22.0	723	3.52	95	8	202	0.74	272	89	33	35
77/272	12.79	464.6	22.0	714	3.42	95	8	202	0.74	272	87	33	36
77/272	12.96	464.2	22.5	708	3.31	95	8	202	0.74	272	86	33	36
77/272	13.13	463.7	22.9	703	3.25	95	8	202	0.74	271	86	33	37
77/272	13.29	463.4	22.1	697	3.03	95	8	202	0.74	269	77	30	35
77/272	13.46	462.7	22.2	691	2.87	95	8	202	0.74	268	73	30	35
77/272	13.63	462.3	21.8	685	2.71	95	8	202	0.74	267	68	28	34
77/272	13.79	461.4	21.9	679	2.52	95	8	202	0.74	265	63	27	34
77/272	13.96	460.7	21.0	671	2.33	95	8	202	0.74	262	56	25	32
77/272	14.13	459.4	20.3	659	2.19	95	8	202	0.74	260	51	23	31
77/272	14.29	457.3	19.8	644	2.02	95	8	202	0.74	257	46	22	30
77/272	14.46	454.9	18.2	628	1.90	95	8	202	0.74	256	40	19	29
77/272	14.63	452.3	17.6	611	1.82	95	8	202	0.74	255	37	19	29
77/272	14.79	448.0	18.5	593	1.38	95	8	202	0.74	252	29	15	26
77/272	14.96	443.1	20.2	577	1.34	95	8	202	0.74	249	31	17	31
77/272	15.13	439.3	17.1	557	1.34	95	8	202	0.74	247	26	15	30
77/272	15.29	435.0	13.8	538	1.34	95	8	202	0.74	243	21	13	29
77/272	15.46	430.3	10.2	518	1.37	95	8	202	0.74	238	16	11	28
77/272	15.63	431.7	0.8	500	1.38	95	8	202	0.74	231	1	0	16
77/272	15.79	445.7	-18.7	493	1.42	95	8	202	0.74	227	-30	-25	*****
77/272	15.96	453.6	-17.0	606	1.31	95	8	202	0.74	221	-25	-23	*****
77/272	16.13	456.9	-17.2	591	1.36	95	8	202	0.74	216	-27	-26	*****
77/273	10.19	429.8	5.1	643	6.75	92	12	225	0.74	269	39	16	21
77/273	10.36	445.0	6.0	686	4.15	92	12	225	0.74	271	28	11	15
77/273	10.52	438.5	20.2	730	3.36	92	12	225	0.74	270	78	31	37
77/273	10.69	439.7	22.0	738	2.87	92	12	225	0.74	271	73	28	33
77/273	10.86	441.7	23.5	746	2.87	92	12	225	0.74	274	78	30	34
77/273	11.02	445.8	23.3	757	3.07	92	12	225	0.74	273	82	31	35
77/273	11.19	446.1	27.1	747	3.44	92	12	225	0.74	272	107	40	44
77/273	11.36	439.1	23.5	713	4.12	92	12	225	0.74	275	112	41	44
77/273	11.52	437.0	22.1	687	3.90	92	12	225	0.74	275	99	36	38
77/273	11.69	436.3	24.8	671	3.52	92	12	225	0.74	275	101	37	38
77/273	11.86	437.1	25.4	666	3.45	92	12	225	0.74	272	101	37	38
77/273	12.02	438.1	28.2	666	3.13	92	12	225	0.74	274	102	37	37
77/273	12.19	439.0	29.3	666	2.87	92	12	225	0.74	273	97	36	36
77/273	12.36	439.7	30.1	662	2.91	92	12	225	0.74	274	101	37	38
77/273	12.52	439.4	28.6	653	2.66	92	12	225	0.74	276	88	32	34
77/273	12.69	438.7	29.9	647	2.59	92	12	225	0.74	276	89	33	35
77/273	12.86	438.8	30.2	642	2.49	92	12	225	0.74	276	87	32	35
77/273	13.02	439.3	30.4	636	2.37	92	12	225	0.74	276	83	31	35
77/273	13.19	439.3	30.1	633	2.33	92	12	225	0.74	276	81	31	35
77/273	13.36	440.6	27.5	632	2.18	92	12	225	0.74	274	69	27	31
77/273	13.52	440.2	29.2	631	2.02	92	12	225	0.74	276	68	27	32
77/273	13.69	440.1	29.3	625	1.76	92	12	225	0.74	272	59	24	30
77/273	13.86	437.9	29.2	612	1.78	92	12	225	0.74	269	60	25	32
77/273	14.02	436.9	27.3	602	1.67	92	12	225	0.74	269	52	22	30
77/273	14.19	435.0	26.8	591	1.62	92	[illegible]	225	0.74	266	50	22	0
77/273	14.36	433.5	23.8	579	1.34	92	[illegible]	225	0.74	263	36	17	5

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77/273	14.52	432.6	25.5	569	1.35	92	12	225	0.74	260	39	19	29
77/273	14.69	429.1	27.0	557	1.26	92	12	225	0.74	257	39	20	31
77/273	14.86	428.9	18.4	543	1.30	92	12	225	0.74	255	27	14	25
77/273	15.02	431.5	11.8	527	1.32	92	12	225	0.74	250	18	10	21
77/277	10.66	408.7	8.3	383	2.59	78	10	135	0.82	254	24	10	13
77/277	10.83	404.9	18.6	438	2.50	78	10	135	0.82	258	53	22	25
77/277	10.99	406.7	30.2	470	2.63	78	10	135	0.82	264	92	36	40
77/277	11.16	406.2	34.1	466	2.98	78	10	135	0.82	268	117	45	49
77/277	11.33	400.4	28.6	445	3.50	78	10	135	0.82	270	116	44	46
77/277	11.49	397.2	26.8	529	3.56	78	10	135	0.82	270	110	41	43
77/277	11.66	397.8	27.1	520	3.45	78	10	135	0.82	270	108	40	42
77/277	11.83	398.3	26.9	514	3.46	78	10	135	0.82	272	107	40	40
77/277	11.99	398.5	27.2	509	3.59	78	10	135	0.82	271	113	42	42
77/277	12.16	398.6	26.7	506	3.73	78	10	135	0.82	275	115	42	43
77/277	12.33	398.6	25.9	502	3.69	78	10	135	0.82	274	110	41	42
77/277	12.49	398.6	26.2	500	3.63	78	10	135	0.82	274	110	41	42
77/277	12.66	398.6	26.1	497	3.55	78	10	135	0.82	273	107	40	42
77/277	12.83	398.5	26.2	495	3.49	78	10	135	0.82	274	105	40	43
77/277	12.99	398.3	25.4	493	3.48	78	10	135	0.82	272	102	39	43
77/277	13.16	398.1	25.6	490	3.33	78	10	135	0.82	271	98	38	43
77/277	13.33	397.8	25.5	487	3.16	78	10	135	0.82	272	93	36	42
77/277	13.49	397.3	26.0	485	3.00	78	10	135	0.82	271	90	36	42
77/277	13.66	396.9	26.1	483	2.77	78	10	135	0.82	268	83	34	41
77/277	13.83	396.6	25.3	480	2.67	78	10	135	0.82	266	78	33	40
77/277	13.99	396.0	25.3	478	2.45	78	10	135	0.82	266	71	31	39
77/277	14.16	395.2	24.1	474	2.28	78	10	135	0.82	263	63	29	37
77/277	14.33	394.5	23.1	470	2.12	78	10	135	0.82	262	56	26	36
77/277	14.49	393.9	22.2	466	1.95	78	10	135	0.82	258	50	24	34
77/277	14.66	393.2	21.5	463	1.86	78	10	135	0.82	258	46	23	34
77/277	14.83	390.9	20.5	458	1.34	78	10	135	0.82	253	31	17	27
77/277	14.99	389.1	22.4	453	1.32	78	10	135	0.82	250	34	19	32
77/277	15.16	388.0	19.1	447	1.32	78	10	135	0.82	249	29	17	31
77/277	15.33	386.4	14.2	438	1.34	78	10	135	0.82	242	22	14	29
77/277	15.49	383.3	12.1	426	1.31	78	10	135	0.82	222	18	13	32
77/278	7.98	441.7	-16.7	563	1.76	78	8	180	0.82	165	-34	-41	*****
77/278	8.15	442.7	-13.2	574	1.77	78	8	180	0.82	168	-27	-30	*****
77/278	8.31	445.7	-12.8	583	1.26	78	8	180	0.82	167	-18	-19	*****
77/278	8.48	436.5	-9.0	574	1.25	78	8	180	0.82	134	-13	-16	*****
77/278	8.65	436.0	-8.9	565	1.24	78	8	180	0.82	116	-12	-17	*****
77/278	8.81	439.2	-13.5	562	1.25	78	8	180	0.82	22	-19	-131	*****
77/278	8.98	440.9	-11.8	559	1.26	78	8	180	0.82	203	-17	-12	*****
77/278	9.15	442.0	3.3	582	1.23	78	8	180	0.82	207	4	3	11
77/278	9.31	443.2	7.6	615	1.22	78	8	180	0.82	119	10	11	26
77/278	9.48	433.9	21.8	636	1.22	78	8	180	0.82	221	30	17	27
77/278	9.65	417.3	40.7	649	1.17	78	8	180	0.82	230	55	29	40
77/278	9.81	418.1	35.0	650	1.18	78	8	180	0.82	235	47	24	33
77/278	9.98	421.8	30.5	644	1.20	78	8	180	0.82	237	42	20	27
77/278	10.15	420.9	36.7	648	1.20	78	8	180	0.82	243	50	23	30
77/278	10.31	420.6	42.6	663	1.19	78	8	180	0.82	247	58	26	32
77/278	10.48	422.0	44.7	679	1.17	78	8	180	0.82	248	60	26	32
77/278	10.65	439.3	10.7	657	2.73	78	8	180	0.82	250	33	14	17

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77/278	10.81	440.5	28.8	711	2.49	78	8	130	0.82	221	82	39	45
77/278	10.98	444.8	20.8	712	2.22	78	8	180	0.82	253	53	22	25
77/278	11.15	443.0	26.6	691	2.30	78	8	130	0.82	136	70	53	58
77/278	11.31	439.4	13.9	662	1.99	78	8	130	0.82	147	32	22	24
77/278	11.48	434.2	23.8	655	1.85	78	8	130	0.82	212	50	24	26
77/278	11.65	433.7	17.9	654	1.79	78	8	130	0.82	109	37	34	36
77/278	11.81	431.0	12.8	619	1.21	78	8	130	0.82	118	17	15	15
77/278	11.98	434.6	8.9	595	1.18	78	8	130	0.82	134	12	9	9
77/278	12.15	418.5	28.6	586	1.13	78	8	180	0.82	109	37	34	35
77/278	12.31	416.2	20.7	576	1.14	78	8	130	0.82	70	27	39	41
77/278	12.48	414.5	8.4	546	1.17	78	8	130	0.82	130	11	8	10
77/278	12.65	423.1	18.6	542	1.24	78	8	180	0.82	253	26	10	12
77/278	12.81	431.2	41.6	605	1.04	78	8	180	0.82	258	50	20	22
77/278	12.98	418.6	75.2	705	5.54	78	8	130	0.82	258	481	195	210
77/278	13.15	436.7	10.0	754	4.71	78	8	180	0.82	257	54	22	25
77/278	13.31	438.9	16.5	771	3.61	78	8	180	0.82	257	68	28	33
77/278	13.48	441.0	20.8	788	2.82	78	8	130	0.82	235	67	31	37
77/278	13.65	441.1	18.3	778	2.34	78	8	180	0.82	168	49	32	40
77/278	13.81	438.2	15.9	755	1.93	78	8	180	0.82	185	35	21	28
77/278	13.98	433.5	22.8	745	1.80	78	8	180	0.82	91	47	60	79
77/278	14.15	431.9	21.2	729	1.68	78	8	180	0.82	239	41	20	28
77/278	14.31	429.5	18.8	724	1.62	78	8	180	0.82	147	35	29	42
77/278	14.48	424.9	-0.8	668	1.15	78	8	180	0.82	5	-1	-26	179
77/278	14.65	415.6	-4.6	611	2.10	78	8	180	0.82	0	-11	*****	*****
77/284	11.71	354.6	22.9	333	2.40	60	15	0	0.75	276	64	23	24
77/284	11.87	374.9	22.1	392	2.41	60	15	0	0.75	276	61	22	23
77/284	12.04	392.7	23.6	458	2.40	60	15	0	0.75	278	65	23	24
77/284	12.21	406.6	26.9	522	2.32	60	15	0	0.75	277	72	26	27
77/284	12.37	397.8	43.3	569	2.31	60	15	0	0.75	278	115	42	43
77/284	12.54	407.8	29.2	581	2.13	60	15	0	0.75	277	72	26	28
77/284	12.71	410.7	36.4	583	2.06	60	15	0	0.75	278	86	32	34
77/284	12.87	412.8	35.6	591	2.00	60	15	0	0.75	277	82	30	33
77/284	13.04	417.2	32.9	588	1.89	60	15	0	0.75	278	71	27	30
77/284	13.21	418.7	34.6	588	1.84	60	15	0	0.75	274	73	28	32
77/284	13.37	419.7	34.4	590	1.74	60	15	0	0.75	275	69	27	31
77/284	13.54	420.3	35.5	589	1.35	60	15	0	0.75	272	55	22	27
77/284	13.71	420.1	38.2	586	1.44	60	15	0	0.75	269	63	26	32
77/284	13.87	420.0	35.0	580	1.27	60	15	0	0.75	266	51	22	28
77/284	14.04	421.0	31.2	568	1.24	60	15	0	0.75	266	44	19	26
77/284	14.21	419.3	31.5	554	1.26	60	15	0	0.75	263	45	21	28
77/284	14.37	417.4	31.1	537	1.07	60	15	0	0.75	262	38	18	26
77/284	14.54	416.9	25.6	518	1.61	60	15	0	0.75	260	47	23	34
77/284	14.71	419.1	14.1	573	1.85	60	15	0	0.75	258	30	15	25
77/284	14.87	414.8	13.9	547	1.87	60	15	0	0.75	253	30	16	27
77/284	15.04	409.9	12.9	547	1.86	60	15	0	0.75	250	27	16	29
77/285	9.47	355.3	2.0	284	1.32	60	5	45	0.75	282	3	1	4
77/285	9.64	365.0	21.1	319	1.31	60	5	45	0.75	283	32	14	20
77/285	9.81	374.5	28.8	369	1.31	60	5	45	0.75	284	43	18	24
77/285	9.97	389.8	26.0	420	1.26	60	5	45	0.75	284	38	15	20
77/285	10.14	407.1	23.0	468	1.31	60		45	0.75	284	34	14	
77/285	10.31	388.5	58.8	510	1.28	60		45	0.75	286	87	34	

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC- TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/285	10.47	391.0	38.9	559	1.92	60	5	45	0.75	288	86	32	38
77/285	10.64	406.3	27.9	557	1.30	60	5	45	0.75	289	42	15	18
77/285	10.81	405.2	51.8	560	1.85	60	5	45	0.75	293	110	40	45
77/285	10.97	409.9	40.0	590	2.06	60	5	45	0.75	291	95	34	37
77/285	11.14	419.7	36.9	581	2.10	60	5	45	0.75	291	89	31	34
77/285	11.31	410.4	38.4	554	3.12	60	5	45	0.75	291	138	49	52
77/285	11.47	401.7	32.0	526	3.77	60	5	45	0.75	293	139	48	50
77/285	11.64	396.5	28.7	506	3.85	60	5	45	0.75	295	128	44	45
77/285	11.81	399.7	27.8	495	3.64	60	5	45	0.75	293	117	40	41
77/285	11.97	400.9	29.2	484	3.74	60	5	45	0.75	295	126	43	43
77/285	12.14	401.2	28.0	469	3.79	60	5	45	0.75	294	122	42	42
77/285	12.31	403.3	27.4	459	3.61	60	5	45	0.75	293	114	39	40
77/285	12.47	403.1	30.0	453	3.66	60	5	45	0.75	291	127	44	46
77/285	12.64	397.9	28.2	571	3.88	60	5	45	0.75	292	126	44	47
77/285	12.81	399.0	26.5	560	3.49	60	5	45	0.75	290	107	38	41
77/285	12.97	399.9	27.3	552	3.38	60	5	45	0.75	287	106	38	42
77/285	13.14	399.6	27.5	543	3.24	60	5	45	0.75	289	103	37	42
77/285	13.31	399.2	26.9	535	3.04	60	5	45	0.75	288	94	35	40
77/285	13.47	398.7	27.2	529	2.83	60	5	45	0.75	286	89	34	39
77/285	13.64	398.2	27.5	525	2.63	60	5	45	0.75	285	83	32	38
77/285	13.81	398.6	26.5	522	2.39	60	5	45	0.75	274	73	30	37
77/285	13.97	397.9	24.7	516	2.21	60	5	45	0.75	257	63	28	36
77/285	14.14	397.1	22.4	509	2.00	60	5	45	0.75	243	51	25	33
77/285	14.31	396.4	19.9	506	1.85	60	5	45	0.75	228	42	22	31
77/285	14.47	394.0	20.6	497	1.30	60	5	45	0.75	219	31	17	26
77/285	14.64	391.1	21.5	485	1.28	60	5	45	0.75	201	31	20	31
77/285	14.81	389.5	16.0	473	1.26	60	5	45	0.75	200	23	15	27
77/285	14.97	386.7	13.4	460	1.25	60	5	45	0.75	206	19	13	24
77/286	11.36	319.2	10.8	201	6.57	80	8	112	0.82	299	83	28	30
77/286	11.53	347.9	15.8	226	4.66	80	8	112	0.82	299	86	29	30
77/286	11.69	373.5	20.6	282	3.58	80	8	112	0.82	301	85	28	29
77/286	11.86	399.5	21.9	364	3.04	80	8	112	0.82	302	77	25	26
77/286	12.03	422.5	26.3	463	2.96	80	8	112	0.82	301	90	30	30
77/286	12.19	426.5	39.0	567	4.14	80	8	112	0.82	300	186	63	64
77/286	12.36	441.8	30.6	613	3.80	80	8	112	0.82	301	134	45	47
77/286	12.53	451.5	25.7	651	3.57	80	8	112	0.82	299	106	36	38
77/286	12.69	458.3	25.7	684	3.52	80	8	112	0.82	300	104	36	38
77/286	12.86	464.9	27.1	721	3.47	80	8	112	0.82	299	109	37	41
77/286	13.03	471.2	27.1	755	3.37	80	8	112	0.82	297	106	37	41
77/286	13.19	474.2	29.2	766	3.18	80	8	112	0.82	297	107	38	43
77/286	13.36	474.0	27.9	762	3.30	80	8	112	0.82	295	107	39	44
77/286	13.53	472.0	29.1	745	3.21	80	8	112	0.82	295	108	40	47
77/286	13.69	470.6	27.5	730	3.10	80	8	112	0.82	295	99	37	45
77/286	13.86	469.9	27.3	718	2.84	80	8	112	0.82	292	90	35	43
77/286	14.03	468.8	26.2	704	2.46	80	8	112	0.82	290	74	30	38
77/286	14.19	467.4	27.5	694	2.18	80	8	112	0.82	289	69	29	38
77/286	14.36	466.7	25.4	746	2.19	80	8	112	0.82	287	64	27	38
77/286	14.53	465.1	24.9	726	2.01	80	8	112	0.82	285	58	26	37
77/286	14.69	462.6	25.5	705	1.86	80	8	112	0.82	282	55	25	38
77/286	14.86	459.1	23.4	683	1.71	80	8	112	0.82	280	46	22	35
77/286	15.03	453.0	26.5	658	1.24	80	8	112	0.82	277	38	19	33

DATE	SOLAR TIME	INLET TEMP.	TEMP. DIFF.	PRESSURE	FLOW RATE	AMBIENT TEMP.	WIND SPEED	WIND DIR.	REFLEC-TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
(YEAR/DAY)	(DEC.HRS.)	(F)	(F)	(PSI)	(GPM)	(F)	(MPH)	(DEG.)		(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/287	9.99	357.3	11.0	299	3.53	70	10	180	0.82	283	45	18	24
77/287	10.16	382.3	13.0	326	1.97	70	10	180	0.82	263	29	12	17
77/287	10.33	394.3	27.3	372	1.77	70	10	180	0.82	285	56	21	26
77/287	10.49	412.3	27.1	428	1.35	70	10	180	0.82	279	42	16	20
77/287	10.66	386.8	70.1	600	1.94	70	10	180	0.82	287	157	59	66
77/287	10.83	408.4	28.3	629	1.94	70	10	180	0.82	289	63	23	26
77/287	10.99	414.1	42.5	631	1.95	70	10	180	0.82	288	95	35	38
77/287	11.16	419.2	42.4	636	2.29	70	10	180	0.82	289	112	40	43
77/287	11.33	409.5	38.9	595	3.57	70	10	180	0.82	289	160	57	60
77/287	11.49	397.2	32.9	554	4.31	70	10	180	0.82	289	164	58	60
77/287	11.66	393.3	29.6	530	4.23	70	10	180	0.82	289	145	51	52
77/287	11.83	397.5	29.2	518	3.85	70	10	180	0.82	289	130	45	46
77/287	11.99	398.4	31.2	508	4.01	70	10	180	0.82	289	144	50	50
77/290	10.64	350.6	19.8	284	2.60	79	10	180	0.82	275	60	23	27
77/290	10.81	373.1	19.0	335	2.65	79	10	180	0.82	277	58	22	25
77/290	10.98	395.8	22.6	385	2.04	79	10	180	0.82	278	53	20	22
77/290	11.14	394.3	49.0	428	2.05	79	10	180	0.82	280	116	43	46
77/290	11.31	393.8	47.4	506	3.31	79	10	180	0.82	279	181	67	71
77/290	11.48	396.3	34.7	497	3.37	79	10	180	0.82	271	135	51	53
77/290	11.64	395.3	31.2	497	3.59	79	10	180	0.82	279	129	47	48
77/290	11.81	397.0	30.7	498	3.66	79	10	180	0.82	281	130	47	47
77/290	11.98	397.6	30.1	493	3.73	79	10	180	0.82	280	130	47	47
77/290	12.14	399.0	28.8	456	3.71	79	10	180	0.82	279	123	45	45
77/290	12.31	400.6	30.5	493	3.65	79	10	180	0.82	280	129	46	48
77/290	12.48	395.0	29.0	476	3.89	79	10	180	0.82	280	130	47	49
77/290	12.64	393.6	29.1	467	3.89	79	10	180	0.82	278	131	48	51
77/290	12.81	395.4	27.1	472	3.45	79	10	180	0.82	279	108	40	43
77/290	12.98	400.7	25.9	473	3.16	79	10	180	0.82	278	94	35	39
77/290	13.14	401.9	26.3	471	3.02	79	10	180	0.82	276	92	35	39
77/290	13.31	402.1	25.3	471	2.98	79	10	180	0.82	275	87	34	38
77/290	13.48	402.0	26.1	468	2.74	79	10	180	0.82	273	82	33	38
77/290	13.64	401.0	27.8	462	2.65	79	10	180	0.82	272	85	34	41
77/290	13.81	399.8	26.1	457	2.54	79	10	180	0.82	272	76	32	39
77/290	13.98	398.3	26.4	453	2.33	79	10	180	0.82	270	71	30	38
77/290	14.14	397.5	26.6	448	2.15	79	10	180	0.82	267	66	29	38
77/290	14.31	396.9	24.4	444	1.97	79	10	180	0.82	247	55	27	37
77/290	14.48	396.1	18.8	439	1.80	79	10	180	0.82	259	39	19	27
77/290	14.64	395.1	21.2	437	1.69	79	10	180	0.82	257	41	21	31
77/290	14.81	392.9	21.4	431	1.26	79	10	180	0.82	245	31	17	27
77/290	14.98	391.5	17.7	422	1.27	79	10	180	0.82	151	26	24	42
77/291	9.48	345.9	8.3	226	2.80	80	4	225	0.81	257	27	13	19
77/291	9.64	361.1	6.7	262	2.81	80	4	225	0.81	261	21	10	15
77/291	9.81	376.2	10.1	302	2.82	80	4	225	0.81	263	33	15	20
77/291	9.98	391.9	9.6	348	2.83	80	4	225	0.81	266	31	13	18
77/291	10.14	406.7	12.2	401	2.83	80	4	225	0.81	267	40	17	21
77/291	10.31	422.9	12.1	458	2.85	80	4	225	0.81	268	39	16	20
77/291	10.48	437.7	13.6	524	2.86	80	4	225	0.81	268	45	18	22
77/291	10.64	453.5	13.8	595	2.89	80	4	225	0.81	270	46	18	21
77/2	10.81	468.0	14.8	671	2.92	80		225	0.81	269	50	19	23
77/2	10.98	482.9	15.2	753	2.92	80		225	0.81	271	51	20	22
77/2	11.14	497.7	16.0	837	2.87	80		225	0.81	271	53	20	22

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
										(BTU/HR./SQ.FT.)			
77/293	11.00	412.5	8.1	557	6.62	85	8	135	0.81	60	62	107	119
77/293	11.16	428.1	2.3	618	6.67	85	8	135	0.81	6	17	273	323
77/293	11.33	441.7	9.8	704	6.67	85	8	135	0.81	270	75	28	30
77/293	11.50	436.5	6.4	716	6.59	85	8	135	0.81	1	48	2516	2672
77/293	11.66	436.0	12.5	713	6.63	85	8	135	0.81	266	95	36	37
77/293	11.83	441.9	12.8	734	6.62	85	8	135	0.81	266	98	37	38
77/293	12.00	448.1	13.6	768	6.57	85	8	135	0.81	270	103	38	38
77/293	12.16	454.6	13.5	800	6.62	85	8	135	0.81	267	103	39	39
77/293	12.33	460.4	12.8	821	6.56	85	8	135	0.81	263	97	37	38
77/293	12.50	461.3	14.2	812	6.61	85	8	135	0.81	269	108	41	43
77/293	12.66	466.1	12.5	822	6.59	85	8	135	0.81	271	95	36	38
77/293	12.83	468.3	15.9	827	4.76	85	8	135	0.81	264	87	34	37
77/293	13.00	469.9	18.0	831	3.92	85	8	135	0.81	262	81	32	36
77/293	13.16	470.7	20.6	837	3.47	85	8	135	0.81	262	82	33	38
77/293	13.33	472.2	19.8	835	3.08	85	8	135	0.81	200	70	38	44
77/293	13.50	471.9	21.6	832	2.83	85	8	135	0.81	263	70	29	35
77/293	13.66	471.6	17.7	801	2.39	85	8	135	0.81	13	49	418	523
77/293	13.83	465.6	24.9	783	2.08	85	8	135	0.81	250	60	27	34
77/293	14.00	463.5	22.7	761	2.08	85	8	135	0.81	244	54	26	33
77/293	14.16	462.6	19.9	735	1.94	85	8	135	0.81	242	44	22	30
77/293	14.33	459.0	20.7	710	1.87	85	8	135	0.81	234	44	23	33
77/293	14.50	455.6	15.7	674	1.60	85	8	135	0.81	0	29	*****	*****
77/293	14.66	448.1	3.2	640	1.34	85	8	135	0.81	95	4	6	22
77/293	14.83	438.1	10.4	610	1.36	85	8	135	0.81	224	16	9	19
77/293	15.00	434.2	14.8	598	1.32	85	8	135	0.81	229	22	13	26
77/298	11.39	436.3	21.0	738	4.38	80	0	0	0.80	272	106	40	42
77/298	11.55	436.8	23.8	740	3.64	80	0	0	0.80	271	100	37	39
77/298	11.72	437.4	27.2	742	3.46	80	0	0	0.80	272	108	40	41
77/298	11.89	437.7	27.2	738	3.48	80	0	0	0.80	267	109	41	42
77/298	12.05	437.0	29.9	738	3.12	80	0	0	0.80	276	107	39	39
77/298	12.14	438.1	21.1	731	2.54	80	0	0	0.80	0	61	*****	*****
77/298	12.22	436.9	0.4	716	1.98	80	0	0	0.80	0	0	*****	*****
77/298	12.30	433.3	-3.3	700	1.34	80	0	0	0.80	0	-5	*****	*****
77/298	12.39	426.9	6.1	695	1.37	80	0	0	0.80	266	9	3	4
77/298	12.47	421.3	35.2	700	1.33	80	0	0	0.80	266	54	20	21
77/298	12.55	418.0	59.5	711	1.78	80	0	0	0.80	259	122	48	50
77/298	12.64	419.7	56.4	721	1.87	80	0	0	0.80	264	121	47	50
77/298	12.72	422.8	41.9	725	2.06	80	0	0	0.80	265	99	38	41
77/298	12.80	430.9	29.9	725	2.06	80	0	0	0.80	248	71	29	32
77/298	12.89	434.5	27.5	729	2.00	80	0	0	0.80	241	63	27	30
77/298	12.97	436.4	31.0	730	1.94	80	0	0	0.80	137	69	53	58
77/298	13.05	436.5	31.1	731	1.96	80	0	0	0.80	184	70	40	44
77/298	13.14	436.4	35.6	735	1.99	80	0	0	0.80	265	81	32	36
77/298	13.22	436.5	37.5	736	2.04	80	0	0	0.80	265	88	35	40
77/298	13.30	436.6	37.2	736	2.04	80	0	0	0.80	265	87	35	40
77/298	13.39	437.0	33.5	725	2.12	80	0	0	0.80	90	82	98	113
77/298	13.47	437.1	22.8	722	2.05	80	0	0	0.80	269	54	22	26
77/298	13.55	437.1	30.2	722	2.00	80	0	0	0.80	251	69	30	36
77/298	13.64	437.5	18.6	706	1.90	80	0	0	0.80	244	40	18	23
77/298	13.72	436.3	12.5	707	1.42	80	0	0	0.80	264	20	8	11
77/298	13.80	433.2	31.8	708	1.37	80	0	0	0.80	265	50	21	26

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/298	13.89	432.3	41.4	715	1.68	80	0	0	0.80	264	80	35	42
77/298	13.97	432.8	35.5	712	1.73	80	0	0	0.80	263	71	31	39
77/298	14.05	433.1	20.4	693	1.33	80	0	0	0.80	0	31	*****	*****
77/298	14.14	432.0	4.8	684	1.37	80	0	0	0.80	202	7	4	8
77/298	14.22	431.5	7.1	679	1.36	80	0	0	0.80	261	11	5	9
77/298	14.30	427.5	25.7	676	1.34	80	0	0	0.80	262	39	18	25
77/298	14.39	424.3	35.2	673	1.29	80	0	0	0.80	259	52	25	34
77/298	14.47	423.0	35.9	670	1.28	80	0	0	0.80	257	53	26	35
77/298	14.55	422.3	33.8	669	1.28	80	0	0	0.80	252	50	25	35
77/298	14.64	423.1	29.9	665	1.29	80	0	0	0.80	249	44	23	33
77/298	14.72	425.6	24.5	661	1.30	80	0	0	0.80	252	36	19	29
77/298	14.80	427.1	21.4	655	1.29	80	0	0	0.80	249	31	17	27
77/298	14.89	426.6	21.1	648	1.28	80	0	0	0.80	248	31	17	28
77/298	14.97	425.4	21.5	643	1.27	80	0	0	0.80	245	31	18	29
77/298	15.05	424.3	21.8	635	1.27	80	0	0	0.80	237	32	19	32
77/298	15.14	423.4	20.5	628	1.26	80	0	0	0.80	233	29	18	32
77/298	15.22	422.6	18.3	620	1.28	80	0	0	0.80	232	27	17	31
77/298	15.30	421.5	15.8	612	1.28	80	0	0	0.80	234	23	15	29
77/298	15.39	420.3	13.6	603	1.28	80	0	0	0.80	228	20	13	28
77/298	15.47	418.5	12.5	594	1.28	80	0	0	0.80	214	18	13	30
77/298	15.55	416.5	10.5	584	1.26	80	0	0	0.80	204	15	12	30
77/298	15.64	414.3	7.8	574	1.26	80	0	0	0.80	173	11	11	32
77/298	15.72	414.0	1.6	774	2.06	80	0	0	0.80	180	3	3	21
77/299	7.72	376.7	-14.1	485	2.16	80	5	180	0.79	200	-35	-38	*****
77/299	8.22	390.7	-3.9	536	2.18	80	5	180	0.79	240	-9	-7	1
77/299	8.72	415.1	1.2	629	2.20	80	5	180	0.79	251	3	1	10
77/299	9.06	433.0	5.4	722	2.20	80	5	180	0.79	258	13	7	15
77/299	9.22	442.8	6.7	777	2.22	80	5	180	0.79	262	17	8	16
77/299	9.39	453.0	8.3	838	2.20	80	5	180	0.79	264	21	10	17
77/299	9.56	462.9	10.0	902	2.22	80	5	180	0.79	267	25	12	18
77/299	9.72	441.0	27.5	890	2.23	80	5	180	0.79	269	70	32	42
77/299	9.89	438.9	27.0	877	2.00	80	5	180	0.79	271	62	27	35
77/299	10.06	437.3	30.5	867	1.89	80	5	180	0.79	272	66	28	35
77/299	10.22	436.8	32.0	859	1.87	80	5	180	0.79	275	69	28	34
77/299	10.39	436.8	35.1	855	1.86	80	5	180	0.79	275	75	30	36
77/299	10.56	437.5	37.4	866	1.86	80	5	180	0.79	276	80	31	36
77/299	10.72	439.7	38.6	864	1.77	80	5	180	0.79	277	78	30	35
77/299	10.89	439.9	41.0	858	2.30	80	5	180	0.79	278	109	41	46
77/299	11.06	441.5	28.1	839	3.31	80	5	180	0.79	278	107	40	44
77/299	11.22	442.3	25.5	835	3.50	80	5	180	0.79	278	103	38	41
77/299	11.39	444.1	25.4	840	3.45	80	5	180	0.79	280	101	37	39
77/299	11.56	440.0	29.6	825	3.88	80	5	180	0.79	280	132	48	50
77/299	11.72	439.6	23.8	817	3.83	80	5	180	0.79	280	105	38	39
77/299	11.89	441.6	26.0	819	3.82	80	5	180	0.79	279	114	41	42
77/299	12.06	441.9	26.4	817	3.80	80	5	180	0.79	278	116	42	42
77/299	12.22	442.1	26.2	814	3.76	80	5	180	0.79	281	113	41	42
77/299	12.39	443.3	25.8	816	3.66	80	5	180	0.79	280	109	39	41
77/299	12.56	444.1	26.6	818	3.45	80	5	180	0.79	280	106	39	41
77/299	12.72	438.7	29.7	801	3.79	80	5	180	0.79	276	130	48	51
77/299	12.89	438.7	25.3	798	3.41	80	5	180	0.79	276	99	37	
77/299	13.06	439.7	27.0	798	3.05	80	5	180	0.79	276	95	36	

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLECTIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/299	13.22	440.0	26.8	794	3.02	80	5	180	0.79	274	93	36	41
77/299	13.39	439.5	26.7	790	2.87	80	5	180	0.79	275	88	35	40
77/299	13.56	438.8	27.9	784	2.67	80	5	180	0.79	275	86	34	40
77/299	13.72	438.5	27.3	779	2.52	80	5	180	0.79	274	79	32	39
77/299	13.89	438.0	26.7	775	2.31	80	5	180	0.79	271	71	30	37
77/299	14.06	437.3	25.4	771	2.17	80	5	180	0.79	269	63	27	35
77/299	14.22	436.5	24.9	766	2.01	80	5	180	0.79	266	57	26	34
77/299	14.39	435.7	22.6	758	1.89	80	5	180	0.79	264	49	23	32
77/299	14.56	434.1	23.1	750	1.69	80	5	180	0.79	261	45	22	31
77/299	14.72	429.8	27.3	738	1.31	80	5	180	0.79	265	41	20	31
77/299	14.89	427.5	24.3	726	1.28	80	5	180	0.79	256	35	19	31
77/299	15.06	426.7	20.3	713	1.25	80	5	180	0.79	256	29	16	28
77/299	15.22	424.1	19.3	696	1.25	80	5	180	0.79	253	27	16	30
77/299	15.39	421.3	15.2	678	1.25	80	5	180	0.79	247	21	13	29
77/307	9.15	381.0	3.1	535	3.92	55	10	330	0.77	266	14	7	13
77/307	9.65	416.1	5.6	667	3.94	55	10	330	0.77	275	25	11	17
77/307	10.15	456.4	9.7	844	2.02	55	10	330	0.77	223	22	11	16
77/307	10.65	476.6	-22.2	856	1.36	55	10	330	0.77	3	-34	-1058	*****
77/307	10.75	462.9	-4.6	853	2.45	55	10	330	0.77	267	-13	-5	*****
77/307	10.84	461.7	19.1	870	2.41	55	10	330	0.77	82	53	69	79
77/307	10.92	463.1	-2.0	893	2.44	55	10	330	0.77	1	-5	-301	*****
77/307	11.00	472.1	-19.3	891	2.44	55	10	330	0.77	25	-54	-229	*****
77/307	11.09	470.9	-14.6	880	2.43	55	10	330	0.77	12	-41	-349	*****
77/307	11.17	468.8	-6.9	877	2.47	55	10	330	0.77	219	-19	-9	*****
77/307	11.25	468.5	12.9	889	2.43	55	10	330	0.77	79	36	47	53
77/307	11.34	469.3	-0.8	910	2.44	55	10	330	0.77	112	-2	-2	*****
77/307	11.42	476.1	-11.4	912	2.45	55	10	330	0.77	156	-32	-21	*****
77/307	11.50	477.9	-1.2	918	2.45	55	10	330	0.77	283	-3	-1	*****
77/307	11.67	479.1	-8.6	935	2.45	55	10	330	0.77	124	-24	-20	*****
77/307	11.75	482.6	-3.3	932	2.43	55	10	330	0.77	115	-9	-8	*****
77/307	11.84	482.5	-2.9	932	2.41	55	10	330	0.77	16	-8	-50	*****
77/307	11.90	483.2	-8.8	931	2.42	55	10	330	0.77	20	-24	-124	*****
77/307	12.07	485.1	24.1	885	2.11	55	10	330	0.77	282	59	21	21
77/307	12.24	464.7	13.3	878	2.18	55	10	330	0.77	283	33	12	12
77/307	12.40	464.1	0.7	836	1.47	60	15	330	0.77	45	1	2	5
77/307	12.57	451.0	4.3	796	1.36	60	15	330	0.77	283	6	2	3
77/307	12.74	439.9	40.6	776	1.25	60	15	330	0.77	78	58	77	84
77/307	12.90	473.5	-41.9	751	2.30	60	15	330	0.77	1	-111	-9802	*****
77/307	13.07	463.3	-9.6	724	2.27	60	15	330	0.77	0	-25	*****	*****
77/307	13.24	463.2	-16.9	702	2.24	60	15	330	0.77	7	-43	-591	*****
77/307	13.40	461.3	-14.7	684	2.28	60	15	330	0.77	140	-38	-30	*****
77/307	13.57	460.9	-8.7	667	2.25	60	15	330	0.77	2	-22	-1053	*****
77/307	13.74	462.7	-14.5	655	2.27	60	15	330	0.77	8	-38	-492	*****
77/307	13.90	461.1	-14.0	642	2.26	60	15	330	0.77	0	-36	*****	*****
77/307	14.07	458.7	-15.5	629	2.28	60	15	330	0.77	75	-40	-63	*****
77/307	14.24	456.4	-16.6	616	2.28	60	15	330	0.77	0	-43	*****	*****
77/307	14.40	453.4	-17.1	601	2.27	60	15	330	0.77	0	-44	*****	*****
77/307	14.57	450.6	-16.3	587	2.24	60	15	330	0.77	67	-42	-80	*****
77/307	14.74	448.3	-16.4	575	2.24	60	15	330	0.77	0	-42	*****	*****
77/307	14.90	446.1	-16.4	562	2.24	60	15	330	0.77	0	-42	*****	*****
77/307	15.07	443.9	-15.6	552	2.25	60	15	330	0.77	0	-40	*****	*****

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION (BTU/HR./SQ.FT.)	COLLECTION RATE (BTU/HR./SQ.FT.)	EFFICIENCY SINGLE MODULE	EFFICIENCY WITHOUT END LOSS
77/307	15.24	442.2	-15.9	543	2.25	60	15	330	0.77	0	-41	*****	*****
77/307	15.40	440.5	-15.7	535	2.26	60	15	330	0.77	0	-41	*****	*****
77/307	15.57	438.9	-15.3	527	2.25	60	15	330	0.77	0	-39	*****	*****
77/308	9.99	356.0	6.2	156	3.01	65	10	360	0.79	243	21	10	14
77/308	10.15	371.5	8.2	227	3.00	65	10	360	0.79	244	28	13	17
77/308	10.32	387.6	6.5	260	3.01	65	10	360	0.79	242	22	10	13
77/308	10.49	399.5	10.6	370	3.07	65	10	360	0.79	241	37	17	21
77/308	10.65	417.3	4.2	396	3.11	65	10	360	0.79	244	15	6	8
77/308	10.82	428.6	1.7	429	3.10	65	10	360	0.79	249	6	2	4
77/308	10.99	437.9	13.3	468	3.07	65	10	360	0.79	213	47	23	26
77/308	11.15	456.3	7.5	529	2.18	65	10	360	0.79	256	18	7	9
77/308	11.32	464.3	19.6	695	1.89	65	10	360	0.79	257	42	17	18
77/308	11.49	480.4	18.3	768	1.39	65	10	360	0.79	256	29	11	12
77/308	11.65	495.5	20.8	848	1.40	70	10	360	0.79	264	34	13	13
77/308	11.82	455.7	75.5	917	1.63	70	10	360	0.79	259	142	56	57
77/308	11.99	479.3	14.6	900	2.26	70	10	360	0.79	264	38	14	14
77/308	12.15	476.9	29.7	875	2.39	70	10	360	0.79	258	82	32	33
77/308	12.32	479.2	25.2	868	2.40	70	10	360	0.79	265	70	27	28
77/308	12.49	479.0	26.7	865	2.34	70	10	360	0.79	256	72	29	30
77/308	12.65	479.6	26.1	865	2.37	70	10	360	0.79	259	71	28	30
77/308	12.82	480.1	24.5	859	2.31	70	10	360	0.79	226	65	30	33
77/308	12.99	478.6	22.8	846	2.15	70	10	360	0.79	258	56	23	26
77/308	13.15	476.2	25.7	834	2.08	70	10	360	0.79	257	62	25	29
77/308	13.32	475.1	24.1	821	2.04	70	10	360	0.79	251	57	24	28
77/308	13.49	473.1	14.3	794	1.92	70	10	360	0.79	247	31	14	17
77/308	13.65	464.3	19.4	761	1.36	70	10	360	0.79	234	30	14	19
77/308	13.82	456.8	31.2	740	1.35	70	10	360	0.79	248	48	22	28
77/308	13.99	453.9	27.1	716	1.29	70	10	360	0.79	15	40	297	396
77/308	14.15	451.9	14.0	686	1.34	70	10	360	0.79	234	21	11	16
77/308	14.32	444.9	13.7	650	1.35	70	10	360	0.79	241	21	10	17
77/308	14.49	438.2	10.0	616	1.34	70	10	360	0.79	233	15	8	14
77/308	14.65	430.5	7.8	578	1.32	70	10	360	0.79	227	11	6	13
77/308	14.82	422.0	16.0	549	1.29	70	10	360	0.79	237	23	13	23
77/308	14.99	416.1	15.5	523	1.29	70	10	360	0.79	229	23	14	25
77/308	15.15	411.4	12.3	496	1.28	70	10	360	0.79	217	18	12	24
77/308	15.32	405.6	9.9	470	1.27	70	10	360	0.79	209	14	10	24
77/308	15.49	399.2	6.9	446	1.27	70	10	360	0.79	204	10	7	22
77/308	15.65	392.2	7.1	423	1.24	70	10	360	0.79	187	10	9	28
77/313	10.47	444.1	13.4	599	2.71	50	17	0	0.82	301	42	15	18
77/313	10.63	458.6	7.9	656	2.78	50	17	0	0.82	297	25	9	11
77/313	10.80	469.0	13.7	725	2.37	50	17	0	0.82	299	37	13	16
77/313	10.97	482.0	17.7	804	1.97	50	17	0	0.82	300	40	14	16
77/313	11.13	492.2	24.7	908	1.79	50	17	0	0.82	299	51	18	20
77/313	11.30	507.3	23.8	953	1.34	50	17	0	0.82	300	37	12	14
77/313	11.47	478.9	19.5	864	2.06	50	17	0	0.82	301	64	22	23
77/313	11.63	476.9	33.2	822	2.11	50	17	0	0.82	302	81	27	28
77/313	11.80	478.3	31.4	943	2.54	50	17	0	0.82	301	92	31	32
77/313	11.97	483.0	30.4	867	2.32	50	17	0	0.82	302	82	27	27
77/313	12.13	482.5	31.6	837	2.31	50	17	0	0.82	301	85	28	29
77/313	12.30	485.3	31.1	855	2.32	50	1	0	0.82	299	84	28	[illegible]
77/313	12.47	487.0	29.2	846	2.26	50	1	0	0.82	297	76	26	[illegible]

DATE	SOLAR TIME	INLET TEMP.	TEMP. DIFF.	PRESSURE	FLOW RATE	AMBIENT TEMP.	WIND SPEED	WIND DIR.	REFLECTIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
(YEAR/DAY)	(DEC.HRS.)	(F)	(F)	(PSI)	(GPM)	(F)	(MPH)	(DEG.)		(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/313	12.63	487.6	31.9	908	2.32	50	17	0	0.82	297	86	30	32
77/313	12.80	485.3	32.4	845	1.95	50	17	0	0.82	295	73	26	28
77/313	12.97	475.6	32.4	841	2.66	50	17	0	0.82	294	100	35	39
77/313	13.13	469.0	25.0	752	2.31	50	17	0	0.82	294	67	24	27
77/313	13.30	467.1	26.8	702	1.87	50	17	0	0.82	295	58	21	24
77/313	13.47	466.0	26.8	730	1.93	50	17	0	0.82	292	60	22	26
77/313	13.63	463.8	28.1	777	1.84	50	17	0	0.82	290	59	23	28
77/313	13.80	462.2	24.1	709	1.70	50	17	0	0.82	289	47	18	23
77/313	13.97	455.1	28.5	660	1.18	50	17	0	0.82	285	38	15	21
77/313	14.13	449.3	31.6	700	1.27	50	17	0	0.82	282	46	19	26
77/313	14.30	447.6	22.5	628	1.16	50	17	0	0.82	279	30	13	19
77/313	14.47	447.2	14.3	671	1.70	50	17	0	0.82	277	28	12	19
77/313	14.63	440.6	15.0	596	1.62	50	17	0	0.82	278	28	13	21
77/313	14.80	434.3	14.9	535	1.49	50	17	0	0.82	271	25	12	21
77/313	14.97	428.5	10.2	476	1.50	50	17	0	0.82	266	17	9	18
77/316	10.40	194.8	5.5	108	6.26	70	8	250	0.79	296	41	15	18
77/316	10.57	223.2	6.7	118	6.38	70	8	250	0.79	298	51	18	21
77/316	10.73	249.7	6.8	128	6.41	70	8	250	0.79	299	52	18	21
77/316	10.90	275.7	7.5	143	6.50	70	8	250	0.79	300	57	20	22
77/316	11.07	301.4	8.6	165	6.60	70	8	250	0.79	301	66	23	25
77/316	11.23	325.9	9.2	191	6.66	70	8	250	0.79	301	71	24	26
77/316	11.40	352.3	8.7	230	6.66	70	8	250	0.79	302	67	23	24
77/316	11.57	376.1	9.9	265	6.71	70	8	250	0.79	301	77	26	27
77/316	11.73	400.4	10.1	358	6.71	70	8	250	0.79	300	78	26	27
77/316	11.90	422.5	10.2	444	6.72	70	8	250	0.79	301	79	27	27
77/316	12.07	444.2	10.2	541	6.74	70	8	250	0.79	299	79	27	27
77/316	12.23	466.5	12.2	591	3.60	70	8	250	0.79	299	50	17	17
77/316	12.40	483.2	19.4	781	3.66	70	8	250	0.79	299	82	28	29
77/316	12.57	499.5	15.9	904	3.69	70	8	250	0.79	298	68	23	25
77/316	12.73	507.9	24.6	949	2.66	70	8	250	0.79	298	76	26	29
77/316	12.90	484.7	37.1	906	2.67	70	8	250	0.79	299	115	40	44
77/320	8.83	380.5	1.8	561	1.94	75	3	270	0.79	232	4	2	9
77/320	9.00	388.4	2.9	554	1.96	75	3	270	0.79	238	6	3	10
77/320	9.16	397.8	3.5	630	1.96	75	3	270	0.79	243	7	4	10
77/320	9.33	407.4	5.3	526	1.86	75	3	270	0.79	248	11	5	11
77/320	9.50	414.8	9.7	576	1.88	75	3	270	0.79	252	21	10	16
77/320	9.66	424.5	9.3	562	1.88	75	3	270	0.79	256	20	9	14
77/320	9.83	434.7	10.1	604	1.87	75	3	270	0.79	260	21	10	14
77/320	10.00	406.2	48.9	623	1.83	75	3	270	0.79	264	103	45	55
77/320	10.16	414.5	21.2	623	1.87	75	3	270	0.79	267	45	19	24
77/320	10.33	415.5	27.4	603	1.87	75	3	270	0.79	269	59	24	29
77/320	10.50	414.2	32.1	556	1.82	75	3	270	0.79	271	67	27	32
77/320	10.66	415.7	32.3	594	1.79	75	3	270	0.79	273	66	26	30
77/320	10.83	417.8	33.9	595	1.81	75	3	270	0.79	275	71	27	31
77/320	11.00	420.2	36.9	592	1.80	75	3	270	0.79	276	76	29	32
77/320	11.16	413.4	44.9	570	2.23	75	3	270	0.79	276	115	43	47
77/320	11.33	413.1	31.4	542	3.09	75	3	270	0.79	279	112	41	44
77/320	11.50	408.9	27.4	517	3.57	75	3	270	0.79	281	113	41	43
77/320	11.66	408.5	24.6	500	3.45	75	3	270	0.79	282	98	35	36
77/320	11.83	410.8	24.9	486	3.45	75	3	270	0.79	280	99	36	37
77/320	12.00	411.2	26.9	556	3.74	75	3	270	0.79	282	116	42	42

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC-TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY SINGLE MODULE	WITHOUT END LOSS
										(BTU/HR./SQ.FT.)			
77/320	12.16	409.6	24.5	574	3.89	75	3	270	0.79	280	110	40	40
77/320	12.33	410.3	24.9	561	3.90	75	3	270	0.79	286	112	40	41
77/320	12.50	410.2	24.6	550	3.73	75	3	270	0.79	286	106	38	40
77/320	12.66	409.8	25.4	543	3.66	75	3	270	0.79	284	107	39	41
77/320	12.83	409.9	24.4	533	3.44	75	3	270	0.79	283	97	36	38
77/320	13.00	409.1	24.7	524	3.21	75	3	270	0.79	280	91	34	37
77/320	13.16	408.0	25.9	516	3.00	75	3	270	0.79	276	90	34	38
77/320	13.33	407.9	25.4	508	2.71	75	3	270	0.79	276	79	31	35
77/320	13.50	407.0	25.9	500	2.62	75	3	270	0.79	275	78	31	36
77/320	13.66	407.0	26.0	492	2.54	75	3	270	0.79	270	76	31	37
77/320	13.83	406.7	25.0	483	2.45	75	3	270	0.79	268	70	30	36
77/320	14.00	405.3	21.8	474	2.21	75	3	270	0.79	263	55	24	31
77/320	14.16	405.0	21.7	465	2.08	75	3	270	0.79	263	52	23	30
77/320	14.33	404.2	21.3	457	1.93	75	3	270	0.79	262	47	22	29
77/320	14.50	403.9	19.8	448	1.84	75	3	270	0.79	259	42	20	28
77/320	14.66	401.5	21.2	438	1.35	75	3	270	0.79	255	33	16	25
77/320	14.83	397.9	24.8	428	1.33	75	3	270	0.79	252	38	20	30
77/320	15.00	397.9	19.1	419	1.34	75	3	270	0.79	245	29	16	27
77/320	15.16	396.6	17.9	406	1.31	75	3	270	0.79	238	27	16	28
77/320	15.33	394.3	16.8	392	1.30	75	3	270	0.79	234	25	16	29
77/320	15.50	390.9	12.0	377	1.29	75	3	270	0.79	227	17	12	26
77/320	15.66	388.0	11.5	363	1.26	75	3	270	0.79	221	16	12	28
77/320	15.83	384.7	9.1	348	1.26	75	3	270	0.79	212	13	10	29
77/321	10.46	357.3	8.7	198	2.26	65	9	45	0.79	271	22	9	11
77/321	10.63	352.8	33.9	334	2.01	65	9	45	0.79	271	79	31	36
77/321	10.79	349.4	32.0	361	2.09	65	9	45	0.79	273	78	30	34
77/321	10.96	359.2	28.2	368	1.94	65	9	45	0.79	274	63	24	27
77/321	11.13	355.7	40.6	362	2.04	65	9	45	0.79	274	96	36	39
77/321	11.29	353.3	38.0	351	2.33	65	9	45	0.79	274	103	39	41
77/321	11.46	351.4	35.5	339	2.66	65	9	45	0.79	276	110	41	43
77/321	11.63	348.1	31.2	327	2.90	65	9	45	0.79	275	105	39	40
77/321	11.79	346.0	28.3	318	3.02	65	9	45	0.79	276	99	37	37
77/321	11.96	346.5	30.0	312	3.04	65	9	45	0.79	276	106	39	39
77/321	12.13	347.3	29.0	309	3.04	65	9	45	0.79	275	102	38	38
77/321	12.29	347.8	26.2	307	2.96	65	9	45	0.79	276	90	33	34
77/321	12.46	348.8	29.3	306	2.86	65	9	45	0.79	272	97	37	38
77/321	12.63	348.8	29.5	304	2.79	65	9	45	0.79	274	96	36	38
77/321	12.79	348.4	28.4	300	2.62	65	9	45	0.79	226	86	40	43
77/321	12.96	347.0	26.7	296	2.37	65	9	45	0.79	242	73	32	35
77/321	13.13	346.0	27.9	293	2.28	65	9	45	0.79	242	74	32	36
77/321	13.29	346.7	29.6	295	2.18	65	9	45	0.79	271	75	30	33
77/321	13.46	349.2	25.9	296	2.06	65	9	45	0.79	259	62	26	30
77/321	13.63	349.4	25.4	294	1.92	65	9	45	0.79	220	56	28	34
77/321	13.79	348.9	24.6	292	1.84	65	9	45	0.79	246	52	24	29
77/321	13.96	347.1	22.6	288	1.39	65	9	45	0.79	232	36	18	23
77/321	14.13	344.9	24.9	284	1.34	65	9	45	0.79	145	38	31	41
77/327	9.63	380.6	8.0	371	6.65	70	4	240	0.73	248	61	30	40
77/327	9.80	376.4	12.1	428	3.32	70	4	240	0.73	254	46	22	28
77/327	9.96	372.9	21.2	428	2.25	70	4	240	0.73	255	55	25	31
77/327	10.13	372.7	24.0	431	2.02	70		240	0.73	261	56	24	[illegible]
77/327	10.30	373.9	26.9	434	1.91	70		240	0.73	263	59	25	[illegible]

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC- TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/327	10.46	375.2	30.2	440	1.84	70	4	240	0.73	266	64	26	31
77/327	10.51	375.9	30.7	442	1.80	70	4	240	0.73	268	64	26	30
77/327	10.68	378.4	33.1	450	1.69	70	4	240	0.73	267	64	26	30
77/327	10.85	381.5	35.2	460	1.80	70	4	240	0.73	270	73	29	32
77/327	11.01	387.2	33.2	463	1.82	70	4	240	0.73	270	70	27	30
77/327	11.18	381.1	43.8	448	2.00	70	4	240	0.73	274	101	38	41
77/327	11.35	379.4	39.1	434	2.35	70	4	240	0.73	274	106	40	42
77/327	11.51	379.4	31.9	424	2.76	70	4	240	0.73	277	102	38	39
77/327	11.68	378.9	32.7	417	2.91	70	4	240	0.73	276	110	41	42
77/327	11.85	379.9	30.5	413	3.12	70	4	240	0.73	276	110	41	41
77/327	12.01	378.8	29.3	407	3.31	70	4	240	0.73	277	112	41	41
77/327	12.18	379.2	27.4	403	3.40	70	4	240	0.73	274	108	40	41
77/327	12.35	378.8	28.1	399	3.35	70	4	240	0.73	277	109	40	41
77/327	12.51	377.9	28.1	394	3.24	70	4	240	0.73	276	105	39	41
77/327	12.68	377.1	27.3	389	3.12	70	4	240	0.73	279	98	37	39
77/327	12.85	377.9	26.3	390	2.85	70	4	240	0.73	279	87	32	35
77/327	13.01	378.8	28.4	390	2.65	70	4	240	0.73	278	87	33	36
77/327	13.18	378.9	28.1	388	2.60	70	4	240	0.73	279	84	32	36
77/327	13.35	378.3	28.4	386	2.47	70	4	240	0.73	278	81	31	36
77/327	13.51	378.1	28.0	383	2.39	70	4	240	0.73	277	77	30	35
77/327	13.68	377.7	28.2	380	2.27	70	4	240	0.73	274	74	30	35
77/327	13.85	377.5	27.7	383	2.25	70	4	240	0.73	272	72	30	36
77/327	14.01	380.8	22.3	385	2.04	70	4	240	0.73	270	52	22	28
77/327	14.18	381.3	23.2	385	1.91	70	4	240	0.73	270	51	22	29
77/327	14.35	381.0	23.3	383	1.75	70	4	240	0.73	266	47	21	29
77/327	14.51	378.2	26.9	379	1.40	70	4	240	0.73	261	43	21	29
77/327	14.68	377.7	23.7	377	1.39	70	4	240	0.73	256	38	19	28
77/327	14.85	378.5	20.4	373	1.39	70	4	240	0.73	264	32	16	25
77/327	15.01	377.3	19.4	367	1.39	70	4	240	0.73	248	31	17	27
77/327	15.18	376.1	17.0	360	1.46	70	4	240	0.73	232	28	18	30
77/327	15.35	374.2	17.0	352	1.41	70	4	240	0.73	236	27	17	31
77/334	11.49	368.9	19.0	364	2.67	60	2	270	0.73	284	59	21	22
77/334	11.65	383.3	26.7	419	2.34	60	2	270	0.73	285	72	26	27
77/334	11.82	372.2	49.1	475	2.74	60	2	270	0.73	288	156	55	56
77/334	11.99	388.4	27.2	504	2.33	60	2	270	0.73	288	73	26	26
77/334	12.15	389.7	37.8	522	2.48	60	2	270	0.73	292	108	38	38
77/334	12.32	385.9	38.0	505	2.91	60	2	270	0.73	291	128	45	46
77/334	12.49	381.7	33.7	483	2.96	60	2	270	0.73	291	115	41	42
77/334	12.65	376.7	31.2	464	2.98	60	2	270	0.73	291	107	38	40
77/334	12.82	374.7	29.6	453	2.76	60	2	270	0.73	289	94	34	37
77/334	12.99	375.3	30.4	451	2.46	60	2	270	0.73	288	86	31	34
77/334	13.15	375.4	30.1	448	2.30	60	2	270	0.73	288	80	29	33
77/334	13.32	375.3	30.3	445	2.22	60	2	270	0.73	287	78	29	33
77/334	13.49	375.2	30.9	442	2.13	60	2	270	0.73	295	76	29	34
77/334	13.65	374.3	32.1	439	2.09	60	2	270	0.73	281	77	31	36
77/334	13.82	373.7	31.4	436	2.02	60	2	270	0.73	282	73	29	35
77/334	13.99	373.8	27.3	433	1.93	60	2	270	0.73	277	61	25	31
77/334	14.15	373.1	26.1	429	1.78	60	2	270	0.73	277	54	23	29
77/334	14.32	370.3	29.6	425	1.37	60	2	270	0.73	271	47	21	27
77/334	14.49	369.3	29.0	422	1.37	60	2	270	0.73	268	46	21	29
77/334	14.65	368.7	22.9	419	1.36	60	2	270	0.73	261	36	17	25

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										(BTU/HR./SQ.FT.)			
77/334	14.82	368.8	20.9	414	1.36	60	2	270	0.73	258	33	17	25
77/334	14.99	367.1	21.1	408	1.36	60	2	270	0.73	253	33	18	27
77/335	8.98	388.0	8.6	452	1.30	50	6	360	0.73	243	12	7	14
77/335	9.14	386.5	13.7	467	1.30	50	6	360	0.73	249	20	11	18
77/335	9.31	380.8	22.3	479	1.32	50	6	360	0.73	254	34	17	25
77/335	9.48	376.5	25.7	487	1.30	50	6	360	0.73	257	38	19	26
77/335	9.64	371.6	29.6	488	1.29	50	6	360	0.73	261	44	20	27
77/335	9.81	370.6	29.4	487	1.28	50	6	360	0.73	264	43	19	25
77/335	9.98	370.5	31.8	485	1.27	50	6	360	0.73	269	46	20	25
77/335	10.14	370.7	35.0	487	1.26	50	6	360	0.73	272	51	21	26
77/335	10.31	370.7	38.7	494	1.26	50	6	360	0.73	274	56	23	27
77/335	10.48	378.8	25.3	507	1.97	50	6	360	0.73	277	57	23	27
77/335	10.64	382.8	27.8	511	1.74	50	6	360	0.73	279	56	21	25
77/335	10.81	380.2	39.7	521	1.63	50	6	360	0.73	282	75	28	32
77/335	10.98	384.2	34.5	539	1.71	50	6	360	0.73	282	68	25	28
77/335	11.14	388.2	37.9	536	1.68	50	6	360	0.73	282	73	27	29
77/335	11.31	381.6	46.7	524	1.88	50	6	360	0.73	282	101	37	39
77/335	11.48	380.2	40.5	512	2.06	50	6	360	0.73	286	96	35	36
77/335	11.64	377.3	40.2	501	2.27	50	6	360	0.73	286	105	38	39
77/335	11.81	376.5	36.4	491	2.49	50	6	360	0.73	286	105	37	38
77/335	11.98	377.5	33.8	485	2.58	50	6	360	0.73	286	101	36	36
77/335	12.14	378.9	34.3	485	2.59	50	6	360	0.73	285	103	37	37
77/335	12.31	379.9	33.7	484	2.63	50	6	360	0.73	285	102	37	38
77/335	12.48	380.2	33.2	484	2.61	50	6	360	0.73	284	100	36	38
77/335	12.64	380.3	33.2	484	2.55	50	6	360	0.73	283	98	36	38
77/335	12.81	379.7	32.6	482	2.49	50	6	360	0.73	282	94	35	37
77/335	12.98	378.4	33.1	479	2.36	50	6	360	0.73	278	90	34	37
77/335	13.14	377.7	30.5	476	2.23	50	6	360	0.73	276	78	30	34
77/335	13.31	376.7	30.6	480	2.16	50	6	360	0.73	276	76	30	34
77/335	13.48	379.3	27.1	485	1.95	50	6	360	0.73	268	61	25	29
77/335	13.64	379.5	30.8	487	1.88	50	6	360	0.73	261	67	28	34
77/335	13.81	379.3	26.2	485	1.73	50	6	360	0.73	187	52	32	39
77/335	13.98	376.1	25.2	482	1.34	50	6	360	0.73	182	39	25	32
77/335	14.14	375.2	18.6	477	1.34	50	6	360	0.73	173	28	19	27
77/335	14.31	374.0	17.9	469	1.34	50	6	360	0.73	105	27	32	45
77/335	14.48	370.7	15.8	460	1.34	50	6	360	0.73	168	24	18	27
77/335	14.64	367.8	8.2	448	1.32	50	6	360	0.73	95	12	17	30
77/335	14.81	363.4	7.3	437	1.31	50	6	360	0.73	95	11	15	30
77/335	14.98	356.7	8.5	424	1.28	50	6	360	0.73	6	12	259	506
77/336	8.94	359.9	9.2	378	1.95	51	5	180	0.73	266	20	11	18
77/336	9.11	352.4	18.4	375	1.94	51	5	180	0.73	270	41	20	30
77/336	9.28	352.5	17.1	373	1.91	51	5	180	0.73	271	38	18	26
77/336	9.44	351.1	20.2	371	1.92	51	5	180	0.73	273	45	21	28
77/336	9.61	351.4	21.5	371	1.93	51	5	180	0.73	275	48	21	28
77/336	9.78	352.3	23.5	373	1.93	51	5	180	0.73	276	52	23	29
77/336	9.94	354.1	25.5	377	1.91	51	5	180	0.73	280	56	23	29
77/336	10.11	356.4	27.6	382	1.72	51	5	180	0.73	282	55	22	27
77/336	10.28	352.3	37.8	376	1.78	51	5	180	0.73	285	78	31	36
77/[illegible]	10.44	348.7	39.1	369	1.36	51	5	180	0.73	287	84	32	37
77[illegible]	10.61	349.1	36.2	366	1.91	51	5	190	0.73	289	80	30	34
77[illegible]	10.78	349.1	36.8	364	2.00	51	5	180	0.73	289	85	32	35

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										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/336	10.94	351.1	35.5	366	2.13	51	5	180	0.73	289	88	32	35
77/336	11.11	353.5	35.2	370	2.30	51	5	180	0.73	288	94	34	37
77/336	11.28	355.1	34.7	370	2.52	51	5	180	0.73	289	101	36	39
77/336	11.44	352.0	32.7	364	2.98	51	5	180	0.73	289	113	40	42
77/336	11.61	350.3	30.4	359	3.17	51	5	180	0.73	289	112	40	41
77/336	11.78	349.5	27.9	355	3.26	51	5	180	0.73	288	106	38	38
77/336	11.94	349.5	28.2	353	3.23	51	5	180	0.73	288	106	37	38
77/336	12.11	350.0	28.5	353	3.24	51	5	180	0.73	286	107	38	39
77/336	12.28	349.6	28.9	353	3.21	51	5	180	0.73	286	108	39	39
77/336	12.44	349.6	28.9	353	3.13	51	5	180	0.73	286	105	38	39
77/336	12.61	349.3	29.0	352	3.04	51	5	180	0.73	282	102	37	39
77/336	12.78	349.5	27.7	351	2.89	51	5	180	0.73	284	93	34	36
77/336	12.94	348.5	28.5	350	2.79	51	5	180	0.73	281	92	34	37
77/336	13.11	348.4	28.3	349	2.72	51	5	180	0.73	279	89	34	37
77/336	13.28	347.0	27.6	346	2.52	51	5	180	0.73	277	81	31	35
77/336	13.44	348.5	25.8	351	2.31	51	5	180	0.73	278	69	27	31
77/336	13.61	351.0	27.6	355	2.21	51	5	180	0.73	275	71	28	33
77/336	13.78	351.3	28.2	356	2.13	51	5	180	0.73	273	70	29	34
77/336	13.94	351.2	23.7	356	2.01	51	5	180	0.73	267	55	24	29
77/336	14.11	350.9	24.2	356	1.87	51	5	180	0.73	270	52	23	29
77/336	14.28	349.3	24.6	355	1.74	51	5	180	0.73	267	49	22	29
77/336	14.44	376.4	-2.6	356	1.39	51	5	180	0.73	261	-4	-1	0
77/336	14.61	347.7	21.2	356	1.38	51	5	180	0.73	254	34	17	24
77/336	14.78	348.8	18.8	354	1.39	51	5	180	0.73	249	30	16	24
77/336	14.94	346.9	20.1	350	1.39	51	5	180	0.73	244	32	18	27
77/339	10.96	396.0	20.7	389	1.93	63	10	360	0.73	283	46	17	19
77/339	11.13	410.9	23.8	455	1.56	63	10	360	0.73	279	43	16	17
77/339	11.30	412.8	33.8	518	2.01	63	10	360	0.73	279	78	29	31
77/339	11.46	406.6	41.9	548	2.05	63	10	360	0.73	282	99	36	38
77/339	11.63	413.7	31.1	568	2.07	63	10	360	0.73	281	74	27	28
77/339	11.80	415.3	35.5	562	2.10	63	10	360	0.73	280	86	31	32
77/339	11.96	408.3	37.3	540	2.52	63	10	360	0.73	280	108	40	40
77/339	12.13	405.2	31.3	522	2.77	63	10	360	0.73	282	100	36	37
77/339	12.30	404.7	28.7	517	2.66	63	10	360	0.73	279	88	32	33
77/339	12.46	406.6	27.5	518	2.37	63	10	360	0.73	276	75	28	29
77/339	12.63	406.6	29.0	519	2.30	63	10	360	0.73	275	77	29	31
77/339	12.80	406.3	28.8	516	2.20	63	10	360	0.73	275	73	28	30
77/339	12.96	406.3	29.0	519	2.09	63	10	360	0.73	272	70	27	30
77/339	13.13	405.8	29.2	519	2.00	63	10	360	0.73	270	67	26	30
77/339	13.30	405.3	27.0	517	1.90	63	10	360	0.73	265	59	24	27
77/339	13.46	404.9	27.0	514	1.81	63	10	360	0.73	266	56	23	27
77/339	13.63	402.3	30.4	511	1.46	63	10	360	0.73	264	51	21	26
77/339	13.80	400.2	32.2	511	1.40	63	10	360	0.73	263	52	22	27
77/339	13.96	399.7	26.6	508	1.40	63	10	360	0.73	256	43	19	24
77/339	14.13	399.4	21.2	495	1.39	63	10	360	0.73	253	34	16	21
77/339	14.30	396.1	20.6	486	1.41	63	10	360	0.73	250	33	16	22
77/339	14.46	392.7	18.6	472	1.40	63	10	360	0.73	246	30	15	22
77/339	14.63	389.1	14.6	457	1.38	63	10	360	0.73	190	23	15	24
77/339	14.80	384.1	15.0	442	1.34	63	10	360	0.73	229	23	13	21
77/339	14.96	378.7	14.0	427	1.34	63	10	360	0.73	160	21	18	31
77/340	11.34	354.0	20.3	308	4.54	40	7	360	0.73	293	107	38	40

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLECTIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/340	11.51	356.0	25.5	332	2.71	40	7	360	0.73	294	80	28	29
77/340	11.67	358.1	31.8	358	2.37	40	7	360	0.73	295	87	30	31
77/340	11.84	364.2	33.4	371	2.18	40	7	360	0.73	295	84	29	29
77/340	12.01	358.1	41.2	364	2.40	40	7	360	0.73	295	115	40	40
77/340	12.17	353.7	38.0	353	2.69	40	7	360	0.73	296	119	41	42
77/340	12.34	349.1	34.4	343	2.82	40	7	360	0.73	293	113	39	41
77/340	12.51	347.8	32.4	337	2.62	40	7	360	0.73	295	99	34	36
77/340	12.67	349.7	32.1	333	2.42	40	7	360	0.73	293	90	32	34
77/340	12.84	350.9	33.2	332	2.26	40	7	360	0.73	291	87	31	34
77/340	13.01	350.9	34.4	330	2.18	40	7	360	0.73	292	87	31	34
77/340	13.17	350.9	32.0	328	2.07	40	7	360	0.73	289	77	28	31
77/340	13.34	349.8	32.7	331	1.99	40	7	360	0.73	288	75	28	32
77/340	13.51	351.1	30.7	346	1.90	40	7	360	0.73	286	68	26	30
77/340	13.67	357.8	27.1	354	1.39	40	7	360	0.73	284	43	17	21
77/340	13.84	357.1	39.0	363	1.37	40	7	360	0.73	281	62	25	30
77/340	14.01	357.3	35.9	375	1.36	40	7	360	0.73	279	56	23	29
77/340	14.17	361.4	26.7	376	1.35	40	7	360	0.73	275	41	18	23
77/340	14.34	363.5	23.0	371	1.35	40	7	360	0.73	272	36	16	22
77/340	14.51	361.7	24.5	365	1.34	40	7	360	0.73	267	38	18	25
77/340	14.67	360.5	19.4	359	1.35	40	7	360	0.73	262	30	15	22
77/340	14.84	358.7	18.7	351	1.36	40	7	360	0.73	264	29	15	22
77/340	15.01	356.2	18.0	344	1.37	40	7	360	0.73	252	28	15	25
77/340	15.17	353.3	16.0	335	1.36	40	7	360	0.73	247	25	14	24
77/340	15.34	350.0	15.4	328	1.35	40	7	360	0.73	240	24	15	26
77/349	11.66	354.4	18.8	306	4.82	70	14	180	0.82	289	105	37	38
77/349	11.82	357.6	22.0	350	3.68	70	14	180	0.82	288	94	33	34
77/349	11.99	357.3	33.0	362	3.41	70	14	180	0.82	288	131	46	47
77/349	12.16	353.4	29.9	358	3.58	70	14	180	0.82	288	124	44	45
77/349	12.32	349.9	29.7	351	3.62	70	14	180	0.82	288	125	45	46
77/349	12.49	347.7	28.4	345	3.55	70	14	180	0.82	288	117	42	44
77/349	12.66	346.5	27.8	340	3.37	70	14	180	0.82	286	109	39	42
77/349	12.82	349.7	24.6	349	2.87	70	14	180	0.82	286	82	30	32
77/349	12.99	351.6	29.3	355	2.69	70	14	180	0.82	285	91	34	37
77/349	13.16	353.7	29.3	358	2.67	70	14	180	0.82	283	91	34	38
77/349	13.32	353.6	26.8	358	2.48	67	14	180	0.82	282	77	29	33
77/349	13.49	353.0	28.2	358	2.36	67	14	180	0.82	282	77	30	34
77/349	13.66	352.5	28.4	358	2.29	67	14	180	0.82	280	75	30	35
77/349	13.82	352.5	27.9	356	2.21	67	14	180	0.82	277	71	29	35
77/349	13.99	352.4	25.2	356	2.08	67	14	180	0.82	274	61	26	32
77/349	14.16	351.4	25.4	358	1.96	67	14	180	0.82	270	58	25	32
77/349	14.32	353.9	20.6	362	1.80	67	14	180	0.82	268	43	19	26
77/349	14.49	352.9	25.1	361	1.39	67	14	180	0.82	265	40	19	26
77/349	14.66	351.9	23.8	351	1.39	67	14	180	0.82	260	38	19	27
77/349	14.82	352.3	21.4	358	1.39	67	14	180	0.82	255	34	18	26
77/349	14.99	351.5	20.9	355	1.39	66	14	180	0.82	249	33	18	28
77/349	15.16	350.3	17.8	350	1.39	66	14	180	0.82	244	28	16	27
77/349	15.32	348.3	14.1	341	1.37	66	14	180	0.82	236	22	14	25
77/350	9.60	376.4	2.8	320	2.24	78	18	180	0.82	255	7	3	7
77/350	9.76	391.4	7.0	352	1.37	78	18	180	0.82	257	11	5	8
77/350	9.93	401.7	15.3	391	1.40	78	1	180	0.82	261	24	11	5
77/350	10.10	409.0	21.7	441	1.38	78	1	180	0.82	262	34	15	9

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	REFLEC- TIVITY	DIRECT RADIATION	COLLECTION RATE	EFFICIENCY	
										(BTU/HR./SQ.FT.)		SINGLE MODULE	WITHOUT END LOSS
77/350	10.26	422.5	19.1	493	1.41	78	18	180	0.82	267	31	13	16
77/350	10.43	436.5	18.7	546	1.40	78	18	180	0.82	268	30	12	15
77/350	10.60	447.9	22.4	607	1.41	78	18	180	0.82	272	36	14	17
77/350	10.76	457.3	26.6	679	1.40	78	18	180	0.82	274	43	17	19
77/350	10.93	468.6	27.6	754	1.38	78	18	180	0.82	278	44	17	19
77/350	11.10	470.4	37.3	823	1.35	78	18	180	0.82	278	58	22	24
77/350	11.26	453.8	39.9	866	2.18	72	10	180	0.82	278	100	38	40
77/350	11.43	465.2	27.5	852	2.04	72	10	180	0.82	277	65	24	25
77/350	11.60	461.3	35.3	832	2.29	72	10	180	0.82	280	93	34	35
77/350	11.76	467.1	28.0	818	2.36	72	10	180	0.82	277	76	28	29
77/350	11.93	467.2	28.5	815	2.51	72	10	180	0.82	274	82	31	31
77/350	12.10	469.0	28.0	815	2.68	72	10	180	0.82	274	87	32	33
77/350	12.26	471.1	26.0	817	2.69	72	10	180	0.82	271	81	30	31
77/350	12.43	470.6	27.6	819	2.68	72	10	180	0.82	270	85	32	34
77/350	12.60	471.3	25.8	814	2.55	72	10	180	0.82	265	76	30	31
77/350	12.76	469.7	25.2	804	2.41	72	10	180	0.82	264	70	28	30
77/350	12.93	467.7	27.2	793	2.29	68	10	180	0.82	261	72	29	32
77/350	13.10	465.9	26.2	780	2.24	68	10	180	0.82	255	68	28	32
77/350	13.26	465.1	22.9	763	2.13	68	10	180	0.82	254	56	24	27
77/350	13.43	460.7	24.7	741	2.02	68	10	180	0.82	253	57	25	29
77/350	13.60	457.3	24.9	719	1.91	68	10	180	0.82	249	55	24	29
77/350	13.76	454.5	24.4	700	1.83	68	10	180	0.82	249	51	23	29
77/350	13.93	452.1	23.0	680	1.74	68	10	180	0.82	239	46	22	28
77/350	14.10	445.5	24.1	658	1.32	68	10	180	0.82	217	36	20	26
77/350	14.26	440.1	22.9	632	1.33	68	10	180	0.82	201	35	21	29
77/350	14.43	435.5	18.7	608	1.33	68	10	180	0.82	198	28	18	26
77/350	14.60	429.3	16.0	583	1.34	65	18	180	0.82	187	24	16	26
77/350	14.76	423.1	13.5	559	1.35	65	18	180	0.82	159	21	17	29
77/350	14.93	417.5	9.8	537	1.34	65	18	180	0.82	143	15	14	28
77/354	12.46	354.1	15.2	363	4.15	50	12	0	0.59	202	73	37	39
77/354	12.63	358.5	10.4	363	2.02	50	12	0	0.59	266	24	9	10
77/354	12.80	367.6	21.0	381	1.68	50	12	0	0.59	278	41	15	17
77/354	12.96	352.7	36.9	403	1.85	50	12	0	0.59	262	79	32	35
77/354	13.13	360.4	22.1	408	1.38	50	12	0	0.59	265	35	14	16
77/354	13.30	357.8	35.1	408	1.38	50	12	0	0.59	267	56	22	26
77/354	13.46	356.9	33.3	412	1.38	50	12	0	0.59	263	53	22	26
77/354	13.63	358.6	28.7	412	1.38	50	12	0	0.59	276	46	18	22
77/354	13.80	359.6	29.6	412	1.38	50	12	0	0.59	276	47	19	24
77/354	13.96	359.0	28.3	409	1.37	50	12	0	0.59	272	45	19	24
77/354	14.30	356.9	22.6	400	1.36	50	12	0	0.59	272	35	16	21
77/354	14.46	354.6	20.5	392	1.35	50	12	0	0.59	263	32	15	21

Appendix E. Part 2 Heat-Loss Data

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE (BTU/HR./SQ.FT.)
77/133	9.11	457.8	-6.3	730	3.38	75	12	160	180	24
77/133	9.36	458.1	-10.8	730	3.39	75	12	160	180	42
77/133	9.61	458.4	-11.0	730	3.37	75	12	160	180	42
77/133	9.86	458.5	-11.1	730	3.38	75	12	160	180	43
77/133	10.11	458.4	-10.8	730	3.36	75	12	160	180	41
77/133	10.36	457.7	-10.6	730	3.38	77	11	160	180	41
77/133	10.61	457.4	-10.8	730	3.38	77	11	160	180	42
77/133	10.86	457.6	-11.0	730	3.38	77	11	160	180	43
77/133	11.11	457.2	-11.0	730	3.40	77	11	160	180	43
77/133	11.36	456.9	-10.8	730	3.37	77	11	160	180	42
77/133	11.61	456.4	-11.0	730	3.38	77	11	160	250	43
77/133	11.86	455.4	-10.9	730	3.36	77	11	160	250	42
77/133	12.11	455.0	-11.0	690	3.35	77	11	160	250	42
77/133	12.36	454.9	-11.1	690	3.36	78	15	160	250	43
77/133	12.61	455.0	-11.7	690	3.36	78	15	160	250	45
77/133	12.86	455.1	-10.9	690	3.38	78	15	160	250	42
77/133	13.11	455.2	-11.0	690	3.39	78	15	160	250	43
77/133	13.36	455.4	-11.2	690	3.40	78	15	160	250	44
77/133	13.61	454.8	-11.0	690	3.40	81	14	160	250	43
77/133	13.86	454.2	-10.8	690	3.38	81	14	160	250	42
77/133	14.11	454.0	-11.1	690	3.38	81	14	160	250	43
77/133	14.36	422.9	-2.9	690	3.33	81	14	160	250	11
77/143	15.60	473.7	-7.1	620	5.05	69	9	180	35	41
77/143	16.10	471.4	-6.9	575	5.05	69	9	180	35	40
77/143	16.60	469.3	-7.3	543	5.05	69	9	180	35	42
77/143	17.10	466.8	-6.8	511	5.05	69	9	180	35	39
77/143	17.60	464.6	-6.9	491	5.05	69	9	180	35	40
77/143	18.10	462.0	-7.0	481	5.00	69	9	180	35	40
77/143	18.60	459.1	-7.2	481	5.00	69	9	180	35	41
77/143	19.10	455.8	-6.9	481	5.00	69	9	180	35	39
77/143	19.60	453.1	-6.9	481	4.91	69	9	180	35	39
77/143	20.10	452.1	-6.9	481	4.98	69	6	180	35	39
77/143	20.60	452.2	-7.0	481	4.98	69	6	180	0	40
77/143	21.10	452.5	-7.1	481	4.98	69	6	180	0	40
77/143	21.60	452.8	-6.8	481	4.98	69	6	180	0	39
77/143	22.10	452.7	-6.9	481	4.98	69	6	180	0	39
77/143	22.60	453.1	-6.5	481	5.05	69	6	180	0	38
77/143	23.10	453.5	-6.8	481	5.05	69	6	180	0	39
77/143	23.60	453.3	-6.7	481	5.11	69	6	180	0	39
77/143	0.10	453.2	-6.5	481	5.18	69	6	180	0	39
77/143	0.60	452.9	-6.3	481	5.18	69	6	180	0	37
77/143	1.10	452.9	-6.1	481	5.31	69	6	180	0	37
77/144	1.60	454.2	-5.8	481	5.38	69	6	180	0	36
77/144	2.10	454.9	-5.4	481	5.38	69	6	180	0	33
77/144	2.60	454.9	-5.3	481	5.51	69	2	180	0	33
77/144	3.10	454.9	-4.6	481	5.64	69	2	160	0	30
77/144	3.60	455.8	-3.9	481	5.70	69	2	160	0	25
77/144	4.10	456.8	-3.4	481	5.80	69	6	160	0	22
7 4	4.60	456.5	-3.0	481	5.	69	6	160	0	2
7 4	5.10	456.6	-2.6	481	6.	69	6	160	0	1
77/144	5.60	456.5	-2.1	481	6.00	69	6	160	0	14

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE (BTU/HR./SQ.FT.)
77/144	6.10	456.5	-1.8	481	6.10	69	6	160	0	12
77/157	16.24	420.2	-6.5	840	5.63	75	2	300	35	42
77/157	17.24	434.3	-6.1	794	5.62	75	3	300	35	39
77/157	18.24	444.9	-6.0	811	5.58	75	3	300	35	38
77/157	19.24	452.5	-5.7	824	5.59	75	3	300	35	36
77/157	20.24	459.6	-5.8	835	5.57	75	3	300	35	37
77/157	21.24	461.2	-5.8	827	5.58	75	3	300	35	37
77/164	14.37	381.4	10.5	711	1.94	79	6	70	135	-23
77/164	14.45	376.3	0.0	711	1.95	79	6	70	135	0
77/164	14.83	378.9	-13.3	711	1.92	79	6	70	135	29
77/164	14.97	384.6	-18.5	711	1.94	79	6	70	135	41
77/164	15.47	405.7	-17.8	711	2.06	79	6	70	135	42
77/164	15.97	412.2	-14.5	711	2.06	79	6	70	135	34
77/164	16.47	419.0	-15.0	711	2.07	79	6	70	135	36
77/164	16.97	423.9	-14.5	711	2.05	79	6	70	135	34
77/164	17.47	428.3	-15.2	711	2.05	79	6	70	135	36
77/164	17.97	431.6	-15.4	711	2.03	79	0	70	135	36
77/164	18.47	435.0	-15.0	711	2.02	79	0	0	0	35
77/164	18.97	439.0	-15.0	711	2.01	79	6	90	0	34
77/164	19.47	443.4	-14.4	711	2.01	79	6	90	0	33
77/164	19.97	440.4	-15.0	711	1.99	79	6	90	0	34
77/164	20.47	440.6	-14.1	711	2.00	79	6	90	0	32
77/164	20.97	443.8	-16.3	711	1.99	79	2	90	0	37
77/164	21.47	448.1	-14.9	711	1.99	79	1	90	0	34
77/164	21.97	447.2	-14.9	711	1.97	79	0	0	0	34
77/164	*****	445.7	-12.3	711	1.97	79	0	0	0	28
77/164	22.97	446.8	-14.2	711	1.98	79	0	0	0	32
77/164	23.47	447.9	-12.3	711	1.99	79	0	0	0	28
77/164	23.97	448.8	-15.1	711	2.00	79	0	0	0	35
77/164	0.47	447.6	-11.7	711	1.98	79	0	0	0	26
77/164	0.97	448.7	-16.0	711	2.01	79	0	0	0	37
77/164	1.47	450.0	-14.6	711	2.00	79	0	0	0	33
77/164	1.97	448.1	-14.0	711	1.99	79	0	0	0	32
77/164	2.47	449.6	-13.3	711	2.00	79	0	0	0	30
77/164	2.97	450.4	-14.9	711	2.00	79	0	0	0	34
77/164	3.47	450.3	-13.5	711	2.02	79	0	0	0	31
77/164	3.97	450.9	-14.9	711	2.03	79	0	0	0	35
77/164	4.47	450.8	-14.6	711	2.02	79	0	0	0	34
77/164	4.97	463.5	-35.6	711	2.03	79	0	0	0	83
77/164	5.47	468.9	-37.5	711	1.00	79	0	0	0	43
77/164	5.97	464.2	-32.4	711	1.02	79	0	0	0	38
77/164	6.47	409.8	-4.5	711	1.12	79	0	0	0	5
77/164	6.97	335.4	6.6	711	3.66	79	0	0	0	-28
77/164	7.47	277.8	3.5	711	3.89	79	0	0	0	-16
77/164	7.97	245.3	1.5	711	3.89	79	0	0	0	-6
77/164	8.47	226.4	0.3	711	3.86	79	0	0	0	-1
77/164	8.97	211.8	0.1	711	3.89	79	0	0	0	0
77/180	16.27	402.1	-7.2	774	3.73	95	5	180	40	31
77/180	16.77	404.0	-7.3	760	3.77	95	8	160	40	31
77/180	17.27	405.7	-6.7	750	3.73	95	8	160	40	29
77/180	17.77	406.8	-7.4	737	3.72	95	8	160	40	31

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION	HEAT LOSS RATE
									(BTU/HR./SQ.FT.)	
77/180	18.27	407.7	-7.5	723	3.72	92	9	160	40	32
77/180	19.27	409.3	-6.3	703	3.69	92	6	160	40	26
77/180	19.77	409.5	-6.8	695	3.69	92	3	180	40	29
77/180	20.27	409.4	-6.9	687	3.70	89	6	180	40	29
77/180	20.77	409.6	-7.2	678	3.70	89	6	180	40	30
77/180	21.27	408.8	-7.4	668	3.68	89	7	200	40	31
77/180	21.77	407.8	-7.1	660	3.65	89	6	200	0	30
77/180	22.27	407.9	-6.6	653	3.65	86	6	200	0	27
77/180	22.77	407.5	-7.2	646	3.66	86	8	200	0	30
77/180	23.27	405.3	-6.6	636	3.68	86	6	200	0	28
77/180	23.77	404.4	-6.9	628	3.67	86	7	200	0	29
77/180	0.27	404.3	-6.6	622	3.66	83	5	200	0	28
77/180	0.77	404.9	-7.1	616	3.63	83	5	200	0	29
77/180	1.27	405.6	-6.8	612	3.64	83	5	200	0	28
77/180	1.77	406.3	-7.0	607	3.65	83	4	200	0	29
77/180	2.27	407.6	-7.1	603	3.64	80	3	180	0	30
77/180	2.77	409.8	-7.0	600	3.68	80	2	180	0	29
77/180	3.27	412.1	-6.8	598	3.64	80	3	180	0	28
77/180	3.77	414.1	-7.0	594	3.64	80	3	180	0	29
77/180	4.27	415.3	-7.3	592	3.53	77	4	200	0	29
77/180	4.77	416.0	-7.3	589	3.56	77	6	200	0	30
77/180	5.27	416.7	-7.0	587	3.56	77	6	200	0	28
77/180	5.77	418.1	-7.2	586	3.54	77	6	200	0	29
77/180	6.27	418.8	-7.3	585	3.56	75	6	200	0	30
77/181	7.28	421.1	-10.3	580	2.63	77	11	180	81	31
77/181	7.53	420.9	-10.6	580	2.67	77	13	180	81	32
77/181	7.78	419.8	-10.4	575	2.66	77	13	200	81	32
77/181	8.03	419.6	-10.6	574	2.68	77	13	200	81	32
77/181	8.28	418.7	-11.0	573	2.69	77	13	200	81	34
77/181	8.53	418.2	-10.7	572	2.67	77	13	200	81	33
77/181	8.78	417.2	-10.5	568	2.69	77	13	200	81	32
77/181	9.03	416.6	-10.4	565	2.65	82	11	200	81	32
77/181	9.28	416.4	-10.5	562	2.66	82	9	200	81	32
77/181	9.53	416.5	-10.3	560	2.68	82	9	200	81	32
77/181	9.78	417.1	-10.2	559	2.65	82	9	200	120	31
77/181	10.03	417.6	-10.2	560	2.66	82	9	200	120	31
77/181	10.28	418.3	-10.1	563	2.68	82	9	200	120	31
77/181	10.53	419.2	-10.3	562	2.67	82	7	200	120	31
77/181	10.78	420.0	-10.2	562	2.67	82	7	180	120	31
77/181	11.03	420.8	-9.6	567	2.68	82	7	180	120	29
77/181	11.28	421.6	-9.9	568	2.69	93	7	180	120	30
77/181	11.53	421.9	-9.8	570	2.72	93	7	180	120	30
77/181	11.78	423.1	-10.7	567	2.73	93	9	180	120	33
77/181	12.03	424.3	-11.4	568	2.47	93	9	180	120	32
77/187	14.95	416.1	-8.8	761	1.44	94	7	180	80	14
77/187	15.45	419.5	-28.0	711	1.46	94	7	180	80	47
77/187	15.95	406.1	-9.5	668	1.43	94	7	180	80	15
77/187	16.45	422.0	-23.1	636	1.44	94	7	180	80	38
77/187	16.95	415.8	-27.9	602	1.44	94	7	180	80	46
77/1	17.45	405.9	-7.4	574	1.41	89	7	180	80	12
77/1	17.95	422.2	-26.4	550	1.44	89	9	180	80	44

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE
77/187	18.45	413.1	-24.6	521	1.44	89	11	180	80	41
77/187	18.95	417.2	-18.2	499	1.43	89	11	180	80	30
77/187	19.45	423.5	-28.1	479	1.40	89	9	180	80	45
77/187	19.95	414.5	-18.8	457	1.38	89	7	180	0	30
77/187	20.45	425.8	-23.8	444	1.40	89	7	180	0	38
77/187	20.95	423.8	-30.1	424	1.41	89	7	180	0	49
77/187	21.45	416.3	-13.5	424	1.36	89	7	180	0	21
77/187	21.95	430.5	-29.4	398	1.40	89	7	180	0	47
77/187	22.45	418.4	-22.3	377	1.37	84	7	180	0	35
77/187	22.95	428.4	-21.9	374	1.34	84	7	180	0	34
77/187	23.45	429.5	-31.0	358	1.52	84	7	180	0	54
77/187	23.95	427.5	-19.2	347	1.39	84	7	180	0	31
77/187	0.45	432.7	-28.2	358	1.72	84	7	180	0	56
77/187	0.95	421.2	-16.1	321	1.57	84	7	180	0	29
77/202	14.89	430.1	-37.5	772	2.11	93	11	180	112	91
77/202	15.14	430.3	-26.0	746	2.12	93	11	180	112	63
77/202	15.39	419.3	-9.9	713	2.08	93	9	180	112	23
77/202	15.64	421.9	-15.1	690	2.09	93	9	180	112	36
77/202	15.89	425.0	-15.3	677	2.09	93	9	180	112	37
77/202	16.14	421.7	-13.8	660	2.09	93	7	180	112	33
77/202	16.39	422.5	-14.7	648	2.10	90	7	180	112	35
77/202	16.64	422.6	-14.3	636	2.11	90	7	180	112	35
77/202	16.89	421.7	-14.4	623	2.10	90	7	180	112	35
77/202	17.14	411.7	-13.5	616	2.09	90	7	180	112	32
77/202	17.39	422.0	-19.3	607	2.12	90	7	180	0	47
77/202	17.64	425.4	-16.7	597	2.09	90	7	180	0	40
77/202	17.89	423.2	-15.4	584	2.07	90	7	180	0	37
77/202	18.14	423.6	-15.5	575	2.05	90	7	180	0	36
77/202	18.39	423.2	-15.3	569	2.06	84	5	180	0	36
77/202	18.64	424.1	-15.7	564	2.05	84	5	180	0	37
77/202	18.89	424.3	-15.5	562	2.02	84	4	180	0	36
77/202	19.14	424.7	-15.8	561	2.04	84	4	180	0	37
77/202	19.39	425.5	-15.4	562	2.02	84	3	180	0	36
77/202	19.64	425.3	-15.1	562	2.03	84	3	180	0	35
77/202	19.89	425.8	-14.9	562	2.02	84	3	180	0	34
77/202	20.14	425.4	-14.9	561	2.03	84	3	180	0	35
77/202	20.38	425.4	-15.0	559	2.01	84	3	180	0	35
77/202	20.64	425.1	-14.7	556	2.01	84	3	180	0	34
77/202	20.89	424.9	-14.9	553	2.02	84	3	180	0	34
77/202	21.14	424.7	-14.8	547	2.00	84	3	180	0	34
77/202	21.39	423.9	-14.6	539	1.98	84	3	180	0	33
77/202	21.64	425.2	-16.0	532	1.99	84	3	180	0	36
77/202	21.89	426.1	-16.1	527	2.00	84	3	180	0	37
77/202	22.14	426.7	-16.0	524	2.00	84	3	180	0	37
77/202	22.39	427.6	-15.5	523	1.98	79	3	180	0	35
77/202	22.64	426.9	-14.4	522	1.99	79	3	180	0	33
77/202	22.89	425.5	-13.2	520	1.99	79	0	0	0	30
77/202	23.14	428.3	-16.6	520	1.99	79	0	0	0	38
77/202	23.39	427.5	-14.8	519	2.00	79	0	0	0	34
77/202	23.64	426.6	-12.8	519	1.98	79	0	0	0	29
77/202	23.89	426.4	-14.7	516	1.97	79	0	0	0	33

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77/202	0.14	428.9	-16.1	516	1.97	79	0	0	0	36
77/202	0.39	427.0	-13.6	514	1.96	75	0	0	0	30
77/202	0.64	428.4	-15.6	513	1.97	75	0	0	0	35
77/202	0.89	428.0	-14.5	513	1.96	75	0	0	0	33
77/202	1.14	427.4	-14.1	512	1.97	75	0	0	0	32
77/202	1.39	428.4	-14.2	512	1.97	75	0	0	0	32
77/202	1.64	427.7	-13.8	512	1.95	75	0	0	0	31
77/202	1.89	428.3	-13.9	511	1.97	75	0	0	0	31
77/202	2.14	427.9	-13.4	510	1.97	75	0	0	0	30
77/202	2.39	428.1	-14.4	509	1.98	75	0	0	0	33
77/202	2.64	427.7	-13.9	508	1.96	69	0	0	0	31
77/202	2.89	429.0	-14.6	508	1.97	69	0	0	0	33
77/202	3.14	427.7	-13.4	506	1.93	69	0	0	0	30
77/202	3.39	428.8	-14.9	505	1.93	69	0	0	0	33
77/202	3.64	429.3	-14.8	504	1.90	69	0	0	0	32
77/202	3.89	428.2	-13.7	502	1.81	69	0	0	0	28
77/202	4.14	428.5	-14.9	499	1.85	69	0	0	0	32
77/202	4.49	429.8	-15.4	499	1.86	69	0	0	0	33
77/202	4.64	429.7	-14.8	499	1.87	69	0	0	0	32
77/202	4.89	429.4	-14.8	498	1.88	69	0	0	0	32
77/202	5.14	429.9	-14.6	499	1.82	69	0	0	0	30
77/202	5.39	429.1	-13.5	499	1.83	69	0	0	0	28
77/202	5.64	428.5	-14.8	498	1.85	69	0	0	0	31
77/202	5.89	429.7	-15.2	498	1.84	69	0	0	0	32
77/202	6.14	430.3	-15.0	502	1.86	69	0	0	0	32
77/202	6.39	429.4	-13.8	507	1.84	69	0	0	0	29
77/209	15.20	410.3	-25.6	705	1.28	79	11	180	72	38
77/209	15.45	411.5	-23.0	691	1.26	79	11	180	72	33
77/209	15.70	419.3	-27.3	686	1.24	79	11	180	72	39
77/209	15.95	422.3	-25.0	689	1.24	79	11	180	72	36
77/209	16.20	426.1	-26.0	692	1.21	79	11	180	72	36
77/209	16.45	428.6	-25.6	693	1.17	79	11	180	72	34
77/209	16.70	431.3	-26.3	694	1.15	79	11	180	72	35
77/209	16.95	434.1	-26.7	696	1.18	79	11	180	72	36
77/209	17.20	437.3	-27.6	698	1.19	79	11	180	72	38
77/209	17.45	439.6	-27.5	698	1.15	79	11	180	72	36
77/209	17.70	438.2	-24.8	698	1.15	79	9	180	0	33
77/209	17.95	436.0	-23.9	695	1.14	79	9	180	0	31
77/209	18.20	436.2	-25.1	688	1.15	79	9	180	0	33
77/209	18.45	436.3	-25.3	682	1.11	79	9	180	0	32
77/209	18.70	436.0	-24.9	675	1.10	79	4	180	0	31
77/209	18.95	436.3	-25.1	670	1.11	79	4	180	0	32
77/209	19.20	436.7	-25.6	665	1.07	79	4	180	0	31
77/209	19.45	437.5	-26.1	660	1.10	79	4	180	0	33
77/209	19.70	438.4	-26.5	657	1.09	79	3	180	0	33
77/209	19.95	438.1	-25.8	654	1.06	79	3	180	0	31
77/209	20.20	437.9	-26.0	650	1.04	79	3	180	0	31
77/209	20.45	438.5	-27.7	644	1.05	79	3	180	0	33
77/209	20.70	439.7	-29.2	638	1.02	79	9	180	0	34
77/209	20.95	440.8	-29.2	634	1.01	79	9	180	0	34
77/209	21.20	441.5	-29.9	630	0.97	79	9	180	0	33

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77/209	21.45	442.1	-31.2	624	0.98	79	9	180	0	35
77/209	21.70	444.1	-33.8	619	0.97	79	9	180	0	37
77/209	21.95	445.4	-34.5	614	0.95	79	13	180	0	38
77/209	22.20	445.6	-34.2	610	0.97	79	13	180	0	38
77/209	22.45	447.5	-36.6	605	0.94	79	13	180	0	40
77/209	22.70	448.8	-37.5	602	0.88	79	13	180	60	38
77/209	7.45	407.1	-4.7	627	6.52	79	7	220	60	35
77/209	7.70	409.2	-4.5	634	6.57	79	7	220	60	34
77/209	7.95	412.0	-4.7	641	6.56	79	7	220	60	35
77/209	8.20	413.2	-4.4	644	6.64	79	7	220	60	33
77/209	8.45	414.1	-4.5	645	6.59	79	7	220	60	34
77/209	8.70	415.9	-4.6	646	6.15	79	7	180	60	32
77/209	8.95	417.9	-4.4	651	6.67	79	7	180	60	34
77/209	9.20	419.9	-4.7	653	6.50	79	7	180	60	35
77/209	9.45	421.7	-4.7	659	6.58	79	7	180	60	35
77/209	9.70	424.3	-4.7	666	6.65	79	3	180	125	36
77/209	9.95	426.7	-4.4	673	6.61	79	3	180	125	33
77/209	10.20	429.2	-4.4	679	6.61	79	3	180	125	33
77/209	10.45	431.5	-4.4	685	6.73	79	3	180	125	34
77/209	10.70	433.7	-4.4	692	6.70	79	5	180	125	34
77/216	10.89	388.3	-24.6	403	1.28	93	5	180	304	36
77/216	11.39	399.7	-14.3	561	1.26	95	7	180	304	21
77/216	11.73	381.5	-1.2	561	1.23	97	7	180	304	1
77/216	12.39	380.6	-11.9	530	2.14	96	6	180	304	29
77/216	12.73	379.2	-9.4	529	2.13	96	6	180	304	23
77/216	13.38	371.9	-4.6	522	3.82	97	6	180	304	20
77/216	13.88	372.0	-5.1	512	3.85	97	6	180	304	22
77/216	14.39	380.1	-15.0	491	1.71	97	6	160	304	29
77/216	14.89	381.3	-12.6	488	1.69	97	6	160	304	24
77/220	9.90	387.4	-6.3	352	2.96	90	6	140	310	21
77/220	10.40	391.0	-4.7	356	2.95	92	5	200	310	16
77/220	10.90	392.4	-6.0	354	2.94	93	7	190	310	20
77/220	11.41	391.0	-4.5	350	3.95	95	4	210	310	20
77/220	11.88	388.1	-4.9	344	3.93	93	3	180	310	22
77/220	12.38	388.0	-4.4	339	3.91	95	5	170	310	20
77/220	13.13	391.7	-6.3	398	1.90	97	6	180	310	13
77/220	13.56	398.3	-15.8	394	1.92	92	4	250	310	35
77/220	14.13	394.2	-12.7	385	1.86	91	3	110	310	27
77/222	11.89	394.7	-4.3	523	3.60	88	2	180	217	18
77/222	12.40	396.2	-7.9	503	2.38	94	2	180	217	21
77/222	12.90	396.2	-7.0	479	2.39	96	2	180	217	19
77/222	13.39	403.2	-16.9	635	1.49	96	4	130	217	29
77/222	13.85	403.8	-12.9	592	1.51	95	5	180	217	22
77/222	14.39	403.4	-15.7	565	1.54	97	4	180	217	28
77/222	14.75	403.4	-13.5	552	1.46	95	4	120	217	22
77/229	16.19	429.1	-11.5	700	2.40	95	4	180	0	32
77/229	16.44	428.9	-11.9	676	2.39	95	4	180	0	32
77/229	16.69	428.6	-12.0	658	2.38	95	4	180	0	33
77/229	16.94	428.1	-11.8	644	2.39	95	4	180	0	32
77/229	17.19	428.3	-12.3	632	2.36	95	5	180	0	33
77/229	17.44	428.6	-12.8	621	2.32	95	5	180	0	34

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION	HEAT LOSS RATE (BTU/HR./SQ.FT.)
77/229	17.69	429.1	-12.8	615	2.32	95	5	180	0	34
77/229	17.94	429.3	-13.4	611	2.32	95	5	180	0	36
77/229	18.19	429.5	-13.1	607	2.30	95	3	160	0	34
77/229	18.44	430.1	-12.7	605	2.31	95	3	160	0	34
77/229	18.69	430.7	-13.6	604	2.32	95	3	160	0	33
77/229	18.94	430.6	-12.3	601	2.30	95	3	160	0	32
77/229	19.19	430.9	-12.2	597	2.29	95	1	160	0	32
77/229	19.44	431.4	-12.0	595	2.30	95	1	160	0	32
77/229	19.69	431.7	-12.9	593	2.29	95	1	160	0	34
77/229	19.94	431.7	-12.2	592	2.28	95	1	160	0	32
77/229	20.19	432.0	-12.3	589	2.27	95	1	180	0	32
77/229	20.44	432.1	-12.3	585	2.27	95	1	180	0	32
77/229	20.69	432.1	-12.8	580	2.29	95	1	180	0	34
77/229	20.94	432.1	-12.7	575	2.27	95	1	180	0	33
77/229	21.19	432.3	-12.7	572	2.29	95	2	200	0	33
77/229	21.44	432.7	-12.7	570	2.28	95	2	200	0	33
77/229	21.69	432.5	-12.6	568	2.29	95	2	200	0	33
77/229	21.94	432.8	-12.5	567	2.29	85	2	200	0	33
77/229	22.19	432.9	-12.8	566	2.27	85	3	250	0	33
77/229	22.44	432.5	-12.5	552	2.28	85	3	250	0	33
77/229	22.69	432.8	-13.0	557	2.27	85	3	250	0	34
77/229	22.94	433.1	-13.5	552	2.27	85	3	250	0	35
77/229	23.19	433.2	-13.3	549	2.28	85	6	250	0	35
77/229	23.44	434.0	-14.1	547	2.28	85	6	250	0	37
77/229	23.69	434.1	-13.7	543	2.29	85	6	250	0	36
77/229	23.94	434.4	-14.2	539	2.28	85	6	250	0	37
77/229	0.19	434.6	-14.0	535	2.28	85	7	250	0	37
77/229	0.44	434.5	-13.7	534	2.27	85	7	250	0	36
77/229	0.69	434.0	-13.1	530	2.28	85	7	250	0	34
77/229	0.94	434.6	-13.7	526	2.26	85	7	250	0	35
77/229	1.19	435.1	-14.1	526	2.27	85	7	250	0	37
77/229	1.44	434.5	-13.4	524	2.24	85	7	250	0	34
77/229	1.69	434.9	-13.6	520	2.27	85	7	250	0	35
77/229	1.94	435.0	-13.6	516	2.28	85	7	250	0	35
77/229	2.19	434.1	-14.5	512	2.27	85	7	250	0	38
77/229	2.44	433.4	-14.1	505	2.27	85	7	250	0	37
77/229	2.69	433.2	-14.4	499	2.27	85	7	250	0	37
77/229	2.94	432.7	-13.8	497	2.26	85	7	250	0	36
77/229	3.19	432.7	-13.9	493	2.26	85	6	270	0	36
77/229	3.44	433.9	-14.4	492	2.26	85	6	270	0	37
77/229	3.69	434.7	-13.8	496	2.27	85	6	270	0	36
77/229	3.94	436.4	-13.7	500	2.27	85	6	270	0	36
77/229	4.19	437.3	-12.6	504	2.28	81	1	0	0	33
77/229	4.44	435.5	-10.9	506	2.25	81	1	0	0	28
77/229	4.69	433.2	-10.7	502	2.25	81	1	0	0	27
77/229	4.94	434.6	-12.9	497	2.25	81	1	0	0	33
77/229	5.19	436.2	-12.8	496	2.25	81	1	0	0	33
77/229	5.44	436.5	-12.4	496	2.26	81	1	0	0	32
77/229	5.69	435.2	-11.4	496	2.28	81	1	0	0	30
77/229	5.94	435.2	-12.9	493	2.28	81	1	0	0	34
77/229	6.19	435.8	-13.7	489	2.26	81	1	0	0	35

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE
77/229	6.44	436.1	-13.2	486	2.28	81	1	0	0	34
77/229	6.69	436.8	-13.7	484	2.27	81	1	0	0	36
77/229	6.94	436.4	-13.3	484	2.27	81	1	0	0	35
77/229	7.19	431.9	-10.7	745	2.34	81	4	50	0	29
77/229	7.44	433.0	-14.2	716	2.35	81	4	50	0	38
77/229	7.69	433.0	-13.3	695	2.35	81	9	50	0	36
77/229	7.94	432.6	-14.1	682	2.35	81	9	50	0	38
77/229	8.19	431.3	-13.8	667	2.33	81	9	50	0	37
77/229	8.44	430.2	-13.8	655	2.32	81	9	50	0	37
77/229	8.69	430.2	-14.7	647	2.31	81	9	50	0	39
77/229	8.94	430.2	-14.3	642	2.30	81	9	50	0	38
77/229	9.19	430.0	-14.0	636	2.29	77	7	70	0	37
77/230	9.66	422.8	-7.9	634	4.09	73	4	60	0	37
77/230	10.16	422.9	-7.4	628	4.05	72	5	50	0	34
77/230	10.66	441.1	-21.4	812	1.41	72	4	20	0	35
77/230	11.16	442.1	-24.0	822	1.40	71	2	20	0	38
77/230	11.66	441.6	-23.4	795	1.41	72	3	20	0	38
77/230	12.66	424.1	-4.2	797	6.50	71	0	0	0	31
77/230	13.16	426.0	-3.8	799	6.54	73	0	0	0	28
77/230	13.66	425.6	-3.7	786	6.56	73	0	0	0	28
77/230	14.16	425.2	-3.8	776	6.58	79	1	20	0	28
77/231	14.45	430.2	-8.5	814	3.40	84	3	180	0	33
77/231	14.78	431.8	-7.8	813	3.40	84	3	180	0	30
77/231	15.11	430.3	-7.9	801	3.40	84	3	180	0	31
77/231	15.45	430.5	-8.7	789	3.41	84	3	180	0	34
77/231	15.78	430.3	-8.1	782	3.45	84	3	180	0	32
77/231	16.11	430.1	-7.9	776	3.42	84	3	180	0	31
77/231	16.45	430.0	-8.3	768	3.40	84	3	180	0	32
77/231	16.78	429.0	-7.8	759	3.42	84	3	180	0	30
77/231	17.11	428.9	-8.0	751	3.44	84	3	180	0	31
77/231	17.45	428.7	-7.5	742	3.42	84	1	180	0	29
77/231	17.78	429.1	-7.8	737	3.42	84	1	180	0	30
77/231	18.11	429.1	-8.0	730	3.42	84	1	180	0	31
77/231	18.45	429.1	-7.8	724	3.42	77	1	180	0	30
77/231	18.78	429.2	-7.8	718	3.41	77	1	180	0	30
77/231	19.11	429.5	-7.8	711	3.38	77	1	180	0	30
77/231	19.45	429.4	-8.1	708	3.40	77	1	180	0	31
77/231	19.78	429.5	-8.6	699	3.37	77	1	180	0	33
77/231	20.11	430.1	-8.4	697	3.39	77	1	180	0	33
77/231	20.45	430.3	-8.3	694	3.37	77	1	180	0	32
77/231	20.78	430.0	-8.3	688	3.43	77	1	180	0	32
77/231	21.11	430.5	-8.6	686	3.38	77	0	180	0	33
77/231	21.45	430.4	-7.8	681	3.38	77	0	180	0	30
77/231	21.78	430.6	-7.8	681	3.39	77	0	180	0	30
77/231	22.11	430.6	-7.8	676	3.37	77	0	180	0	30
77/231	22.45	430.5	-7.6	672	3.37	77	0	180	0	29
77/231	22.78	430.9	-8.0	669	3.39	77	0	180	0	31
77/231	23.11	430.5	-7.7	663	3.38	77	0	180	0	30
77/231	23.45	430.7	-7.8	661	3.36	77	0	180	0	30
77/231	23.78	430.7	-8.0	655	3.32	77	3	180	0	30
77/231	0.11	430.8	-8.7	650	3.37	77	3	180	0	33

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE
77/231	0.45	430.5	-8.5	647	3.37	77	3	180	0	33
77/231	0.78	430.7	-8.8	641	3.36	77	7	180	0	34
77/231	1.11	430.6	-9.1	637	3.37	77	7	180	0	35
77/231	1.45	430.4	-9.4	632	3.33	77	7	180	0	36
77/231	1.78	430.5	-9.7	628	3.33	77	7	180	0	37
77/231	2.11	430.7	-9.4	626	3.32	77	7	180	0	36
77/231	2.45	430.8	-9.5	623	3.30	77	7	180	0	36
77/231	2.78	430.8	-9.1	622	3.29	77	7	180	0	34
77/231	3.11	430.9	-9.3	621	3.30	77	7	180	0	35
77/231	3.45	430.9	-9.2	619	3.32	77	7	180	0	35
77/231	3.78	431.0	-9.6	617	3.31	77	7	180	0	36
77/231	4.11	430.9	-9.2	616	3.29	77	7	180	0	35
77/231	4.45	430.9	-9.2	614	3.29	77	7	180	0	35
77/231	4.78	431.1	-8.8	614	3.30	77	7	180	0	33
77/231	5.11	430.9	-8.8	613	3.30	77	7	180	0	33
77/231	5.45	430.6	-9.4	607	3.30	79	7	180	0	35
77/231	5.78	430.9	-8.9	604	3.28	79	7	180	0	33
77/231	6.11	430.7	-8.9	604	3.30	79	7	180	0	34
77/231	6.45	430.7	-9.1	602	3.31	81	7	180	0	34
77/231	6.78	430.1	-9.0	599	3.34	81	7	180	0	34
77/231	7.11	429.9	-8.8	597	3.39	81	7	180	0	34
77/231	7.45	429.8	-8.9	596	3.47	85	7	180	0	35
77/231	7.78	429.3	-8.4	599	3.57	85	7	180	0	34
77/234	12.17	420.1	-3.4	508	6.68	97	7	250	327	26
77/234	12.44	421.2	-4.1	511	6.69	98	5	180	327	31
77/234	12.67	429.6	-10.8	626	2.72	99	6	220	327	34
77/234	13.21	415.2	-9.8	582	2.71	97	7	180	327	30
77/234	13.44	418.6	-10.5	565	2.69	99	7	270	327	32
77/234	13.67	418.8	-10.1	556	2.68	96	6	200	327	31
77/234	14.01	422.4	-18.9	673	1.42	99	6	270	327	31
77/234	14.21	425.3	-21.5	660	1.42	97	6	220	327	35
77/234	14.44	426.4	-20.1	647	1.40	98	4	220	327	32
77/234	14.67	427.6	-20.7	640	1.40	97	4	220	327	33
77/235	19.09	411.1	-8.8	610	3.24	97	4	200	0	33
77/235	19.43	411.1	-8.6	609	3.25	97	3	200	0	32
77/235	19.76	411.4	-8.9	607	3.24	97	3	200	0	33
77/235	20.09	411.5	-8.6	607	3.21	97	3	200	0	32
77/235	20.43	411.4	-9.0	605	3.21	89	7	220	0	33
77/235	20.76	412.0	-9.5	602	3.19	89	7	220	0	35
77/235	21.09	412.3	-9.7	601	3.19	89	7	220	0	35
77/235	21.43	412.5	-9.5	599	3.18	89	9	220	0	35
77/235	21.76	412.6	-9.9	598	3.17	89	9	220	0	36
77/235	22.09	412.5	-9.5	596	3.12	89	9	220	0	34
77/235	15.76	409.6	-8.1	646	3.44	97	5	200	56	32
77/235	16.09	409.0	-7.5	635	3.41	97	5	200	56	29
77/235	16.43	408.5	-8.1	628	3.43	97	7	200	56	32
77/235	16.76	408.2	-8.2	622	3.43	97	7	200	56	32
77/235	17.09	408.3	-8.5	618	3.37	97	7	200	56	33
77/235	17.43	408.7	-8.7	614	3.38	97	6	200	56	34
77/235	17.76	408.8	-8.1	611	3.37	97	6	200	56	31
77/235	18.09	409.5	-8.4	611	3.35	97	6	200	56	32

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE (BTU/HR./SQ.FT.)
77/235	18.43	410.0	-8.7	610	3.32	97	4	200	66	33
77/235	18.76	410.2	-8.2	610	3.31	97	4	200	66	31
77/235	*****	413.0	-9.8	596	3.20	89	8	220	0	36
77/235	22.76	413.3	-9.7	595	3.16	89	8	220	0	35
77/235	23.09	413.1	-9.4	593	3.18	89	8	220	0	34
77/235	23.43	413.4	-5.8	593	3.15	79	7	250	0	35
77/235	23.76	413.5	-10.1	590	3.16	79	7	250	0	37
77/235	0.09	413.8	-9.7	590	3.15	79	7	250	0	35
77/235	0.43	413.6	-9.4	589	3.15	79	7	270	0	34
77/235	0.76	414.0	-9.5	589	3.15	79	7	270	0	34
77/235	1.09	414.1	-9.1	588	3.13	79	7	270	0	33
77/235	1.43	414.0	-5.1	587	3.12	79	7	250	0	32
77/235	1.76	413.6	-9.9	583	3.13	79	7	250	0	35
77/235	2.09	414.1	-9.8	581	3.12	79	7	250	0	35
77/235	2.43	414.5	-9.7	581	3.14	79	5	250	0	35
77/235	2.76	414.6	-9.5	581	3.14	79	3	200	0	34
77/235	3.09	414.4	-8.7	582	3.12	79	3	200	0	31
77/235	3.43	414.2	-8.9	581	3.12	79	2	200	0	32
77/235	3.76	414.5	-9.0	580	3.11	79	2	200	0	32
77/235	4.09	414.3	-8.9	578	3.10	79	2	200	0	32
77/235	4.43	414.1	-9.1	576	3.12	79	4	200	0	32
77/235	4.76	414.7	-9.8	574	3.14	79	4	200	0	35
77/235	5.09	414.7	-9.3	572	3.11	79	4	200	0	33
77/235	5.43	414.9	-9.0	573	3.12	79	4	200	0	32
77/235	5.76	414.9	-9.1	573	3.09	79	4	200	0	32
77/235	6.09	414.6	-9.1	571	3.11	79	4	200	0	32
77/235	6.43	414.8	-9.3	570	3.10	79	4	200	0	33
77/236	15.37	386.3	-5.4	608	3.21	89	1	310	0	35
77/236	15.87	394.4	-8.7	591	3.19	89	0	0	0	24
77/236	16.37	391.4	-8.3	563	3.19	89	5	160	0	30
77/236	16.87	392.7	-8.2	557	3.17	89	2	180	0	30
77/236	17.37	392.3	-8.6	553	3.16	89	4	180	0	31
77/236	17.87	393.1	-8.5	551	3.15	89	4	180	0	31
77/236	18.37	392.9	-8.6	549	3.17	89	4	200	0	31
77/236	18.87	393.1	-8.4	549	3.11	89	1	270	0	30
77/236	19.37	392.9	-8.1	547	3.17	89	2	270	0	29
77/236	19.87	393.3	-7.8	546	3.14	89	0	0	0	28
77/236	20.37	393.1	-7.5	545	3.13	89	0	0	0	27
77/236	20.87	393.0	-9.1	538	3.11	89	4	190	0	32
77/236	21.37	394.2	-8.9	538	3.10	89	4	210	0	32
77/236	21.87	393.5	-8.3	537	3.10	89	1	220	0	29
77/236	22.37	393.7	-8.5	535	3.13	89	1	270	0	30
77/236	22.87	394.0	-8.2	535	3.07	89	0	0	0	29
77/236	23.37	393.8	-7.3	535	3.09	79	0	0	0	26
77/236	23.87	393.7	-7.8	532	3.14	79	2	240	0	28
77/236	0.37	394.6	-8.7	529	3.13	79	3	240	0	31
77/236	0.87	394.8	-9.0	527	3.09	79	3	210	0	32
77/236	1.37	394.6	-8.7	525	3.05	79	2	220	0	30
77/236	1.87	394.7	-8.7	524	3.09	79	2	220	0	31
77/236	2.37	394.9	-8.3	523	3.10	79	0	0	0	29
77/236	2.87	394.4	-8.2	521	3.08	79	1	220	0	29

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION	HEAT LOSS RATE (BTU/HR./SQ.FT.)
77/236	3.37	395.0	-9.1	518	3.07	79	4	220	0	32
77/236	3.87	395.0	-8.9	516	3.08	79	4	220	0	31
77/236	4.37	395.3	-9.3	514	3.08	79	4	220	0	33
77/236	4.87	395.6	-9.3	513	3.09	79	4	220	0	33
77/236	5.37	395.9	-9.6	511	3.09	79	4	250	0	34
77/236	5.87	395.5	-8.6	512	3.08	79	2	250	0	30
77/236	6.37	395.2	-8.9	510	3.08	76	4	270	48	31
77/236	10.95	480.9	-7.6	854	3.51	94	0	0	226	30
77/236	11.28	476.9	-7.8	827	3.48	93	1	270	226	31
77/236	11.85	484.1	-17.8	779	1.68	97	2	180	226	34
77/236	12.15	482.5	-19.7	758	1.69	93	2	220	226	38
77/236	12.70	482.3	-20.6	866	1.48	97	4	180	226	35
77/236	13.03	481.9	-22.4	876	1.47	99	3	220	226	38
77/236	13.55	460.7	-6.1	882	4.70	97	3	220	226	33
77/235	13.68	460.1	-6.8	874	4.75	93	3	220	226	37
77/236	14.13	456.4	-4.5	865	6.62	95	1	220	226	34
77/236	14.30	455.2	-4.5	856	6.62	87	4	900	226	34
77/237	15.02	428.9	-18.1	706	2.34	99	7	200	119	49
77/237	15.36	421.4	-10.3	694	2.30	99	7	200	119	27
77/237	15.69	424.3	-15.1	684	2.31	99	7	200	119	40
77/237	16.02	423.7	-13.0	685	2.30	99	7	200	119	34
77/237	16.36	423.3	-13.0	682	2.28	99	7	200	119	34
77/237	16.69	423.3	-13.7	676	2.29	94	8	200	119	36
77/237	17.02	423.7	-13.9	674	2.27	94	8	200	119	36
77/237	17.36	423.4	-13.5	672	2.29	94	8	200	119	35
77/237	17.69	423.9	-13.8	670	2.24	94	8	200	119	35
77/237	18.02	424.7	-14.7	667	2.26	94	7	200	119	38
77/237	18.36	425.2	-14.1	668	2.25	94	7	200	0	36
77/237	18.69	425.5	-13.6	668	2.20	89	4	200	0	34
77/237	19.02	426.2	-13.7	667	2.21	89	4	250	0	35
77/237	19.36	426.1	-14.6	662	2.22	89	9	250	0	37
77/237	19.69	426.4	-15.6	657	2.20	89	9	250	0	39
77/237	20.02	426.9	-15.1	655	2.18	89	9	250	0	38
77/237	20.36	427.7	-15.3	653	2.21	87	9	250	0	39
77/237	20.69	427.7	-15.3	651	2.19	87	9	250	0	38
77/237	21.02	427.3	-15.6	646	2.16	87	9	250	0	39
77/237	21.36	427.4	-15.6	642	2.18	87	9	250	0	39
77/237	21.69	427.7	-15.6	639	2.18	85	9	250	0	39
77/237	22.02	427.6	-16.4	633	2.17	85	9	250	0	41
77/237	22.36	427.1	-15.6	629	2.16	85	9	250	0	39
77/237	22.69	427.5	-15.9	626	2.14	85	9	250	0	39
77/237	23.02	426.5	-15.2	622	2.15	85	9	250	0	37
77/237	23.36	426.4	-15.5	617	2.14	85	9	250	0	38
77/237	23.69	426.1	-15.1	615	2.11	82	9	250	0	36
77/237	0.02	426.0	-15.4	611	2.16	82	9	250	0	38
77/237	0.36	425.3	-15.8	605	2.15	82	9	250	0	39
77/237	0.69	424.3	-15.8	599	2.12	79	9	250	0	38
77/237	1.02	423.2	-15.2	594	2.12	79	9	250	0	37
77/237	1.36	422.9	-15.5	589	2.11	79	9	250	0	37
77/237	1.69	422.7	-15.5	586	2.[illegible]	79	9	250	0	38
7 7	2.02	423.0	-15.3	584	2.	79	9	250	0	3[illegible]

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE (BTU/HR./SQ.FT.)
77/237	2.36	423.3	-15.1	584	2.12	79	9	250	0	37
77/237	2.69	423.5	-15.1	582	2.13	77	9	250	0	37
77/237	3.02	423.4	-15.3	580	2.11	77	9	250	0	37
77/237	3.36	423.7	-15.9	577	2.09	77	6	250	0	38
77/237	3.69	423.7	-15.6	575	2.10	77	6	250	0	38
77/237	4.02	424.1	-15.6	573	2.09	77	6	250	0	37
77/237	4.36	423.9	-15.8	570	2.11	77	6	250	15	38
77/237	4.69	423.8	-15.5	567	2.09	75	6	250	15	37
77/237	5.02	423.8	-15.7	565	2.10	75	6	250	15	38
77/237	5.36	423.9	-15.4	564	2.10	75	6	250	15	37
77/237	5.69	425.0	-15.5	565	2.09	75	6	250	15	37
77/237	6.02	425.5	-15.6	566	2.09	79	6	250	15	37
77/237	6.36	426.3	-15.8	566	2.08	79	6	250	15	38
77/237	6.69	426.3	-16.0	564	2.10	79	6	250	15	39
77/238	7.45	426.3	-16.4	563	2.10	79	9	250	158	39
77/238	7.79	425.5	-16.1	563	2.13	79	9	250	158	39
77/238	8.24	417.7	-9.1	569	3.54	79	9	250	158	37
77/238	8.44	417.3	-9.2	565	3.60	85	9	250	158	38
77/243	15.43	403.1	-16.9	590	2.06	94	7	160	64	40
77/243	15.76	407.3	-14.7	554	2.06	94	6	160	64	35
77/243	16.10	404.5	-11.8	520	2.03	94	9	160	64	27
77/243	16.43	404.7	-13.8	488	2.01	94	7	160	64	32
77/243	16.76	405.5	-13.9	460	1.95	93	7	160	64	31
77/243	17.10	406.5	-15.4	436	1.97	93	6	160	64	35
77/243	17.43	407.7	-16.3	416	1.94	93	5	160	64	36
77/243	17.76	407.8	-16.3	396	1.92	93	7	160	64	36
77/243	18.10	408.5	-16.6	380	1.91	93	7	160	64	36
77/243	18.43	408.9	-15.5	370	1.91	93	4	160	64	34
77/243	18.76	409.7	-15.6	368	1.93	89	3	160	0	35
77/243	19.10	408.8	-14.1	366	1.92	89	3	160	0	31
77/243	19.43	409.0	-14.5	364	1.94	89	3	160	0	32
77/243	19.76	409.1	-14.9	361	1.92	89	5	180	0	33
77/243	20.10	409.8	-15.5	357	1.92	89	4	180	0	34
77/243	20.43	410.1	-15.0	354	1.96	89	4	180	0	34
77/243	20.76	410.0	-15.7	350	1.91	85	7	200	0	34
77/243	21.10	411.5	-16.2	347	1.93	85	7	200	0	36
77/243	21.43	412.0	-16.4	347	1.90	85	6	200	0	36
77/243	21.76	411.7	-15.7	346	1.93	85	4	200	0	35
77/243	22.10	412.1	-15.8	345	1.94	85	2	200	0	35
77/243	22.43	411.4	-15.1	344	1.90	85	2	180	0	33
77/243	22.76	411.6	-15.9	340	1.93	83	3	180	0	35
77/243	23.10	413.1	-15.7	338	1.92	83	3	180	0	35
77/243	23.43	413.0	-16.4	336	1.90	83	5	180	0	36
77/243	23.76	413.5	-15.8	334	1.94	83	5	180	0	35
77/243	0.10	415.0	-16.5	332	1.91	83	4	180	0	36
77/243	0.43	414.1	-15.0	332	1.92	81	3	180	0	33
77/243	0.76	413.7	-15.1	330	1.90	81	4	180	0	33
77/243	1.10	414.3	-15.4	328	1.91	81	3	180	0	34
77/243	1.43	415.0	-15.9	327	1.91	81	4	180	0	35
77/243	1.76	414.9	-14.5	327	1.86	79	2	180	0	31
77/243	2.10	414.0	-13.9	325	1.89	79	1	160	0	30

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE (BTU/HR./SQ.FT.)
77/243	2.43	414.8	-15.7	322	1.89	79	4	160	0	34
77/243	2.76	416.4	-15.5	322	1.89	79	1	110	0	34
77/243	3.10	414.7	-13.2	321	1.90	77	2	110	0	29
77/243	3.43	414.9	-15.6	317	1.91	77	2	110	0	34
77/243	3.76	417.1	-16.4	315	2.01	77	3	110	0	38
77/243	4.10	416.7	-14.6	315	1.90	75	2	110	0	32
77/243	4.43	414.7	-14.4	314	1.91	75	2	110	0	31
77/243	4.76	416.1	-15.9	311	1.99	75	2	110	0	36
77/243	5.10	416.4	-13.9	311	1.91	75	1	130	0	30
77/243	5.43	413.5	-12.1	311	1.88	76	0	130	0	26
77/243	5.76	414.3	-16.0	305	1.90	76	2	130	0	35
77/243	6.10	418.3	-16.1	305	2.09	76	3	130	0	39
77/243	6.43	418.2	-14.4	307	2.07	79	4	130	0	34
77/244	6.78	419.7	-15.7	418	2.00	84	3	180	90	36
77/244	7.11	420.1	-15.9	417	2.02	84	3	180	90	37
77/244	7.44	420.2	-16.0	416	1.98	84	3	180	90	36
77/244	7.78	420.6	-16.1	415	1.96	84	3	180	90	36
77/244	8.11	420.7	-16.4	415	1.97	84	3	180	90	37
77/244	8.44	420.9	-17.0	413	1.97	86	3	180	90	38
77/244	8.48	421.1	-17.0	413	1.96	86	3	180	90	38
77/244	8.56	421.3	-16.8	413	1.93	86	3	180	90	37
77/244	8.64	421.1	-16.3	413	1.94	86	3	180	90	36
77/244	8.73	421.1	-16.4	413	1.95	86	3	180	90	37
77/244	8.81	421.5	-16.8	413	1.95	86	3	180	180	38
77/244	8.89	421.6	-16.4	414	1.94	86	3	180	180	36
77/244	9.23	422.3	-16.4	416	1.99	86	3	180	180	37
77/244	9.56	423.2	-16.2	419	1.93	91	3	180	180	36
77/244	9.89	424.5	-16.3	423	1.98	91	3	180	180	37
77/244	10.23	425.7	-17.0	422	1.97	91	3	180	180	38
77/244	10.56	426.5	-16.4	428	1.99	93	3	180	180	37
77/244	10.89	427.2	-15.9	473	2.01	93	3	180	180	37
77/244	11.23	428.1	-16.1	474	2.00	93	3	180	180	37
77/244	11.56	428.4	-15.6	474	1.96	94	3	180	180	35
77/244	11.89	422.9	-11.2	480	3.16	96	3	180	270	41
77/244	12.23	423.1	-9.0	483	3.09	96	3	180	270	32
77/244	12.56	423.4	-9.3	483	3.20	96	3	180	270	34
77/244	12.89	423.7	-9.0	484	3.21	96	3	180	270	33
77/244	13.23	419.1	-4.2	742	6.58	96	7	180	270	32
77/244	13.56	418.7	-4.2	730	6.61	96	7	180	270	32
77/244	13.89	417.9	-4.5	719	6.60	96	7	180	270	34
77/244	14.23	417.5	-4.4	711	6.62	96	7	180	270	33
77/244	14.56	416.7	-4.4	703	6.62	96	7	180	270	33
77/244	14.89	416.9	-4.0	699	6.62	96	7	180	270	30
77/244	15.23	398.3	7.4	671	2.06	96	7	180	110	-17
77/244	15.56	377.7	-1.3	620	2.04	95	7	180	110	3
77/244	15.89	358.0	-2.5	569	2.03	95	7	180	110	5
77/244	16.23	376.2	-16.7	538	2.04	95	7	180	110	39
77/244	16.56	379.8	-12.3	522	2.06	92	6	180	110	29
77/244	16.89	373.9	-9.9	503	2.04	92	6	180	110	23
77/244	17.23	376.2	-14.6	486	2.[illegible]	92	6	180	110	3[illegible]
[illegible]44	17.56	377.8	-12.5	479	2[illegible]	90	6	180	110	2

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE (BTU/HR./SQ.FT.)
77/244	17.89	377.2	-11.9	476	2.05	90	6	180	110	28
77/244	18.23	376.9	-11.6	472	2.04	90	6	180	110	27
77/244	18.56	377.6	-11.7	470	2.02	88	1	180	0	27
77/244	18.89	377.9	-12.0	469	2.02	88	1	180	0	28
77/244	19.23	377.8	-11.7	468	2.00	88	1	180	0	27
77/244	19.56	378.0	-11.7	467	1.99	88	0	0	0	27
77/244	19.89	377.8	-11.2	466	2.00	88	0	0	0	26
77/244	20.23	378.1	-11.8	464	1.99	88	0	0	0	27
77/244	20.56	378.6	-11.4	463	2.00	83	0	0	0	26
77/244	20.89	378.4	-12.1	462	2.00	83	0	0	0	28
77/244	21.23	379.1	-12.9	459	2.00	83	0	0	0	30
77/244	21.56	379.7	-12.7	458	2.02	83	2	180	0	29
77/244	21.89	379.5	-12.4	457	1.98	83	2	180	0	28
77/244	22.23	379.5	-12.8	456	2.00	83	2	180	0	29
77/244	22.56	380.1	-13.6	455	2.01	80	4	180	0	31
77/244	22.89	380.6	-14.0	453	2.00	80	4	180	0	32
77/244	23.23	380.2	-12.5	453	2.00	80	4	180	0	29
77/244	23.56	379.7	-12.2	453	2.01	80	2	180	0	28
77/244	23.89	379.9	-12.4	452	2.00	80	2	180	0	28
77/244	0.23	380.2	-12.4	451	2.01	80	2	180	0	29
77/244	0.56	379.7	-11.4	450	1.99	79	0	0	0	26
77/244	0.89	380.1	-12.3	449	1.97	79	0	0	0	28
77/244	1.23	379.9	-12.2	448	1.99	79	0	0	0	28
77/244	1.56	379.6	-12.0	446	1.99	77	0	0	0	27
77/244	1.89	380.1	-11.7	445	2.00	77	0	0	0	27
77/244	2.23	380.0	-11.1	426	1.99	77	0	0	0	25
77/244	2.56	379.9	-10.8	445	2.00	75	0	0	0	25
77/244	2.89	379.8	-10.6	445	1.99	75	0	0	0	24
77/244	3.06	379.8	-11.0	444	1.99	75	0	0	0	25
77/244	3.56	379.8	-10.9	442	1.99	73	0	0	0	25
77/244	3.89	380.0	-10.2	442	1.99	75	0	0	0	23
77/244	4.23	380.0	-10.7	442	1.98	75	0	0	0	24
77/244	4.56	380.0	-10.4	442	1.98	75	0	0	0	24
77/244	4.89	380.7	-11.2	441	1.96	75	0	0	0	25
77/244	5.23	380.7	-11.1	441	1.97	75	0	0	0	25
77/244	5.55	380.5	-10.9	441	1.96	77	0	0	0	24
77/244	5.89	380.6	-10.9	440	1.97	77	0	0	0	25
77/244	6.23	380.4	-10.4	442	1.97	77	0	0	0	23
77/277	15.66	416.3	-31.0	768	2.01	79	7	180	40	72
77/277	16.16	419.1	-17.9	740	2.01	79	7	180	40	41
77/277	16.66	423.1	-16.0	733	2.01	79	7	180	40	37
77/277	17.16	426.9	-16.4	731	1.99	77	7	180	40	37
77/277	17.66	429.8	-16.7	728	1.96	77	7	180	40	37
77/277	18.16	429.7	-14.6	726	1.94	77	7	180	40	32
77/277	18.66	429.7	-16.1	713	1.92	77	7	180	40	35
77/277	19.16	430.8	-16.2	703	1.90	75	7	180	40	35
77/277	19.66	430.9	-16.3	693	1.90	75	7	180	40	35
77/277	20.16	431.0	-16.7	683	1.89	75	7	180	40	36
77/277	20.66	431.1	-16.1	676	1.88	72	7	180	0	35
77/277	21.16	430.8	-16.3	664	1.89	72	7	180	0	35
77/277	21.66	430.8	-16.1	657	1.85	72	7	180	0	34

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   DATE          SOLAR       INLET     TEMP.    PRESSURE    FLOW    AMBIENT    WIND      WIND        TOTAL        HEAT LOSS
                 TIME        TEMP.     DIFF.                RATE     TEMP.     SPEED     DIR.      RADIATION        RATE
(YEAR/DAY)    (DEC.HRS.)     (F)       (F)        (PSI)     (GPM)     (F)      (MPH)    (DEG.)        (BTU/HR./SQ.FT.)

  77/277        22.16       431.5     -16.2       652       1.86       72        7        180           0            34
  77/277        *****       430.5     -16.0       645       1.85       69        7        180           0            34
  77/277        23.16       431.9     -17.4       635       1.83       69        7        180           0            36
  77/277        23.66       431.5     -16.7       629       1.83       69        7        180           0            35
  77/277         0.16       431.9     -17.8       619       1.82       68        7        190           0            37
  77/277         0.66       432.5     -18.6       611       1.74       68        9        180           0            37
  77/277         1.16       432.9     -18.8       602       1.81       68        9        180           0            39
  77/277         1.66       433.3     -18.8       597       1.82       67        9        180           0            39
  77/277         2.16       433.4     -18.7       592       1.82       67        9        180           0            39
  77/277         2.66       433.3     -18.1       589       1.80       67        9        180           0            37
  77/277         3.16       433.7     -18.6       582       1.80       65        7        180           0            38
  77/277         3.66       433.8     -17.8       578       1.78       65        7        180           0            36
  77/277         4.16       433.4     -17.7       573       1.76       65        7        180           0            36
  77/277         4.66       433.6     -17.2       569       1.77       64        7        180           0            35
  77/277         5.16       433.5     -17.0       565       1.77       64        7        180           0            34
  77/277         5.66       433.3     -16.2       562       1.77       64        7        180           0            33
  77/277         6.16       433.3     -17.4       555       1.77       67        7        180           0            35
  77/277         6.66       433.9     -17.8       551       1.78       67        7        180           0            36
  77/277         7.16       433.7     -17.3       547       1.75       69        7        180           0            35
  77/278        15.23       433.6     -14.1       742       2.17       79        4         90          80            35
  77/278        15.73       430.9     -14.2       722       2.13       79        4         90          80            35
  77/278        16.23       432.5     -14.5       709       2.12       79        4         90          80            35
  77/278        16.73       432.3     -13.4       702       2.08       79        4         90          80            32
  77/278        17.23       432.1     -14.2       686       2.07       79        4         90          80            34
  77/278        17.73       432.8     -15.0       673       2.07       79        4         90          80            35
  77/278        18.23       432.7     -14.5       662       2.06       79        4         90          80            34
  77/278        18.73       433.7     -16.4       647       2.05       79        4         90          80            38
  77/278        19.23       433.6     -14.7       641       2.07       79        4         90          80            35
  77/278        19.73       434.3     -15.3       634       2.04       79        4         90          80            36
  77/278        20.23       433.9     -15.2       625       2.05       79        4         90           0            36
  77/278        20.73       434.4     -15.8       617       2.03       79        4         90           0            37
  77/278        21.23       434.5     -16.0       608       2.03       79        4         90           0            37
  77/278        21.73       434.9     -15.2       606       2.05       79        4         90           0            36
  77/278        22.23       434.3     -15.1       597       2.02       79        4         90           0            35
  77/278        22.73       434.8     -15.6       587       2.03       79        4         90           0            36
  77/278        23.23       434.4     -14.8       582       2.03       79        4         90           0            34
  77/278        23.73       434.9     -15.3       575       2.01       79        4         90           0            35
  77/278         0.23       434.8     -14.9       571       2.03       79        4         90           0            35
  77/278         0.73       435.0     -15.1       566       2.03       79        4         90           0            35
  77/278         1.23       434.5     -14.6       559       2.02       79        4         90           0            34
  77/278         1.73       434.7     -14.6       554       2.02       79        4         90           0            34
  77/278         2.23       435.1     -15.0       550       2.00       79        4         90           0            34
  77/278         2.73       434.4     -14.1       544       2.02       79        4         90           0            32
  77/278         3.23       435.1     -14.8       540       2.01       79        4         90           0            34
  77/278         3.73       435.0     -14.5       534       2.01       79        4         90           0            33
  77/279         9.49       435.3     -24.8       429       1.18       63        0          0          84            33
  77/279         9.83       439.4     -27.6       444       1.17       65        0          0          84            37
  77/279        10.06       441.9     -26.9       451       1.18       66        0          0          84            36
  77/279        10.61       418.2      -8.1       463       2.35       69        1         90          84            26
  77/279        10.84       419.1      -5.9       455       2.[illegible]       71        1         90          84            3[illegible]
  7[illegible]9        11.51       415.4      -5.5       463       [illegible]       75        1         90          84            3[illegible]
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DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE (BTU/HR./SQ.FT.)
77/280	11.65	362.7	-4.4	297	4.94	83	7	180	225	25
77/280	11.92	363.6	-4.7	296	4.98	85	7	180	225	27
77/280	12.25	367.6	-8.6	287	3.20	85	7	180	225	32
77/280	12.45	369.3	-7.8	288	3.15	85	7	180	225	28
77/280	12.65	367.5	-6.4	289	3.21	85	7	180	225	23
77/280	13.32	381.9	-21.4	279	1.34	85	7	180	225	33
77/280	13.65	381.9	-18.1	279	1.34	85	7	180	225	28
77/280	13.99	377.9	-15.8	279	1.34	85	7	180	225	24
77/294	12.89	468.1	-7.5	702	2.99	81	7	180	98	25
77/294	13.05	466.1	-10.4	678	3.00	81	9	150	98	36
77/294	13.22	465.8	-10.7	661	3.01	81	7	160	98	37
77/294	13.35	464.9	-10.9	649	3.01	83	9	160	98	37
77/294	13.57	458.3	-5.2	631	4.94	84	6	160	98	29
77/294	13.74	457.5	-5.6	624	4.92	81	7	130	98	31
77/294	13.90	456.5	-5.8	617	4.95	81	4	100	98	33
77/294	14.30	473.7	-21.6	609	1.35	81	5	130	98	33
77/294	14.47	473.2	-23.1	600	1.34	83	6	180	98	35
77/294	14.64	473.6	-24.4	591	1.36	83	6	180	98	38
77/298	15.72	413.2	-3.0	759	2.12	79	0	0	0	7
77/298	16.22	384.3	-2.5	655	2.19	79	0	0	0	6
77/298	16.72	358.1	-2.7	583	2.15	75	0	0	0	6
77/298	17.22	347.8	-14.5	525	2.13	75	0	0	0	36
77/298	17.72	357.5	-7.2	491	2.08	75	0	0	0	17
77/298	18.22	355.4	-9.7	456	2.08	69	0	0	0	23
77/298	18.72	354.9	-8.8	430	2.08	69	0	0	0	21
77/298	19.22	354.6	-9.3	408	2.05	69	0	0	0	22
77/298	19.72	354.6	-9.7	392	2.06	64	0	0	0	23
77/298	20.22	354.6	-9.2	383	2.08	64	0	0	0	22
77/298	20.72	355.7	-9.8	379	2.06	64	0	0	0	23
77/298	21.22	355.9	-9.7	376	2.07	64	0	0	0	23
77/298	21.72	355.9	-8.9	375	2.08	64	0	0	0	21
77/298	22.22	355.7	-9.0	371	2.09	64	0	0	0	21
77/298	*****	356.0	-9.5	367	2.08	64	3	180	0	23
77/298	23.22	356.2	-9.6	365	2.05	64	3	180	0	23
77/298	23.72	356.2	-9.8	362	2.06	64	3	180	0	23
77/298	0.22	356.7	-10.5	359	2.05	64	3	180	0	25
77/298	0.72	357.2	-10.9	357	2.07	64	3	180	0	26
77/298	1.22	356.8	-10.0	357	2.07	64	3	180	0	24
77/298	1.72	356.5	-10.1	354	2.04	64	3	180	0	24
77/298	2.22	357.1	-10.7	352	2.08	64	3	180	0	26
77/298	2.72	357.1	-10.5	350	2.08	64	3	180	0	25
77/298	3.22	357.1	-10.8	348	2.07	64	3	180	0	26
77/298	3.72	357.9	-10.8	347	2.06	64	3	180	0	26
77/298	4.22	357.3	-10.6	346	2.06	64	3	180	0	25
77/298	4.72	357.4	-10.3	344	2.08	64	3	180	0	25
77/298	5.22	357.3	-10.2	343	2.06	64	3	180	0	24
77/298	5.72	357.1	-10.2	342	2.06	64	3	180	0	24
77/298	6.22	357.1	-10.0	340	2.04	64	3	180	0	23
77/298	6.72	357.2	-10.5	338	2.06	69	3	180	18	25
77/298	7.22	356.7	-10.0	337	2.08	69	3	180	18	24
77/300	13.10	419.5	-14.4	470	1.92	77	6	210	48	32

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE
77/300	13.18	419.8	-15.5	468	1.92	77	6	210	48	34
77/300	13.27	421.1	-17.2	467	1.94	77	6	210	48	38
77/300	13.35	422.5	-18.0	466	1.93	77	6	210	48	40
77/300	13.43	422.8	-16.7	465	1.91	77	6	210	48	36
77/300	13.52	423.1	-16.0	466	1.91	77	6	210	48	35
77/300	13.60	423.7	-16.4	467	1.91	77	6	210	48	36
77/300	13.68	424.4	-16.7	467	1.91	77	6	210	48	36
77/300	13.77	425.0	-16.5	468	1.91	77	6	210	48	36
77/300	13.85	425.7	-16.6	469	1.92	78	6	210	48	36
77/300	13.93	426.1	-16.4	470	1.89	78	6	210	38	35
77/300	14.02	426.8	-16.5	471	1.91	78	6	210	38	36
77/300	14.10	427.3	-16.7	473	1.89	78	6	210	38	36
77/300	14.18	427.9	-17.0	474	1.89	78	6	210	38	37
77/300	14.27	428.7	-17.4	475	1.88	77	6	210	38	37
77/300	14.35	429.4	-18.2	477	1.87	77	6	210	38	39
77/300	14.43	429.7	-16.8	478	1.87	77	5	210	38	36
77/300	14.52	430.3	-16.7	480	1.87	77	5	210	38	36
77/300	14.60	431.3	-17.4	481	1.86	77	5	210	38	37
77/300	14.68	432.1	-17.4	483	1.84	75	4	200	38	37
77/300	14.77	432.8	-17.3	485	1.84	75	4	200	33	36
77/301	10.72	424.3	-16.2	640	1.41	79	6	240	80	26
77/301	11.22	431.5	-17.7	640	1.37	79	6	240	80	28
77/301	11.72	436.3	-18.9	641	1.37	79	6	240	80	29
77/301	12.22	440.1	-19.9	641	1.35	79	6	240	80	31
77/301	12.72	442.6	-18.8	640	1.33	79	6	240	80	28
77/301	13.22	444.9	-18.9	638	1.33	79	6	240	80	29
77/301	13.72	447.2	-19.7	631	1.31	79	6	240	80	29
77/301	14.22	449.1	-20.1	627	1.32	79	6	240	80	30
77/301	14.72	450.9	-20.2	624	1.31	79	6	240	80	30
77/301	15.05	451.9	-19.7	621	1.30	79	6	240	80	29
77/305	9.30	212.3	-9.5	101	2.62	59	9	210	0	30
77/305	9.80	240.9	-10.0	100	2.64	59	12	190	0	31
77/305	10.30	265.3	-10.8	103	2.67	59	9	190	0	34
77/305	10.80	285.7	-11.0	111	2.67	61	11	190	0	34
77/305	11.30	303.0	-10.3	123	2.74	61	7	180	0	33
77/305	11.80	317.6	-8.7	229	2.78	61	6	180	0	28
77/305	12.30	332.7	-9.9	245	2.82	61	6	180	0	32
77/305	12.80	345.3	-10.1	268	2.81	59	6	210	0	33
77/305	13.30	355.7	-10.0	290	2.82	59	7	210	0	32
77/305	13.80	364.5	-10.0	309	2.83	59	3	240	0	33
77/305	14.30	373.5	-10.4	330	2.82	59	1	260	0	34
77/305	14.80	381.9	-9.9	351	2.83	59	0	260	0	32
77/305	15.30	390.8	-10.1	375	2.81	59	0	260	0	33
77/305	15.80	399.0	-10.2	359	2.84	62	0	260	0	33
77/306	9.32	286.1	3.8	98	6.60	54	14	300	95	-29
77/306	9.79	334.7	-2.4	144	6.70	54	14	300	95	18
77/306	10.29	358.7	5.2	337	6.78	54	14	300	95	-41
77/306	10.79	409.7	2.0	469	6.80	54	14	300	95	-15
77/306	11.29	425.1	-3.3	538	6.81	59	14	300	95	26
77/	11.79	439.2	-7.3	564	4.01	59	14	300	95	33
77/	12.29	436.1	-8.5	545	3.97	59	14	300	95	39

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE
77/306	12.79	431.7	-8.4	524	3.96	54	14	300	95	38
77/306	13.29	427.5	-8.7	503	3.91	54	14	300	95	39
77/306	13.79	425.1	-7.9	491	3.88	54	14	300	95	35
77/306	14.29	424.3	-8.0	485	3.89	54	9	300	0	36
77/306	14.79	422.4	-8.1	475	3.87	54	9	300	0	36
77/306	15.29	420.7	-8.0	467	3.85	54	9	300	0	35
77/306	15.79	420.5	-8.3	462	3.84	52	9	300	0	36
77/306	16.16	402.0	10.3	650	3.82	52	9	300	0	-45
77/306	16.66	370.7	-1.2	566	3.92	52	9	300	0	5
77/306	17.16	341.3	-1.5	490	3.82	52	9	300	0	6
77/306	17.66	315.3	-1.2	432	3.80	52	9	300	0	5
77/306	18.16	325.8	-3.7	407	3.78	52	9	300	0	16
77/306	18.66	325.1	-5.2	383	3.80	52	9	300	0	23
77/306	19.16	324.7	-4.8	365	3.76	50	0	300	0	21
77/306	19.66	324.3	-4.7	352	3.78	50	0	300	0	20
77/306	20.16	324.5	-5.1	344	3.78	50	0	300	0	22
77/306	20.66	324.5	-5.2	338	3.78	50	0	300	0	23
77/306	21.16	324.7	-5.0	335	3.82	50	0	300	0	22
77/306	21.66	324.6	-4.6	332	3.81	50	0	300	0	20
77/306	22.16	324.4	-4.4	328	3.79	50	0	300	0	19
77/306	22.66	324.7	-4.6	325	3.79	50	0	300	0	20
77/306	23.16	324.7	-4.8	322	3.79	50	0	300	0	21
77/306	23.66	324.5	-4.3	318	3.79	50	0	300	0	19
77/307	0.15	324.7	-4.6	316	3.78	50	4	300	0	20
77/307	0.65	324.7	-4.8	314	3.76	50	4	300	0	21
77/307	1.15	324.9	-4.9	312	3.77	50	4	300	0	21
77/307	1.65	324.9	-4.8	311	3.78	50	4	300	0	21
77/307	2.15	324.9	-4.8	309	3.75	50	4	300	0	21
77/307	2.65	325.1	-5.0	307	3.76	50	4	300	0	22
77/307	3.15	325.0	-5.2	306	3.74	50	4	300	0	22
77/307	3.65	325.1	-5.2	305	3.73	50	4	300	0	22
77/307	4.15	325.1	-5.2	304	3.74	50	4	300	0	22
77/307	4.65	325.1	-5.1	304	3.74	50	4	300	0	22
77/307	5.15	325.1	-5.0	303	3.74	50	4	300	0	21
77/307	5.65	325.1	-5.0	303	3.75	50	4	300	0	22
77/307	6.15	325.2	-5.1	301	3.75	50	4	300	0	22
77/307	6.65	325.3	-5.2	301	3.76	50	4	300	0	22
77/307	7.15	324.9	-4.7	301	3.78	50	4	300	0	20
77/307	7.65	324.6	-4.7	298	3.81	50	4	300	0	21
77/307	8.15	323.8	-4.5	296	3.85	50	4	300	0	20
77/311	12.32	414.5	-14.6	413	1.91	72	9	180	30	32
77/311	12.82	417.1	-16.3	505	1.95	72	9	180	30	36
77/311	13.32	419.5	-17.0	496	1.93	75	12	180	30	38
77/311	13.82	421.6	-17.1	492	1.90	75	12	180	30	37
77/311	14.32	424.2	-17.9	491	1.90	75	9	180	30	39
77/311	14.99	366.1	-4.0	626	1.93	75	9	180	30	9
77/311	15.49	360.9	-25.6	556	1.97	75	9	180	30	58
77/311	15.99	364.7	-10.8	532	1.96	69	9	180	30	24
77/311	16.49	362.2	-12.5	501	1.95	69	9	180	30	28
77/311	16.99	363.3	-12.3	477	1.90	69	9	180	30	27
77/312	9.01	370.0	-15.8	291	1.81	51	0	0	116	33

DATE (YEAR/DAY)	SOLAR TIME (DEC.HRS.)	INLET TEMP. (F)	TEMP. DIFF. (F)	PRESSURE (PSI)	FLOW RATE (GPM)	AMBIENT TEMP. (F)	WIND SPEED (MPH)	WIND DIR. (DEG.)	TOTAL RADIATION (BTU/HR./SQ.FT.)	HEAT LOSS RATE
77/312	9.51	379.4	-15.3	311	1.80	51	0	0	116	32
77/312	10.01	388.6	-15.7	332	1.81	51	0	0	116	33
77/312	10.51	396.3	-17.1	352	1.82	51	1	90	116	36
77/312	11.01	402.4	-16.9	367	1.83	51	3	90	116	35
77/312	11.51	409.8	-15.9	389	1.82	51	3	210	116	33
77/312	12.01	417.6	-15.8	408	1.86	51	3	210	116	34
77/312	12.51	424.1	-15.4	429	1.87	51	3	210	116	33
77/312	13.01	429.5	-15.8	444	1.86	51	3	210	116	34
77/312	13.51	434.3	-17.0	454	1.86	59	5	220	116	36
77/312	14.01	436.5	-16.4	461	1.89	61	4	220	160	35
77/312	14.51	439.1	-16.3	467	1.87	63	5	220	160	35
77/312	15.01	440.8	-17.2	467	1.87	63	2	220	160	37
77/312	15.51	441.3	-17.0	464	1.85	63	3	220	160	36
77/312	17.51	362.5	-12.0	454	1.86	69	9	180	0	26
77/312	18.01	362.5	-12.4	432	1.87	69	9	180	0	27
77/312	18.51	363.5	-13.4	419	1.86	69	9	180	0	29
77/312	19.01	363.6	-12.9	410	1.86	64	9	180	0	28
77/312	19.51	364.0	-13.0	404	1.85	64	9	180	0	28
77/312	20.01	363.9	-13.2	397	1.88	59	9	180	0	28
77/312	20.51	363.9	-13.6	390	1.86	59	9	180	0	29
77/312	21.01	364.4	-13.5	383	1.88	54	9	180	0	29
77/312	21.51	364.1	-13.2	379	1.87	54	9	180	0	28
77/312	22.01	363.8	-12.7	374	1.87	54	9	180	0	27
77/312	22.51	364.5	-14.0	368	1.86	54	9	180	0	30
77/312	23.01	364.2	-12.4	364	1.87	54	6	180	0	27
77/312	23.51	364.3	-13.4	359	1.87	54	6	180	0	29
77/312	0.01	364.1	-12.0	357	1.86	54	6	180	0	26
77/312	0.51	363.6	-12.3	352	1.85	54	6	180	0	26
77/312	1.01	364.7	-14.7	346	1.85	54	6	330	0	31
77/312	1.51	366.1	-14.6	345	1.86	54	6	330	0	31
77/312	2.01	366.2	-13.7	339	1.87	54	6	330	0	29
77/312	2.51	366.0	-13.3	335	1.82	54	6	330	0	28
77/312	3.01	366.9	-15.9	325	1.85	54	6	330	0	34

APPENDIX F

1. CAPITAL COSTS

Capital costs for the conceptual design were estimated using the cost structure presented below. Capital costs include all direct and indirect costs associated with equipment, materials, labor, and A/E management. Also included are the costs of spare parts, contingencies, and escalation.

The terms used to describe the cost items should be those used for standard fossil-fuel power plants. Listed below are the definitions for the major solar equipment:

Collector - A mechanical device that collectors solar radiation and concentrates it by optically focusing it on a relatively small area.

Receiver - A mechanical device that collects solar radiation of a collector. The receiver absorbs the radiation and transfers its energy to a heat-transfer fluid flowing through it.

Collector/Receiver - A combined collector and receiver working as a unit.

Module - A complete unit including collector/receiver, tracking drive and controller, and associated plumbing. The unit should be a representation of a small part of a large field of solar energy collecting devices.

Total Direct Cost - Includes material, purchased parts, and shop labor, but excludes one-time engineering and tooling costs.

2. OPERATIONS AND MAINTENANCE COSTS

Operating costs include administration, supplies, and operators' salaries, including benefits, insurance and taxes. Maintenance costs include preventive, corrective, and utility maintenance, such as collector array washing.

Operations and maintenance (O&M) estimates are separated into two parts: operational and experimental. Sample summary tables of total cost estimates for the first year operations, aterials and spare parts are included. These items are further broken down in other sample tables. Although these samples are provided only for guidance, the categories should be followed at least to the second level.

Replacement items and costs should be tabulated by the years of occurrence.

Requirements associated with maintenance of turbomachinery, service for the fluid transfer equipment, and cleaning and maintenance of the mirror surfaces and collector field should be analyzed.

FORMAT A

SUMMARY OF CAPITAL COSTS

	SYSTEM	EXPERIMENTAL	
Direct Costs			
Collector Field			
Modules (xxxx ft^2 of concentrator aperture area)	\$ XXXX		
Piping, Instruments, Controls and other equipment	\$ XXXX		
Site Construction Materials	\$ XXXX		
Packing, Shipping, and Inspection	\$ XXXX		
Labor	\$ XXXX		
TOTAL Collector Field	\$ XXXX		
Energy Plant			
Turbine and Turbine/Generator System	\$ XXXX		
Fossil Fuel Boiler System	\$ XXXX		
Thermal Storage	\$ XXXX		
Thermal Distribution	\$ XXXX		
Building and Miscellaneous	\$ XXXX		
Labor	\$ XXXX		
TOTAL Energy Plant	\$ XXXX		
Interfacing Equipment, and Control and Display System			
Electrical Interfacing Eqpt.	\$ XXXX		
Control & Display System	\$ XXXX		
TOTAL Electrical and Control Display	\$ XXXX		
Tooling and One Time Engineering Costs	\$ XXXX		
TOTAL Direct Capital Costs	\$ XXXX		
TOTAL Experimental Costs		\$ XXXX	
Indirect Costs			
Construction Facilities, Equipment, Materials and Supplies	\$ XXXX		
Construction Management	\$ XXXX		
Interest During Construction	\$ XXXX		Based on ½ constructio time, 9%
Labor Burden	\$ XXXX		
Overhead	\$ XXXX		
Spare Parts Allowance	\$ XXXX		
Temporary Facilities	\$ XXXX		
Contingency Allowance	\$ XXXX		
Escalation During Construction	\$ XXXX		Based on ½ constructio time, 6%
TOTAL Indirect Costs	\$ XXXX		
TOTAL Investment (st startup)	\$ XXXX		

FORMAT B

CAPITAL COSTS

	SYSTEM	EXPERIMENTAL
Solar Collector Field		
Equipment:		
Collector/Receiver (xxxx $/ft^2)		
Module (xxxx $/ft^2)		
Module, per unit	$ XXXX	
Modules (Total)	$ XXXX	
Modules piping connections	$ XXXX	
Packing, Shipping, & Inspection	$ XXXX	
SUBTOTAL	$ XXXX	
Module Array headers and plumbing	$ XXXX	
Fluid Control Elements (Valves, etc.)	$ XXXX	
Electrical wiring and Instruments	$ XXXX	
Storage tanks	$ XXXX	
Pumps & other equipment	$ XXXX	
Fluids	$ XXXX	
Site Construction Materials:		
Module Foundations and Supports	$ XXXX	
Other Construction Materials	$ XXXX	
Packing, Shipping, & Inspection	$ XXXX	
SUBTOTAL	$ XXXX	
Special Installation Equipment	$ XXXX	
TOTAL EQUIPMENT AND MATERIALS	$ XXXX	
Labor		
Installation of Module Array, headers and piping	$ XXXX	
Installation of Fluid Control (Valves, etc.) Elements	$ XXXX	
Storage Tanks Installation	$ XXXX	
Grading, excavation, asphalt paving, storm drainage, pond, fence, module supports, and foundations	$ XXXX	
Check Out	$ XXXX	
TOTAL LABOR	$ XXXX	
COLLECTOR FIELD TOTAL	$ XXXX	
EXPERIMENTAL		$ XXXX
Energy Plant		
Materials & Equipment		
Power Block		
Prime Mover & Generator	$ XXXX	
Transportation, Inspection & Checkout of Prime Mover and Generator	$ XXXX	
Heat Exchangers	$ XXXX	
Condenser	$ XXXX	
Pumps, Pipes & Valves (Heat Exchanger and Condenser)	$ XXXX	
Fluids	$ XXXX	

	SYSTEM	EXPERIMENTAL
Energy Plant, Materials & Equipment (cont'd)		
Power Block (cont'd)		
Shipping Inspection and Checkout Heat Exchangers & Condenser	$ XXXX	
Fossil Fuel Boiler	$ XXXX	
Fuel Storage	$ XXXX	
Boiler Pumps, Pipes & Valves	$ XXXX	
Shipping Inspection & Checkout of Boiler	$ XXXX	
SUBTOTAL	$ XXXX	
Thermal Storage		
Tank(s)	$ XXXX	
Instruments and Controls	$ XXXX	
Valves, Piping Penatrations, and Supports	$ XXXX	
Insulation	$ XXXX	
Shipping, Hydrostatic testing, Checkout	$ XXXX	
SUBTOTAL	$ XXXX	
HVAC Thermal Distribution System		
Pipe, Valves & Insulation	$ XXXX	
Circulation Pumps	$ XXXX	
Air Handler Heat Exchangers	$ XXXX	
Instrumentation & Control	$ XXXX	
Pavement Repair Materials	$ XXXX	
Other Equipment & Materials	$ XXXX	
SUBTOTAL	$ XXXX	
Building and Miscellaneous		
Building	$ XXXX	
Nitrogen System Tanks & Compressor Insulation	$ XXXX	
Water Chemistry System	$ XXXX	
Miscellaneous (e.g. Cooling Tower, Temperature Reg., Air Compressor, Reg. & Filters)	$ XXXX	
SUBTOTAL	$ XXXX	
ENERGY PLANT MATERIALS & EQUIPMENT	$ XXXX	
Labor (Installation & Checkout)		
Prime Mover & Generator	$ XXXX	
Heat Exchanger(s) System	$ XXXX	
Condenser System	$ XXXX	
Boiler System	$ XXXX	
Thermal Storage System	$ XXXX	
HVAC System Modification and Addition	$ XXXX	
Building Construction & Site Preparation	$ XXXX	

Energy Plant, Materials & Equipment (cont'd)

	SYSTEM	EXPERIMENTAL
Miscellaneous Equipment	$ XXXX	
ENERGY PLANT LABOR	$ XXXX	
TOTAL ENERGY PLANT	$ XXXX	
EXPERIMENTAL		$ XXXX

Electrical Interfacing Equipment and Control Display System

	SYSTEM	EXPERIMENTAL
Equipment		
Electrical Interfacing Equipment		
Motor wiring and misc. wiring	$ XXXX	
Elec. Switching Gear	$ XXXX	
Elec. Buses & Lo Voltage Transformer	$ XXXX	
Transformer & Hi Volt switching	$ XXXX	
Synchronization Eqpt.	$ XXXX	
Instrumentation Controls and Safety	$ XXXX	
SUBTOTAL	$ XXXX	
Control Information and Display Systems		
Minicomputer, Control Monitor System, Signal Conditioners, and other Peripherals	$ XXXX	
Integrated System Display Panel	$ XXXX	
Software	$ XXXX	
Manual Controls & Displays	$ XXXX	
SUBTOTAL	$ XXXX	
EQUIPMENT TOTAL	$ XXXX	
Labor		
Installation of Electrical Interfacing Equipment	$ XXXX	
Installation of Control Information and Display System	$ XXXX	
TOTAL LABOR	$ XXXX	
TOTAL ELECTRICAL AND CONTROL DISPLAY SYSTEM	$ XXXX	
EXPERIMENTAL		$ XXXX

FORMAT C

SUMMARY OF OPERATIONS
MAINTENANCE AND EXPERMENTAL REQUIREMENTS

Labor	PERSONNEL (Man-Years)		ANNUAL Charge ($)	
Plant O & M				
Day Shift	XX		$ XXXX	
Night Shift	XX		$ XXXX	
Prime Contractor Support	XX		$ XXXX	
Collector System Support	XX		$ XXXX	
TOTAL ANNUAL O & M COST		XX		$ XXXX
Experimental				
Engineers	XX		$ XXXX	
Technicians	XX		$ XXXX	
Others	XX		$ XXXX	
		XX		$ XXXX
TOTAL LABOR		XX		$ XXXX

Equipment & Supplies		
Plant O & M		
Supplies	$ XXXX	
Spare Parts	$ XXXX	
Total O & M Supplies and Parts		$ XXXX
Experimental		
Supplies	$ XXXX	
Instruments	$ XXXX	
Experimental Supplies & Instruments		$ XXXX

TOTAL PLANT O & M LABOR AND EQUIPMENT SUPPLY	$ XXXX
TOTAL EXPERIMENTAL LABOR, SUPPLIES AND EQUIPMENT	$ XXXX

FORMAT D

LABOR FORCE FOR OPERATIONS & MAINTENANCE

Plant Operations & Maintenance	Personnel (No.)	Rate ($/Hr)	Time (Hr/Week)	Weekly Expenditure ($/Week)
Day Shift				
1) Plant Operator				
2) Pipe & Boiler Mechanic				
3) Collector Field Tech (Optics & Elect)				
SUBTOTALS				
Night Shift				
1) Plant Operator & Maint Foreman (elect-Mech)				
2) Collector Field Tech (Optics & Mech)				
SUBTOTALS				
Design Contractor Support				
1) Field Engineering				
2) Maintenance requirements and Tech Support Documentation				
SUBTOTALS				
Collector System Contractor Support				
SUBTOTAL				
O & M TOTALS				

Experimental Operations and Support	Personnel (No.)	Rate ($/Hr)	Time (Hr/Week)	Weekly Expenditure ($/Week)
Test Engineer				
Failure Analysist				
Logistics Planner				
Performance Evaluation Eng.				
Reports				
EO&S TOTALS				

FORMAT E

OTHER O & M COSTS

	Cost ($ Year)	
* Spare Parts		
Collector & Receivers	$ XXXX	
Pumps	$ XXXX	
Valves	$ XXXX	
Instrumentation	$ XXXX	
Computer & Peripherals	$ XXXX	
Misc	$ XXXX	
TOTAL O & M Spare Parts		$ XXXX
Operating Supplies		
Water Treatment Supplies	$ XXXX	
Computer Supplies	$ XXXX	
Collector Cleaning	$ XXXX	
Welding Supplies	$ XXXX	
Insulation, Tape, & Paint	$ XXXX	
Admin Supplies	$ XXXX	
Photo Supplies	$ XXXX	
Fuel	$ XXXX	
Heat Transfer Fluid	$ XXXX	
Misc	$ XXXX	
TOTAL O & M Supplies		$ XXXX

OTHER EXPERIMENTAL O & S COSTS

Supplies	$ XXXX	
Instruments	$ XXXX	
Misc	$ XXXX	
TOTAL Experimental Supplies & Instruments		$ XXXX

FORMAT F

ANNUAL MAINTENANCE COSTS

Equipment Repair and Replacement

No. Units	Unit	MTBF	Repair Labor	Repair Part	Replace Labor	Replace Part	TOTAL
xx	Pump						
x	Drive						
xx	Motor						
x	Field Controller						
xx	Valves						
xxx	Sensors						
xx	Bearings						

SAMPLE

MAINTENANCE MANHOURS

	PREVENTIVE	CORRECTIVE	UTILITY (CLEANING)	TOTAL
<u>Collector Field</u> Modules (xxxx ft^2 of concentrator aperture area) Piping, Instruments, Controls and other equipment				
<u>Energy Plant</u> Turbine and Turbine/Generator System Fossil Fuel Boiler System Thermal Storage Thermal Distribution Building				
<u>Interfacing Equipment, and Control and Display System</u> Electrical Interfacing Eqpt. Control & Display System				
<u>HVAC</u>				

FORMAT G

AVERAGE STRAIGHT-TIME HOURLY EARNINGS FOR OCCUPATIONS STUDIED IN SELECTED INDUSTRY DIVISIONS, JULY--OCTOBER 1976 [1] [2]

Ref. (Occupational Earnings Selected Areas 1976
U.S. Dept. of Labor Bureau of Labor Statistics)

Occupation	Atlanta, Ga. May 1976	Waco and Killeen--Temple, Tex. July 1976
<u>Maintenance, toolroom, and powerplant</u>		
Maintenance carpenters	$6.81	6.39[6]
Maintenance electricians	6.94	6.05
Maintenance painters	7.28	5.93[6]
Maintenance machinists	6.65	5.89
Maintenance mechanics (machinery)	6.27	5.40
Maintenance mechanics (motor vehicles)	6.74	6.24
Maintenance pipefitters	7.38	7.29[6]
Millwrights	7.61	7.61[5]
Tool and die makers	7.07	4.64
Stationary engineers	6.80	5.80[6]
Boiler tenders	4.07	5.18[6]
<u>Material movement and custodial</u>		
Truckdrivers	5.54[3]	3.88[4]
Truckdrivers, light truck	3.49	2.67
Truckdrivers, medium truck	5.15	5.72
Truckdrivers, heavy truck (trailer)	6.62	3.68
Truckdrivers, heavy truck (other than trailer)	4.83	3.42[6]
Shipping Packers	3.90	3.26
Material handling laborers	4.58	3.20
Forklift operators	4.94	4.05
Guards and watchmen	2.85	3.47
Janitors, porters, and cleaners	2.89	3.02

NOTES:

[1] Earnings excluded premium pay for overtime and for work on weekends, holidays, and late shifts.

[2] Manufacturing; transportation, communication, and other public utilities; wholesale trade; retail trade; finance, insurance, and real estate; and selected services.

[3] Data were not collected for this occupation in all areas.

[4] Includes all drivers regardless of size and type of truck operated.

[5] No data reported, use value reported for Atlanta, GA. (May 1976).

[6] Data taken from West Texas (Sept. 1976).

EXCERPTS FROM

Bulletin 1900-23

U.S. Department of Labor

Bureau of Labor Statistics

May, 1976

MAINTENANCE MECHANIC (Motor Vehicles)—Continued

This classification does not include mechanics who repair customers' vehicles in automobile repair shops.

MAINTENANCE PIPEFITTER

Installs or repairs water, steam, gas, or other types of pipe and pipefittings in an establishment. Work involves most of the following: Laying out work and measuring to locate position of pipe from drawings or other written specifications; cutting various sizes of pipe to correct lengths with chisel and hammer or oxyacetylene torch or pipe-cutting machines; threading pipe with stocks and dies; bending pipe by hand-driven or power-driven machines; assembling pipe with couplings and fastening pipe to hangers; making standard shop computations relating to pressures, flow, and size of pipe required; and making standard tests to determine whether finished pipes meet specifications. In general, the work of the maintenance pipefitter requires rounded training and experience usually acquired through a formal apprenticeship or equivalent training and experience. Workers primarily engaged in installing and repairing building sanitation or heating systems are excluded.

MAINTENANCE SHEET-METAL WORKER

Fabricates, installs, and maintains in good repair the sheet-metal equipment and fixtures (such as machine guards, grease pans, shelves, lockers, tanks, ventilators, chutes, ducts, metal roofing) of an establishment. Work involves most of the following: Planning and laying out all types of sheet-metal maintenance work from blueprints, models, or other specifications; setting up and operating all available types of sheet-metal working machines; using a variety of handtools in cutting, bending, forming, shaping, fitting, and assembling; and installing sheet-metal articles as required. In general, the work of the maintenance sheet-metal worker requires rounded training and experience usually acquired through a formal apprenticeship or equivalent training and experience.

MILLWRIGHT

Installs new machines or heavy equipment, and dismantles and installs machines or heavy equipment when changes in the plant layout are required. Work involves most of the following: Planning and laying out work; interpreting blueprints or other specifications; using a variety of handtools and rigging; making standard shop computations relating to stresses, strength of materials, and centers of gravity; aligning and balancing equipment; selecting standard tools, equipment, and parts to be used; and installing and maintaining in good order power transmission equipment such as drives and speed reducers. In general, the millwright's work normally requires a rounded training and experience in the trade acquired through a formal apprenticeship or equivalent training and experience.

MAINTENANCE TRADES HELPER

Assists one or more workers in the skilled maintenance trades, by performing specific or general duties of lesser skill, such as keeping a worker supplied with materials and tools; cleaning working area, machine, and equipment; assisting journeyman by holding materials or tools; and performing other unskilled tasks as directed by journeyman. The kind of work the helper is permitted to perform varies from trade to trade: In some trades the helper is confined to supplying, lifting, and holding materials and tools, and cleaning working areas; and in others he is permitted to perform specialized machine operations, or parts of a trade that are also performed by workers on a full-time basis.

MACHINE-TOOL OPERATOR (Toolroom)

Specializes in the operation of one or more types of machine tools, such as jig borers, cylindrical or surface grinders; engine lathes; or milling machines, in the construction of machine-shop tools, gauges, jigs, fixtures, or dies. Work involves most of the following: Planning and performing difficult machining operations; processing items requiring complicated setups or a high degree of accuracy; using a variety of precision measuring instruments; selecting feeds, speeds, tooling, and operation sequence; and making necessary adjustments during operation to achieve requisite tolerances or dimensions. May be required to recognize when tools need dressing, to dress tools, and to select proper coolants and cutting and lubricating oils. For cross-industry wage study purposes, machine-tool operators (toolroom) in tool and die jobbing shops are excluded from this classification.

TOOL AND DIE MAKER

Constructs and repairs machine-shop tools, gauges, jigs, fixtures or dies for forgings, punching, and other metal-forming work. Work involves most of the following: Planning and laying out work according to models, blueprints, drawings, or other oral and written specifications; using a variety of tool and die maker's handtools and precision measuring instruments; understanding of the working properties of common metals and alloys; setting up and operating of machine tools and related equipment; making necessary shop computations relating to dimensions of work, speeds, feeds, and tooling of machines; heat-treating of metal parts during fabrication as well as of finished tools and dies to achieve required qualities; working to close tolerances; fitting and assembling of parts to prescribed tolerances and allowances; and selecting appropriate materials, tools, and processes. In general, the tool and die maker's work requires a rounded training in machine-shop and toolroom practice usually acquired through a formal apprenticeship or equivalent training and experience.

For cross-industry wage study purposes, tool and die makers in tool and die jobbing shops are excluded from this classification.

STATIONARY ENGINEER

Operates and maintains and may also supervise the operation of stationary engines and equipment (mechanical or electrical) to supply the establishment in which employed with power, heat, refrigeration, or air-conditioning. Work involves: Operating and maintaining equipment such as steam engines, air compressors, generators, motors, turbines, ventilating and refrigerating equipment, steam boilers and boiler-fed water pumps; making equipment repairs; and keeping a record of operation of machinery, temperature, and fuel consumption. May also supervise these operations. Head or chief engineers in establishments employing more than one engineer are excluded.

BOILER TENDER

Fires stationary boilers to furnish the establishment in which employed with heat, power, or steam. Feeds fuels to fire by hand or operates a mechanical stoker, gas, or oil burner; and checks water and safety valves. May clean, oil, or assist in repairing boilerroom equipment.

REGISTERED INDUSTRIAL NURSE

A registered nurse who gives nursing service under general medical direction to ill or injured employees or other persons who become ill or suffer an accident on the premises of a factory or other establishment. Duties involve a combination of the following: Giving first aid to the ill or injured; attending to subsequent dressing of employees' injuries; keeping records of patients treated; preparing accident reports for compensation or other purposes; assisting in physical examinations and health evaluations of applicants and employees; and planning and carrying out programs involving health education, accident prevention, evaluation of plant environment, or other activities affecting the health, welfare, and safety of all personnel. Nursing supervisors or head nurses in establishments employing more than one nurse are excluded.

REGISTERED INDUSTRIAL NURSE—Continued

MAINTENANCE, TOOLROOM, AND POWERPLANT

MAINTENANCE CARPENTER

Performs the carpentry duties necessary to construct and maintain in good repair building woodwork and equipment such as bins, cribs, counters, benches, partitions, doors, floors, stairs, casings, and trim made of wood in an establishment. Work involves most of the following: Planning and laying out of work from blueprints, drawings, models, or verbal instructions; using a variety of carpenter's handtools, portable power tools, and standard measuring instruments; making standard shop computations relating to dimensions of work; and selecting materials necessary for the work. In general, the work of the maintenance carpenter requires rounded training and experience usually acquired through a formal apprenticeship or equivalent training and experience.

MAINTENANCE ELECTRICIAN

Performs a variety of electrical trade functions such as the installation, maintenance, or repair of equipment for the generation, distribution, or utilization of electric energy in an establishment. Work involves most of the following: Installing or repairing any of a variety of electrical equipment such as generators, transformers, switchboards, controllers, circuit breakers, motors, heating units, conduit systems, or other transmission equipment; working from blueprints, drawings, layouts, or other specifications; locating and diagnosing trouble in the electrical system or equipment; working standard computations relating to load requirements of wiring or electrical equipment; and using a variety of electrician's handtools and measuring and testing instruments. In general, the work of the maintenance electrician requires rounded training and experience usually acquired through a formal apprenticeship or equivalent training and experience.

MAINTENANCE PAINTER

Paints and redecorates walls, woodwork, and fixtures of an establishment. Work involves the following: Knowledge of surface peculiarities and types of paint required for different applications; preparing surface for painting by removing old finish or by placing putty or filler in nail holes and interstices; and applying paint with spray gun or brush. May mix colors, oils, white lead, and other paint ingredients to obtain proper color or consistency. In general, the work of the maintenance painter requires rounded training and experience usually acquired through a formal apprenticeship or equivalent training and experience.

MAINTENANCE MACHINIST

Produces replacement parts and new parts in making repairs of metal parts of mechanical equipment operated in an establishment. Work involves most of the following: Interpreting written instructions and specifications; planning and laying out of work; using a variety of machinist's handtools and precision measuring instruments; setting up and operating standard machine tools; shaping of metal parts to close tolerances; making standard shop computations relating to dimensions of work, tooling, feeds, and speeds of machining; knowledge of the working properties of the common metals; selecting standard materials, parts, and equipment required for this work; and fitting and assembling parts into mechanical equipment. In general, the machinist's work normally requires a rounded training in machine-shop practice usually acquired through a formal apprenticeship or equivalent training and experience.

MAINTENANCE MECHANIC (Machinery)

Repairs machinery or mechanical equipment of an establishment. Work involves most of the following: Examining machines and mechanical equipment to diagnose source of trouble; dismantling or partly dismantling machines and performing repairs that mainly involve the use of handtools in scraping and fitting parts; replacing broken or defective parts with items obtained from stock; ordering the production of a replacement part by a machine shop or sending the machine to a machine shop for major repairs; preparing written specifications for major repairs or for the production of parts ordered from machine shops; reassembling machines; and making all necessary adjustments for operation. In general, the work of a machinery maintenance mechanic requires rounded training and experience usually acquired through a formal apprenticeship or equivalent training and experience. Excluded from this classification are workers whose primary duties involve setting up or adjusting machines.

MAINTENANCE MECHANIC (Motor Vehicles)

Repairs automobiles, buses, motortrucks, and tractors of an establishment. Work involves most of the following: Examining automotive equipment to diagnose source of trouble; disassembling equipment and performing repairs that involve the use of such handtools as wrenches, gauges, drills, or specialized equipment in disassembling or fitting parts; replacing broken or defective parts from stock; grinding and adjusting valves; reassembling and installing the various assemblies in the vehicle and making necessary adjustments; and aligning wheels, adjusting brakes and lights, or tightening body bolts. In general, the work of the motor vehicle maintenance mechanic requires rounded training and experience usually acquired through a formal apprenticeship or equivalent training and experience.

APPENDIX G

Appendix G. Part I Program Listings

Program No. 1

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11		057	RCL7	36 07	
002	0	00		058	x	-35	
003	PRTX	-14		059	STOi	35 45	
004	SPC	16-11		060	1	01	
005	1	01		061	1	01	
006	2	02		062	STOI	35 46	
007	STOI	35 46		063	RCLi	36 45	
008	RCLi	36 45		064	1	01	
009	RCL7	36 07		065	-	-45	
010	RCL6	36 06		066	RCL9	36 09	
011	+	-55		067	x	-35	
012	x	-35		068	RCLi	36 45	
013	GSBe	23 16 15		069	RCL5	36 05	
014	RCLi	36 45		070	Yˣ	31	
015	÷	-24		071	ENT↑	-21	
016	1	01		072	ENT↑	-21	
017	RCLi	36 45		073	1	01	
018	-	-45		074	-	-45	
019	STOi	35 45		075	÷	-24	
020	RCL7	36 07		076	x	-35	
021	x	-35		077	STO8	35 08	
022	STO9	35 09		078	RCL4	36 04	
023	RCL3	36 03		079	1	01	
024	1/X	52		080	-	-45	
025	STO3	35 03		081	RCLA	36 11	
026	RCL4	36 04		082	X⇄Y	-41	
027	Yˣ	31		083	Yˣ	31	
028	STO2	35 02		084	RCL6	36 06	
029	RCLD	36 14		085	x	-35	
030	CHS	-22		086	CHS	-22	
031	GSBe	23 16 15		087	GSBe	23 16 15	
032	1	01		088	1	01	
033	RCL4	36 04		089	7	07	
034	X²	53		090	STOI	35 46	
035	RCL4	36 04		091	RCLi	36 45	
036	+	-55		092	RCL6	36 06	
037	1/X	52		093	x	-35	
038	2	02		094	STOi	35 45	
039	x	-35		095	1	01	
040	RCL7	36 07		096	2	02	
041	RCLD	36 14		097	STOI	35 46	
042	-	-45		098	RCLi	36 45	
043	x	-35		099	RCL6	36 06	
044	RCLE	36 15		100	x	-35	
045	x	-35		101	STO6	35 06	
046	CHS	-22		102	GSBe	23 16 15	
047	STOD	35 14		103	DSZI	16 25 46	
048	1	01		104	RCLi	36 45	
049	5	05		105	1	01	
050	STOI	35 46		106	-	-45	
051	RCLi	36 45		107	RCL6	36 06	
052	RCL7	36 07		108	x	-35	
053	x	-35		109	STO6	35 06	
054	STOi	35 45		110	RTN	24	
055	ISZI	16 26 46		111	*LBLe	21 16 15	
056	RCLi	36 45		112	F0?	16 23 00	

REGISTERS

0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	I				

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS

```
113  PRTX      -14
114  ST+0   35-55 00
115  RCL2      36 02
116     x       -35
117   F1?   16 23 01
118  PRTX       -14
119  ST+1   35-55 01
120   RTN        24
121   R/S        51
```

130

140

150

160

170

180

190

200

210

220

LABELS					FLAGS
A	B	C	D	E	0
a	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS

FLAGS			TRIG		DISP	
	ON	OFF				
0	☐	☐	DEG	☐	FIX	☐
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☐	ENG	☐
3	☐	☐			n ______	

Program No. 2

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11		057	1	01	
002	SPC	16-11		058	0	00	
003	1	01		059	STOI	35 46	
004	PRTX	-14		060	RCLi	36 45	
005	1	01		061	RCL3	36 03	
006	0	00		062	X⇄Y	-41	
007	STOI	35 46		063	Y^x	31	
008	RCLi	36 45		064	STO2	35 02	
009	RCL7	36 07		065	RCL5	36 05	
010	x	-35		066	RCLi	36 45	
011	RCL3	36 03		067	X>Y?	16-34	
012	STO2	35 02		068	GTO1	22 01	
013	x	-35		069	RCL8	36 08	
014	CHS	-22		070	GSBe	23 16 15	
015	SPC	16-11		071	*LBL1	21 01	
016	PRTX	-14		072	RCLE	36 15	
017	SPC	16-11		073	RCL6	36 06	
018	ST+0	35-55 00		074	x	-35	
019	ST+1	35-55 01		075	GSBe	23 16 15	
020	1	01		076	P⇄S	16-51	
021	RCLE	36 15		077	3	03	
022	-	-45		078	STOI	35 46	
023	STOE	35 15		079	*LBLC	21 13	
024	1	01		080	X⇄I	16-41	
025	0	00		081	GSBc	23 16 13	
026	STOI	35 46		082	ISZI	16 26 46	
027	0	00		083	7	07	
028	STOi	35 45		084	ENT↑	-21	
029	*LBLB	21 12		085	X⇄I	16-41	
030	1	01		086	X≤Y?	16-35	
031	4	04		087	GTOC	22 13	
032	STOI	35 46		088	RCLB	36 12	
033	0	00		089	RCL0	36 00	
034	STO7	35 07		090	1	01	
035	STOi	35 45		091	-	-45	
036	1	01		092	Y^x	31	
037	0	00		093	RCL8	36 08	
038	STOI	35 46		094	x	-35	
039	RCL4	36 04		095	RCLE	36 15	
040	RCLi	36 45		096	x	-35	
041	X=Y?	16-33		097	P⇄S	16-51	
042	GTOE	22 15		098	GSBe	23 16 15	
043	1	01		099	P⇄S	16-51	
044	+	-55		100	RCLC	36 13	
045	STOi	35 45		101	RCL0	36 00	
046	SPC	16-11		102	1	01	
047	SPC	16-11		103	-	-45	
048	PRTX	-14		104	Y^x	31	
049	1	01		105	RCL9	36 09	
050	4	04		106	x	-35	
051	STOI	35 46		107	RCLE	36 15	
052	0	00		108	x	-35	
053	PSE	16 51		109	P⇄S	16-51	
054	PSE	16 51		110	GSBe	23 16 15	
055	SPC	16-11		111	P⇄S	16-51	
056	STOi	35 45		112	1	01	

REGISTERS

0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	I				

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	1	01	
114	STOI	35 46	
115	RCL0	36 00	
116	P⇄S	16-51	
117	RCL5	36 05	
118	X⇄Y	-41	
119	X>Y?	16-34	
120	GTO2	22 02	
121	RCLi	36 45	
122	1	01	
123	-	-45	
124	RCL9	36 09	
125	x	-35	
126	RCLE	36 15	
127	1	01	
128	-	-45	
129	x	-35	
130	GSBe	23 16 15	
131	RCL8	36 08	
132	RCLi	36 45	
133	1	01	
134	-	-45	
135	RCL9	36 09	
136	x	-35	
137	-	-45	
138	ST-9	35-45 09	
139	*LBL2	21 02	
140	DSZI	16 25 46	
141	RCL4	36 04	
142	RCLi	36 45	
143	-	-45	
144	1	01	
145	+	-55	
146	RCLD	36 14	
147	x	-35	
148	GSBe	23 16 15	
149	SPC	16-11	
150	RCL7	36 07	
151	PRTX	-14	
152	ST+0	35-55 00	
153	RCL2	36 02	
154	x	-35	
155	PRTX	-14	
156	ST+1	35-55 01	
157	GTOB	22 12	
158	*LBLE	21 15	
159	SPC	16-11	
160	SPC	16-11	
161	SPC	16-11	
162	RCL0	36 00	
163	PRTX	-14	
164	SPC	16-11	
165	RCL1	36 01	
166	PRTX	-14	
167	RTN	24	
168	*LBLc	21 16 13	

STEP	KEY ENTRY	KEY CODE	COMMENTS
169	X⇄I	16-41	
170	STOI	35 46	
171	4	04	
172	-	-45	
173	X=0?	16-43	
174	GTOd	22 16 14	
175	RCLi	36 45	
176	RCLA	36 11	
177	RCL0	36 00	
178	1	01	
179	-	-45	
180	Y^x	31	
181	x	-35	
182	RCLE	36 15	
183	x	-35	
184	*LBLd	21 16 14	
185	X=0?	16-43	
186	RCLi	36 45	
187	P⇄S	16-51	
188	GSBe	23 16 15	
189	P⇄S	16-51	
190	RTN	24	
191	*LBLe	21 16 15	
192	F0?	16 23 00	
193	PRTX	-14	
194	ST+7	35-55 07	
195	RCL2	36 02	
196	x	-35	
197	F1?	16 23 01	
198	PRTX	-14	
199	RTN	24	
200	R/S	51	
210			
220			

LABELS					FLAGS
A	B	C	D	E	0
a	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS

FLAGS			TRIG	DISP
	ON	OFF		
0	☐	☐	DEG ☐	FIX ☐
1	☐	☐	GRAD ☐	SCI ☐
2	☐	☐	RAD ☐	ENG ☐
3	☐	☐		n ____

Appendix G. Part 2 Utilization Instructions

AMERICAN TECHNOLOGICAL UNIVERSITY

SOLAR TOTAL ENERGY PROJECT

HP-97 OR HP-67 COST ANALSYS PROGRAM

INSTRUCTIONS

THE COST ANALYSIS PROGRAM WAS DEVELOPED AT ATU TO ANALYZE THE COSTS OF A SOLAR TOTAL ENERGY SYSTEM, BUT THE APPLICATION OF THE PROGRAM NEED NOT BE RESTRICTED TO SUCH APPLICATIONS. ANY SYSTEM MAY BE COSTED, PROVIDED THAT THE VARIABLES USED IN THE PROGRAM AND SUBSTITUTED FOR OR SET TO ZERO AS IS APPROPRIATE.

THE HP-97 AND HP-67 PROGRAMMABLE CALCULATORS AS OF THIS WRITING HAVE 25 DATA REGISTERS IN ADDITION TO THE FOUR STACK REGISTERS AND THE SPECIAL I REGISTER. ALL 25 OF THESE REGISTERS ARE USED IN THE PROGRAM AS DESCRIBED BELOW. THE NOTATION WHICH IS USED HEREIN IS THAT R-N WILL REPRESENT PRIMARY REGISTER N WHEREAS RS-N WILL REPRESENT SECONDARY REGISTER N. FOR EXAMPLE,

R-0 REPRESENTS PRIMARY REGISTER 0
R-A REPRESENTS PRIMARY REGISTER A
RS-0 REPRESENTS SECONDARY REGISTER 0

REGISTER CONTENTS

REGISTER		DATA REPRESENTED	DEFAULT VALUE
R-0	*	SUM OF THE NET COSTS	0
R-1	*	SUM OF THE NET PRESENT VALUE	0
R-2		THE INVERSE OF THE DISCOUNT RATE FOR YEAR T	1
R-3		THE DISCOUNT RATE	1.12
R-4		THE NUMBER OF YEARS IN THE ANALYSIS PERIOD	20
R-5		THE LOAN PERIOD	20
R-6		THE LAND COST	37,500
R-7		THE CAPITAL INVESTMENT	5,000,000
R-8	*	THE ANNUAL PAYMENT	0
R-9	*	THE BALANCE DUE ON THE LOAN	0

```
RS-0                THE TAX CREDIT                   0.20
RS-1                THE INTEREST RATE                0.09
RS-2                THE EQUITY RATE                  0.20
RS-3                THE OPERATION AND MAINTENANCE 75,000
RS-4                THE REPLACEMENT COSTS            0
RS-5                THE TAX RATE FOR THE CAPITAL     0
                        INVESTMENT
RS-6                THE INSURANCE RATE               0.01
RS-7                THE TAX RATE FOR THE LAND        0.03
RS-8                THE ELECTRICITY COSTS           40,000
RS-9                THE FUEL COSTS                  35,000
R-A                 THE INFLATION RATE               1.06
R-B                 THE ELECTRICITY ESCALATION       1.10
R-C                 THE FUEL ESCALATION RATE         1.12
R-D                 THE SALVAGE VALUE               250,000
R-E                 THE INCOME TAX RATE              0.50
.
.
    *   THESE VALUES ARE CALCULATED OR ACCUMULATED DURING THE
        EXECUTION OF THE PROGRAMS AND SHOULD NOT BE PROVIDED WITH
        DEFAULT VALUES.
.
.
*************************************************************************
*                                                                       *
*            P R O G R A M   F E A T U R E S                            *
*                                                                       *
*************************************************************************
.
A.  OUTPUT CAPABILITIES
    -------------------
.
THE PROGRAM HAS A NUMBER OF OPTIONS AVAILABLE FOR DISPLAYING OR
PRINTING THE VALUES STORED.  THE FOLLOWING DATA IS ALWAYS OUTPUT
.
    YEAR
    TAX CREDIT APPLIED IN YEAR 1
    YEARLY NET REAL COST
    YEARLY NET PRESENT VALUE COST
    PERIOD ANALYSIS TOTAL NET COST
    PERIOD ANALYSIS TOTAL PRESENT VALUE COST
.
THE FOLLOWING DATA IS OPTIONALLY PRINTED UNDER YEAR 0
.
    EQUITY PAYMENT
    SALVAGE VALUE
    LAND PAYOFF
    LAND RESALE
.
THE FOLLOWING DATA ITEMS ARE OPTIONALLY OUTPUT UNDER EACH YEAR -
.
```

ANNUAL PAYMENT FOR CAPITAL INVESTMENT
LAND INTEREST COSTS
OPERATION AND MAINTENANCE COSTS
REPLACEMENT COSTS
CAPITAL PROPERTY TAX COSTS
INSURANCE COSTS
LAND PROPERTY TAX COST
ELECTRICITY COSTS
FUEL COSTS
TAX REDUCTION AS A RESULT OF INTEREST ON CAPITAL INVESTMENT
 (PRINTED AS A NEGATIVE NUMBER)
TAX REDUCTION AS A RESULT OF DEPRECIATION ON CAPITAL INVESTMENT
 (SUM OF YEARS METHOD IS USED, AND NUMBER PRINTED IS NEGATIVE)

ALL DATA ITEMS ARE PRINTED IN THE ORDER LISTED.

B. PRINTING OPTIONS

THE PRINTING OPTIONS ARE CONTROLLED BY FLAGS 0 AND 1. IF FLAG 0 IS SET THEN THE REAL COST VALUES ARE PRINTED FOR THOSE DATA ITEMS WHICH ARE DESCRIBED AS BEING OPTIONALLY PRINTED. IF FLAG 0 IS CLEARED THEN THESE VALUES ARE NOT PRINTED. IF FLAG 1 IS SET THEN THE OPTIONALLY PRINTED PRESENT VALUES DATA ITEMS ARE PRINTED, AND IF FLAG 1 IS CLEARED THEN THE THE OPTIONAL PRESENT VALUE ITEMS ARE NOT PRINTED.

THE DEFAULT IS FOR ALL DATA ITEMS TO BE PRINTED I.E. BOTH FLAG 0 AND FLAG 1 ARE SET. NOTE THAT THE FOLLOWING COMBINATIONS ARE AVAILABLE.

1. PRINTING OUT ONLY YEAR NUMBER AND TOTALS (YEARLY AND SYSTEM ANALYSIS PERIOD - SEE VALUES WHICH ARE ALWAYS PRINTED)
2. THE ALWAYS PRINTED VALUES AND THE REAL COST VALUES.
3. THE ALWAYS PRINTED VALUES AND THE PRESENT VALUE COSTS.
4. THE ALWAYS PRINTED VALUES, REAL COST VALUES, AND PRESENT VALUE COSTS.

WHEN BOTH REAL AND PRESENT VALUE COSTS ARE PRINTED THE REAL COST VALUE ALWAYS PRECEDES THE PRESENT VALUE COST.

SINCE THE FLAG SETTINGS ARE STORED ON THE PROGRAM MAGNETIC CARDS, IT IS NECESSARY TO PERFORM THE FLAG CLEARING OPERATION SUBSEQUENT TO LOADING EACH PROGRAM, OR THE FLAGS MAY BE CLEARED OR SET DURING THE PROGRAM EXECUTION (SEE THE APPROPRIATE USERS MANUAL FOR INSTRUCTIONS).

C. CHANGING DEFAULT VALUES

THE DEFAULT VALUES FOR THE PROGRAM ARE STORED ON A MAGNETIC CARD.

TO CHANGE ANY DEFAULT VALUE, SIMPLY LOAD THE DATA INTO THE CALCULATOR, ENTER THE VALUE OF THE DATA ITEM TO BE CHANGED INTO THE X REGISTER, AND STORE THIS NEW VALUE IN THE APPROPRIATE REGISTER. NOTE THAT THE ESCALATION RATES, DISCOUNT RATE, AND INTEREST RATE IS STORED AS ONE PLUS THE ACTUAL RATE. THIS WAS DONE SINCE THAT IS THE REPRESENTATION NORMALLY USED IN THE PROGRAM AND PROVIDES SOME ECONOMY IN PROGRAM STEPS.

D. REPLACEMENT VALUES

REPLACEMENT COSTS MAY BE ENTERED FOR EACH YEAR. AFTER THE YEAR NUMBER IS DISPLAYED OR PRINTED, A ZERO WILL APPEAR IN THE X REGISTER AND A PAUSE WILL BE EXECUTED. IN ACTUALITY, TWO PAUSES ARE ECECUTED. (SEE THE OPERATORS MANUAL FOR INSTRUCTIONS ON USE OF THE PAUSE COMMAND). THIS ALLOWS APPROXIMATELY TWO SECONDS DURING WHICH A NUMBER MAY BE ENTERED. IF NO REPLACEMENT VALUE IS DESIRED FOR THAT YEAR YOU NEED DO NOTHING AND ZERO IS USED AS THE REPLACEMENT VALUE. IF A REPLACEMENT VALUE IS DESIRED, SIMPLY ENTER THE REPLACEMENT VALUE INTO THE X REGISTER AND ALLOW THE PROGRAM TO PROCEED.

EXECUTING THE PROGRAM

THE DATA MAGNETIC CARD WHICH ACCOMPANIES THE PROGRAMS CONTAINS ALL THE DATA REQUIRED TO EXECUTE THE ANALYSIS. DATA ITEMS WHICH HAVE DEFAULT VALUES OF ZERO ARE EITHER CALCULATED (E.G. ANNUAL PAYMENT) OR HAVE DEFAULT VALUE OF ZERO (E.G. THE PROPERTY TAX ON THE CAPITAL INVESTMENT). THOSE DATA ITEMS WHICH ARE MARKED BY ASTERISKS IN THE REGISTER CONTENTS DESCRIPTION SHOULD NOT BE ALTERED WITHOUT CAREFULLY EXAMINING THE CONSEQUENCES THEREOF. IT SHOULD ALSO BE NOTED THAT THE CONTENTS OF SOME REGISTERS ARE ALTERED DURING THE EXECUTION OF THE PROGRAM AND THE VALUES STORED THEREIN ARE NOT NECESSARILY THOSE DESCRIBED IN THE REGISTER CONTENTS DESCRIPTION ABOVE.

THE FOLLOWING STEPS MUST BE FOLLOWED IN ORDER TO RUN THE COST ANALYSIS PROGRAM.

1. LOAD THE DATA INTO THE CALCULATOR FROM THE MAGNETIC CARD. THIS SETS THE DEFAULT VALUES AS OUTLINED ABOVE.

2. LOAD PROGRAM-1 INTO THE CALCULATOR.

3. IF IT IS DESIRED TO MAKE CHANGES TO THE DEFAULT DATA SETTINGS, ENTER THE VALUE OF THE DATA ITEM TO BE CHANGED INTO THE PROPER REGISTER.

4. IF IT IS NOT DESIRED TO HAVE ALL THE VALUES PRINTED, CLEAR THE PROPER FLAG, I. E. FLAG 0 OR FLAG 1 FOR REAL VALUES AND PRESENT VALUES RESPECTIVELY. FLAG SETTINGS ARE STORED ON THE PROGRAM MAGNETIC CARDS, SO THE FLAG CLEARING OPERATION SHOULD BE ACCOMPLISHED SUBSEQUENT TO LOADING EACH PROGRAM, AND MAY BE EFFECTED DURING THE OPERATION OF THE PROGRAM (SEE THE APPROPRIATE USERS MANUAL FOR DETAILS ON HOW THIS IS ACCOMPLISHED).

5. HIT A IN ORDER TO START THE FIRST PROGRAM EXECUTING.

6. WHEN PROGRAM-1 HAS FINISHED EXECUTING, LOAD PROGRAM-2 INTO THE CALUCLATOR.

7. DEPRESS A IN ORDER TO START PROGRAM-2 EXECUTING.

8. IF IT IS DESIRED TO ENTER ANY REPLACEMENT COSTS, YOU MAY DO SO AS OUTLINED IN THE FEATURES SECTION ABOVE.

IT IS POSSIBLE TO CLEAR OR SET EITHER OR BOTH OF FLAGS 0 OR 1 DURING THE EXECUTION OF THE PROGRAMS IN ORDER TO ALTER THE OUTPUT CAPABILITIES.

OUTPUT EXAMPLE

THE FOLLOWING IS AN EXAMPLE OF THE OUPROGRAM OUTPUT WITH A DESCRIPTION OF EACH FIELD.

```
        --------------- OUTPUT FROM PROGRAM 1 ---------------

YEAR ****************************************************        0.00
SPACE ***************************************************
EQUITY, REAL COST -----------------------------------------   1017500.00
EQUITY, PRESENT VALUE COST ................................   1017500.00
SALVAGE VALUE, REAL COST -----------------------------------  -250000.00
SALVAGE VALUE, PRESENT VALUE COST .........................    -25916.69
SALE OF LAND, REAL VALUE -----------------------------------  -264939.96
SALE OF LAND, PRESENT VALUE ...............................    -27444.73
LAND PAYOFF, REAL COSTS -----------------------------------     70000.00
LAND PAYOFF, PRESENT VALUE COST ...........................      7256.67

             --------------- OUTPUT OF PROGRAM 2 ---------------

SPACE ***************************************************
YEAR ****************************************************        1.00
SPACE ***************************************************
```

```
TAX CREDIT ********************************************    -892857.14
SPACE *************************************************
SPACE *************************************************
YEAR **************************************************             1.
SPACE *************************************************
ANNUAL PAYMENT, REAL COST -----------------------------      438165.90
ANNUAL PAYMENT, PRESENT VALUE ........................      391327.41
INTEREST ON LAND, REAL COST --------------------------        3150.00
INTEREST ON LAND, PRESENT VALUE ......................        2812.50
OPERATION AND MAINTENANCE, REAL COST -----------------       37500.00
OPERATION AND MAINTENANCE,PRESENT VALUE ..............       33482.14
REPLACEMENT COSTS, REAL COST -------------------------           0.00
REPLACEMENT COSTS, PRESENT VALUE .....................           0.00
CAPITAL PROPERTY TAX, REAL COST ----------------------           0.00
CAPITAL PROPERTY TAX, PRESENT VALUE ..................           0.00
INSURANCE, REAL COST ---------------------------------       25000.00
INSURANCE, PRESENT VALUE .............................       22321.43
LAND PROPERTY TAX, REAL COST -------------------------        1312.50
LAND PROPERTY TAX, PRESENT VALUE .....................        1171.88
ELECTRICITY, REAL COST -------------------------------       20000.00
ELECTRICITY, PRESENT VALUE ...........................       17857.14
FUEL, REAL COST --------------------------------------       17500.00
FUEL, PRESENT VALUE ..................................       15625.00
INTEREST INCOME TAX ADJUSTMENT, REAL VALUE -----------     -180000.00
INTEREST INCOME TAX ADJUSTMENT, PRESENT VALUE ........     -160714.29
DEPRECIATION INCOME TAX ADJUSTMENT, REAL VALUE -------     -226190.48
DEPRECIATION INCOME TAX ADJUSTMENT, PRESENT VALUE ....     -201955.78
SPACES ************************************************
YEARLY TOTAL, REAL COST *******************************      136457.
YEARLY TOTAL, PRESENT VALUE ***************************      121837.43

          -------------- FINAL TWO VALUES PRINTED ----------

SYSTEM ANALYSIS PERIOD TOTAL, REAL COST **************      533862.76
SPACES ************************************************
SYSTEM ANALYSIS PERIOD TOTAL, PRESENT VALUE **********      445234.54
```

- THE PRECEDING OUTPUT WILL CONTINUE THROUGH THE SUBSEQUENT YEARS OF THE ANALYSIS PERIOD AND BE CULMINATED WITH THE REAL AND PRESENT VALUE COSTS FOR THE ENTIRE ANALYSIS PERIOD.

- THOSE LINES WHICH HAVE ASTERISKS (******) AS DELIMINATORS WILL ALWAYS BE PRINTED ON THE OUTPUT. THOSE LINES WITH HYPHENS (------) AS DELIMINATORS WILL BE PRINTED ONLY IF FLAG 0 IS SET. THOSE LINES WITH PERIODS (......) AS DELIMINATORS WILL BE PRINTED ONLY IF FLAG 1 IS SET.

- IF THE NUMBER OF YEARS IN THE LOAN PERIOD IS LESS THAN THE PERIOD OF ANALYSIS, THEN THE ANNUAL PAYMENT AND INTEREST INCOME TAX ADJUSTMENT LINES WILL NOT BE PRINTED FOR THOSE YEARS IN EXCESS OF THE LOAN

PERIOD. THAT IS, THE TOTAL NUMBER OF LINES PRINTED PER YEAR WILL DECREASE BY FOUR WHENEVER BOTH FLAG 0 AND FLAG 1 ARE SET.

.

ANY QUESTIONS REGARDING THIS PROGRAM SHOULD BE DIRECTED TO THE FOLLOWING ADDRESS -

.

SOLAR TOTAL ENERGY PROJECT
AMERICAN TECHNOLOGICAL UNIVERSITY
P. O. BOX 1416
KILLEEN, TEXAS 76541

.

OR TELEPHONE (817) 526-1286

APPENDIX H

Appendix H. Part I Program Listings

```
C.
C.              SEPTEMBER 7, 1977
C.
      DIMENSION REALS(4),SENS(27,20),NBR(27),ICOL(27),TOTALS(13)
      DIMENSION PRSVAL(40,13),REPMAT(50)
      DIMENSION METHOD(5,3)
      DATA METHOD /60HSUM OF YEARS        STRAIGHT LINE        DECLINING
     1BALANCE    /
      DATA MAXPRM/27/,MAXITR/100/,MAXVAL/20/,REPMAT/50*0.0/
      DATA ICOL/27*1/,NBR/27*1/,TOTALS/13*0.0/,MAXLIN/30/,LINECT/0/
      DATA PRSVAL/520*0.0/,MINPBK/100/
      DATA SUMCST/0.0/,MAXDEP/2/
      LOGICAL OK,PAYBAK,PRTFLG
      REAL PARAM(27),LOANYR,IRATE,INS,INTCAP,NETCST,INSRAT,INTLND
      EQUIVALENCE (CAPINV,PARAM(1)),(DWNPMT,PARAM(2)),(IRATE,PARAM(3)),
     1    (DISRTE,PARAM(4)),(LOANYR,PARAM(5)),(SYSYR,PARAM(6)),
     2    (OANDM,PARAM(7)),(OMRATE,PARAM(8)),(ELECT,PARAM(9)),
     3    (ERATE,PARAM(10)),(FUEL,PARAM(11)),(FRATE,PARAM(12)),
     4    (TXRATE,PARAM(13)),(TAXCRD,PARAM(14)),(INS,PARAM(15)),
     5    (PCTAX,PARAM(16)),(PCRATE,PARAM(17)),(INSRAT,PARAM(18)),
     6    (CSTLND,PARAM(19)),(ACRES,PARAM(20)),(DEPYRS,PARAM(21)),
     7    (REPLAC,PARAM(22)),(SALVAG,PARAM(23)),(PLTAX,PARAM(24)),
     8    (PLRATE,PARAM(25)),(REPRTE,PARAM(26)),(APPLND,PARAM(27))
C.
C.         THE EQUIVALENCE STATEMENT ALLOWS REFERENCE TO THE PARAMETERS
C.         VIA BOTH MNEMONIC NAMES AND VIA THE ARRAY.  THE ARRAY NAME
C.         IS USED WHENEVER GENERALITY IS REQUIRED E.G. IN CHANGING
C.         DEFAULT VALUES AND IN MAKING SENSITIVITY CHANGES
C.
C.         FIRST INITIALIZE ALL VARIABLES.  ASSIGNMENT STATEMENTS
C.         RATHER THAN A DATA STATEMENT IS USED TO MAKE THE INITIAL
C.         VALUES MORE READABLE
C.
      CAPINV = 5000000
      DWNPMT = 0.20
      IRATE  = 0.09
      DISRTE = 0.12
      LOANYR = 20.0
      SYSYR  = 20.0
      OANDM  = 75000.0
      OMRATE = 0.06
      ELECT = 40000.
      ERATE  = 0.10
      FUEL = 35000.
      FRATE  = 0.12
      TXRATE = 0.50
      TAXCRD = 0.20
      INS    = 0.01
```

```
      PCTAX  = 0.00
      PCRATE = 0.06
      INSRAT = 0.06
      CSTLND = 17500.
      ACRES  = 5.
      DEPYRS = 20.
      REPLAC = 0.0
      SALVAG = 250000.
      PLTAX  = 0.03
      PLRATE = 0.06
      REPRTE = 0.06
      APPLND = 0.06
C.         THE FOLLOWING PARAMETERS ARE RUN CONTROL PARAMETERS
C.         AND ALTHOUGH SOME OF THEM MAY BE SUBJECT TO BEING CHANGED
C.         BY THE USER, THEY ARE SEPARATED HERE SINCE THEY ARE NOT
C.         COST PARAMETERS IN THE STRICTEST SENSE OF THE WORD.
C.
C.         INITIALIZE THE FLAG REPRESENTING WHETHER A PAYBACK
C.         POINT HAS BEEN REACHED YET TO FALSE.
C.
      PAYBAK = .FALSE.
C.
C.         INITIALIZE THE FLAG INDICATING THAT THE ENTIRE PRESENT
C.         VALUE ARRAY IS TO BE PRINTED
C.
      PRTFLG = .TRUE.
C.
C.         LUR = THE LOGICAL UNIT NUMBER ON WHICH THE INPUT RESIDES
C.
      LUR    = 5
C.
C.         LUW = THE LOGICAL UNIT NUMBER USED FOR OUTPUT
C.
      LUW    = 6
C.
C.         MODDEP = THE MODE FLAG FOR THE TYPE OF DEPRECIATION WHICH
C.         IS TO BE USED.
C.                 MODDEP = 0     NO DEPRECIATION ALLOWED
C.                 MODDEP = 1     SUM OF YEARS METHOD
C.                 MODDEP = 2     STRAIGHT LINE METHOD
C.
      MODDEP = 1
C.
C.         THIS SECTION ACCOMPLISHES THE TASK OF READING PARAMETER
C.         CARDS TO EITHER
C.             A.  CHANGE THE DEFAULT VALUE FOR A PARAMETER
C.             B.  SPECIFY SENSITIVITY ANALYSIS FOR A PARAMETER
C.             C.  CONTROL THE NUMBER OF SENSITIVITY ITERATIONS
C.             D.  CHANGE THE LOGICAL UNIT NUMBER FOR OUTPUT
C.             E.  CHANGE THE LOGICAL UNIT NUMBER FOR INPUT
C.             F.  CHANGE THE METHOD OF DEPRECIATION
```

```
C.              G.  CHANGE THE VALUE FOR THE MINIMUM PAYBACK PERIOD
C.          SENSITIVITY ANALYSIS IS DESIGNATED BY A VALUE OF 999
C.          IN THE FIRST THREE POSITIONS OF THE RECORD.  CHANGES
C.          TO DEFAULT VALUES ARE INDICATED BY THE RELATIVE PARAMETER
C.          NUMBER (ARRAY RELATIVE).
C.
  100 CONTINUE
      READ(LUR,11,END=600)IFLAG,(REALS(I),I=1,4)
   11 FORMAT(I3,4F10.2)
C.
C.          IF SENSITIVITY ANALYSIS IS SPECIFIED
C.
      IF (IFLAG.EQ.999) GO TO 200
C.
C.          IF MAXIMUM POSSIBLE SENSITIVITY ITERATIONS HAS BEEN CHANGED
C.
      IF (IFLAG.EQ.998) GO TO 400
C.
C.          LOGICAL UNIT NUMBER FOR THE OUTPUT HAS BEEN CHANGED
C.
      IF (IFLAG.EQ.997) GO TO 500
C.
C.          METHOD OF DEPRECIATION HAS BEEN CHANGED
C.
      IF (IFLAG.EQ.996) GO TO 550
C.
C.          ALTER THE MINIMUM TIME IN WHICH A PAYBACK PERIOD MAY
C.          OCCUR.  FREQUENTLY WHEN THERE IS AN INVESTMENT TAX CREDIT
C.          THE FIRST TWO OR THREE YEARS SHOW A NET SAVINGS.  THE
C.          SYSTEM WILL NOT LOOK FOR A PAYBACK PERIOD BEFORE THE
C.          MINIMUM PAYBACK PERIOD.  IF THE MINIMUM PAYBACK IS
C.          SPECIFIED TO BE 1 YEAR, THEN THE SYSTEM MAY ERRONEOUSLY
C.          PICK THE FIRST OR SECOND YEAR AS THE PAYBACK YEAR.
C.
      IF (IFLAG.EQ.995) GO TO 575
C.
C.         CHANGE THE DEFAULT LOGICAL UNIT NUMBER FOR INPUT
C.
      IF (IFLAG.EQ.994) GO TO 510
C.
C.          ACCEPT REPLACEMENT VALUES FOR A GIVEN YEAR
C.
      IF (IFLAG.EQ.993) GO TO 520
C.
C.          SET THE FLAG INDICATING WHETHER THE PRESENT VALUE
C.          ARRAY IS TO BE PRINTED IN ENTIRETY OR IF JUST THE
C.          PRESENT VALUE SUMMARY IS TO BE PRINTED
C.
      IF (IFLAG.EQ.992) GO TO 530
C.
C.          CHECK TO MAKE SURE THAT THE RELATIVE PARAMETER NUMBER IS
```

```
C.          WITHIN RANGE
C.
      IF (IFLAG.LE.0 .OR. IFLAG.GT.MAXPRM) GO TO 2000
C.
C.          CHANGE THE DEFAULT VALUE OF THE PARAMETER
C.
      PARAM(IFLAG) = REALS(1)
C.
C.          LOOP BACK AND READ THE NEXT CARD
C.
      GO TO 100
  200 CONTINUE
C.
C.          IF WE GET HERE WE HAVE A PARAMETER WHICH IS TO BE VARIED
C.          FOR SENSITIVITY ANALYSIS.  THE SENSITIVITY PARAMETERS ARE
C.          STORED IN THE REALS ARRAY AS FOLLOWS
C.               REALS(1) - RELATIVE PARAMETER NUMBER
C.               REALS(2) - INITIAL VALUE
C.               REALS(3) - ENDING VALUE (APPROXIMATE)
C.               REALS(4) - INCREMENT VALUE (REALS(2) + N * REALS(4) IS
C.                                 GREATER THAN OR EQUAL TO REALS(3) WHERE
C.                                 N IS THE NUMBER OF DIFFERENT VALUES USED)
C.
C.               SET THE INITIAL VALUE IN THE PARAMETER ARRAY
C.
          NPARAM = IFIX(REALS(1) + 0.2)
          PARAM(NPARAM) = REALS(2)
C.
C.          SET THE VALUES IN THE SENSITIVITY ARRAY
C.
C.          COMPUTE THE NUMBER OF DIFFERENT PARAMETER VALUES
C.
      NVALUE = IFIX((REALS(3) - REALS(2)) / REALS(4) + 1.50)
      IF (NVALUE.GT.MAXVAL) GO TO 2100
      DO 300 I = 1,NVALUE
          SENS(NPARAM,I) = REALS(2) + (I - 1) * REALS(4)
  300 CONTINUE
C.
C.          SET THE NUMBER OF VALUES IN THE PROPER COLUMN OF THE
C.          NBR ARRAY
      NBR(NPARAM) = NVALUE
C.
C.          LOOP BACK AND READ THE NEXT CARD
C.
      GO TO 100
  400 CONTINUE
C.
C.          THIS POINT IS REACHED IF THE USER HAS ALTERED THE MAXIMUM
C.          NUMBER OF ITERATIONS (DIFFERENT CASES) TO BE COMPUTED
C.
      MAXITR = IFIX(REALS(1) + 0.2)
```

```
C.
C.          LOOP BACK TO READ THE NEXT RECORD
C.
      GO TO 100
  500 CONTINUE
C.
C.          THIS POINT IS REACHED WHEN THE LOGICAL UNIT NUMBER FOR
C.          THE OUTPUT HAS BEEN CHANGED
C.    LUW = IFIX(REALS(1) + 0.2)
C.
C.          BRANCH BACK TO READ NEXT RECORD
C.
      GO TO 100
  510 CONTINUE
C.
C.          THIS POINT IS REACHED WHENEVER THE LOGICAL UNIT NUMBER
C.          FOR THE INPUT FILE IS TO BE CHANGED.  THIS IS REALISTIC
C.          ONLY IF THERE IS A DATA FILE ON A DEVICE SUCH AS DISK OR
C.          TAPE WHICH IS TO BE USED IN ADDITION TO THE CARD FILE.
C.          FOR EXAMPLE, THE USER COULD ESTABLISH A STANDARD SET OF
C.          DEFAULT VALUES AND MAINTAIN THEM IN A DISK FILE.  THEN
C.          ALL THAT WOULD BE NECESSARY WOULD BE TO PROVIDE THE
C.          CHANGES TO THE PROPER PARAMETERS AND THEN ENTER THE
C.          STANDARD DEFAULT FILE.  CARE SHOULD BE TAKEN THAT THE
C.          PARAMETERS IN THE STANDARD DEFAULT FILE DO NOT SUPERCEDE
C.          THOSE PARAMETERS IN THE CARD INPUT FILE.
C.
      LUR = IFIX(REALS(1) + 0.2)
C.
C.          BRANCH BACK TO READ THE NEXT RECORD
C.
      GO TO 100
  520 CONTINUE
C.
C.          AT THIS POINT THE INPUT RECORD HAS SPECIFIED THAT
C.          A REPLACEMENT VALUE HAS BEEN SPECIFIED FOR A GIVEN
C.          YEAR.  THE FIRST REAL VALUE REPRESENTS THE YEAR AND
C.          THE SECOND REPRESENTS THE REPLACEMENT VALUE.
C.
      I = IFIX(REALS(1) + 0.2)
C.
C.          I NOW CONTAINS THE VALUE OF THE YEAR.  STORE THE
C.          REPLACEMENT VALUE IN THE REPMAT MATRIX.
C.
      REPMAT(I) = REALS(2)
C.
C.          RETURN TO READ THE NEXT INPUT
C.
      GO TO 100
  530 CONTINUE
C.
```

```
C.          AT THIS POINT THE USER HAS SPECIFIED WHETHER THE ENTIRE
C.          PRESENT VALUE ARRAY IS TO BE PRINTED OR IF ONLY THE
C.          SUMMARY (PERIOD TOTALS) ARE TO BE PRINTED.
C.          IF REALS(1) = 0 THEN ONLY THE SUMMARY IS TO BE PRINTED
C.          OTHERWISE EVERYTHING IS TO BE PRINTED.  THE DEFAULT IS
C.          TO SET THE PRTFLG TO TRUE
C.
C.          THE FLAG WILL FIRST BE SET TO TRUE AND THEN CHANGED IF
C.          REALS (1) IS LESS THAN 0.5.  THIS IS DONE SO THAT MORE
C.          THAN ONE RESET PARAMETER CARD MAY BE USED AND STILL HAVE
C.          THE FLAG PROPERLY SET.  THE FLAG IS ALWAYS SET TO TRUE IN
C.          THE INITIALIZE SECTION.
C.
      PRTFLG = .TRUE.
      IF (REALS(1).LT.0.5) PRTFLG = .FALSE.
C.
C.          RETURN TO READ NEXT INPUT RECORD
C.
      GO TO 100
  550 CONTINUE
      MODDEP = IFIX(REALS(1) + 0.2)
      IF (MODDEP.GT.MAXDEP) GO TO 2300
      GO TO 100
  575 CONTINUE
      MINPBK = IFIX(REALS(1) + 0.2)
      GO TO 100
  600 CONTINUE
C.
C.          AT THIS POINT WE HAVE JUST ENCOUNTERED END OF FILE ON TH
C.          INPUT FILE
C.
C.          FIRST INSURE THAT THE NUMBER OF ITERATIONS DOES NOT
C.          EXCEED THE MAXIMUM ALLOWED AND INITIALIZE THE FIRST ROW
C.          OF THE SENS ARRAY
      LSTCOL = 1
      J = 1
      DO 700 I = 1,MAXPRM
C.
C.          THE VALUE OF J WILL BE THE NUMBER OF ITERATIONS AND
C.          IS THE PRODUCT OF ALL OF THE ELEMENTS IN THE NBR ARRAY
C.
         J = J * NBR(I)
         IF (NBR(I).GT.1) LSTCOL = I
C.          SET THE FIRST ROW OF THE SENS ARRAY TO THE INITIAL PARAMETER
C.          VALUES
C.
         SENS(I,1) = PARAM(I)
  700 CONTINUE
C.          ALL OF THE PRELIMINARY CHECKS AND DATA ASSIGNMENTS ARE
C.          OVER.  FIRST WE WILL FIND THE LAST ENTRY IN THE NBR ARRAY
C.          WITH A VALUE GREATER THAN 1.  THE ITERATIONS WILL BEGIN
```

```
C.         IN THIS COLUMN.  THEN WE STEP DOWN TO THE NEXT COLUMN
C.         WITH AN ENTRY GREATER THAN 1 AND PICK THE SUCCEEDING
C.         ENTRY.  THIS BEING DONE, WE STEP BACK TO THE END ANY
C.         VARY ALL THE OTHER ENTRIES IN ORDER TO PRODUCE ALL POSSIBLE
C.         COMBINATIONS.
C.
      IF (J.GT.MAXITR) GO TO 2200
C.
C.         LASTN WILL REPRESENT THE NUMBER OF DIFFERENT VALUES OF
C.         THE LAST PARAMETER TO BE VARIED.  WE WILL LOOP ON THIS
C.         LAST COLUMN
C.
      LASTN = NBR(LSTCOL)
C.
C.         THIS LABEL WILL START THE MAIN OR OUTER LOOP
C.
  800 CONTINUE
      DO 1100 I = 1,LASTN
          ICOL(LSTCOL) = I
C.         SET UP THE PARAM ARRAY.  THE INDEX FOR EACH PARAMETER
C.         IS MAINTAINED IN THE ICOL ARRAY.
C.
          DO 850 J = 1,MAXPRM
               PARAM(J) = SENS(J,ICOL(J))
  850     CONTINUE
C.         IF MODDEP = 1 THEN THE SUM OF THE YEARS METHOD IS USED
C.         TO COMPUTE THE DEPRECIATION.  COMPUTE THE SUM OF THE
C.         YEARS (USED AS THE DEMONINATOR IN THE DEPRECIATION
C.         FORMULA) BY USE OF THE ARITHMETIC PROGRESSION FORMULA
C.         WITH INITIAL TERM OF 1 AND WITH DIFFERENCE OF 1.
C.
          IF (MODDEP.EQ.1) DEPDEN = DEPYRS + DEPYRS * (DEPYRS - 1.) / 2.
C.
C.             COMPUTE THE LAND COST
C.
          CSTLND = CSTLND * ACRES
C.
C.         NOW PERFORM THE MAINLINE CALCULATIONS SUCH AS ANNUAL
C.         PAYMENTS, INSURANCE COSTS, ETC.  THESE ARE BASICALLY ALL
C.         THE VALUES WHICH ARE PRINTED IN THE HEADING.
C.
C.         ANNUAL PAYMENT COMPUTATION
          TCAPIN = CAPINV + CSTLND
          DWNPAY = TCAPIN * DWNPMT
C.             AMOUNT OF LOAN
          PRINC  = CAPINV * (1.0 - DWNPMT)
          CRDTAX = TAXCRD * CAPINV
C.
C.             DO A LITTLE HOUSEKEEPING REGARDING DATA TYPES
C.
          LIFSYS = IFIX(SYSYR + 0.2)
```

```
      LIFLON = IFIX(LOANYR + 0.2)
C.
C.          COMPUTE ANNUAL PAYMENT
C.
      FACTOR = (1.0 + IRATE) ** LIFLON
      ANNPAY = (TCAPIN - DWNPAY) * IRATE * FACTOR / (FACTOR - 1.0)
C.
C.          WRITE THE HEADER
C.
      WRITE(LUW,1111) CAPINV,LIFSYS,CSTLND,FUEL,DWNPAY,OANDM,
     1                FRATE,IRATE,OMRATE,DISRTE,INS,ELECT
      WRITE(LUW,1112) LIFLON,INSRAT,TXRATE,TAXCRD,ERATE,PLTAX,
     1                SALVAG,PCRATE,PCTAX,PLRATE,ANNPAY
C.          OK IS A BOOLEAN WHICH INDICATES THAT WE HAVE REACHED
C.          THE END OF A COLUMN OTHER THAN THE LAST COLUMN.  WHEN
C.          THIS OCCURS WE STEP DOWN TO THE NEXT COLUMN IN WHICH
C.          NBR , 1 AND VARY ALL HIGHER COLUMN PARAMETERS
      FUEL = FUEL / (1. + FRATE)
      ELECT = ELECT / (1. + ERATE)
      OM = OANDM / (1. + OMRATE)
      INS = INS * CAPINV / (1.0 + INSRAT)
      INTLND = IRATE * CSTLND * (1.0 - DWNPMT)
      PLTAX = CSTLND * PLTAX / (1.0 + PLRATE)
      PCTAX = CAPINV * PCTAX / (1.0 + PCRATE)
C.
C.           INITIALIZE THE PRESENT VALUE FACTOR
C.
      PRSFCT = 1.0
C.
C.
      J = 0
C.
C.          WRITE OUT YEAR ZERO FIGURES - BASICALLY DOWN PAYMENT
C.
      TOTALS(1) = TOTALS(1) + DWNPAY
      TOTALS(13) = TOTALS(13) + DWNPAY
      PRSVAL(1,1) = PRSVAL(1,1) + DWNPAY
      PRSVAL(1,13) = PRSVAL(1,13) + DWNPAY
C.
C.          WRITE OUT THE HEADING
C.
      WRITE(LUW,2222)
      LINECT = 1
      WRITE(LUW,3333) J,(TOTALS(J), J = 1,13)
C.
      BALANC = PRINC
C.
C.          LOOP ON THE LIFE OF THE SYSTEM AND COMPUTE THE
C.          YEARLY FIGURES.
C.
      DO 950 J = 1,LIFSYS
```

```
C.
C.                  ADJUST THE PRESENT VALUE FACTOR FOR THIS YEAR
C.
               PRSFCT = PRSFCT / (1.0 + DISRTE)
C.
C.                  J REPRESENTS THE YEAR.  IF THE YEAR EXCEEDS THE
C.                  LIFE OF THE LOAN THEN THE PRINCIPAL AND INTEREST
C.                  ARE ZERO
C.
               IF (J.LE.LIFLON) GO TO 910
               ANNPAY = 0.0
               PRINC  = 0.0
               BALANC = 0.0
  910          CONTINUE
               INTCAP = BALANC * IRATE
               PRINC  = ANNPAY - INTCAP - INTLND
               BALANC = BALANC - PRINC
               INS    = INS    * (1.0 + INSRAT)
               OM     = OM * (1. + OMRATE)
               REPLAC = REPMAT(J)
               PLTAX = PLTAX * (1.0 + PLRATE)
               PCTAX = PCTAX * (1.0 + PCRATE)
               FUEL = FUEL * (1. + FRATE)
               ELECT = ELECT * (1. + ERATE)
               IF (MODDEP.EQ.1) DEPREC = (DEPYRS - J + 1.)
     1                                   * (CAPINV - SALVAG) / DEPDEN
               IF (MODDEP.EQ.2) DEPREC = (CAPINV - SALVAG) / DEPYRS
C.
C.                 IF THE NUMBER OF YEARS OVER WHICH THE SYSTEM IS TO
C.                 BE DEPRECIATED IS LESS THAN THE YEAR UPON WHICH
C.                 WE ARE WORKING THEN THERE WILL BE NO DEPRECIATION AS
C.                 ALL DEPRECIATION HAS BEEN ACCOUNTED FOR BY NOW.
C.                 ALSO IF WE ARE IN THE MODE WHERE THERE IS NO
C.                 DEPRECIATION (MODE 0) THEN SET IT EQUAL TO ZERO
C.
               IF (DEPYRS.LT.J .OR. MODDEP.EQ.0) DEPREC = 0.0
               TAXDIF = -TXRATE * ( INTCAP + OM + INS + PCTAX + PLTAX
     1                             + REPLAC + DEPREC + INTLND
     2                             + ELECT + FUEL)
               IF (J.GT.1) GO TO 920
               TAXDIF = TAXDIF - CRDTAX
               DWNPAY = 0.0
               CRDTAX = 0.0
  920          CONTINUE
               NETCST = DWNPAY + ANNPAY + OM + INS + ELECT + FUEL
     1                         + PCTAX + PLTAX + TAXDIF + REPLAC
C.
C.                  IF THIS IS THE LAST YEAR WE WILL INCLUDE THE
C.                  SALVAGE VALUE, LAND PAYOFF, AND LAND RESALE
C.                  VALUE INTO THE NET COST COLUMN.  THESE ITEMS
C.                  ARE NOT ACCOUNTED FOR IN THE TAX DIFFERENCE
```

```
C.                  COLUMN.
C.
               IF (J.LT.LIFSYS) GO TO 930
C.
C.                   FIRST ACCOUNT FOR THE SALVAGE VALUE
C.
               NETCST = NETCST - SALVAG
C.
C.                   SECOND, PAY OFF THE PRINCIPAL ON THE LAND
C.
               NETCST = NETCST + CSTLND * (1.0 - DWNPMT)
C.
C.                   THIRD, THE RESALE VALUE OF THE LAND
C.
               NETCST = NETCST - CSTLND * (1.0 + APPLND) ** (LIFSYS - 1)
  930          CONTINUE
               SUMCST = SUMCST - NETCST
               TOTALS(1) = TOTALS(1) + PRINC
               TOTALS(2) = TOTALS(2) + INTCAP
               TOTALS(3) = TOTALS(3) + INTLND
               TOTALS(4) = TOTALS(4) + OM
               TOTALS(5) = TOTALS(5) + INS
               TOTALS(6) = TOTALS(6) + REPLAC
               TOTALS(7) = TOTALS(7) + FUEL
               TOTALS(8) = TOTALS(8) + ELECT
               TOTALS(9) = TOTALS(9) + DEPREC
               TOTALS(10) = TOTALS(10) + PLTAX
               TOTALS(11) = TOTALS(11) + PCTAX
               TOTALS(12) = TOTALS(12) + TAXDIF
               TOTALS(13) = TOTALS(13) + NETCST
C.
C.             COMPUTE THE PRESENT VALUES AND ACCUMULATE INTO
C.             PRSVAL ARRAY
          PRSVAL(J+1,1) =    PRSFCT * PRINC
          PRSVAL(J+1,2) =    PRSFCT * INTCAP
          PRSVAL(J+1,3) =    PRSFCT * INTLND
          PRSVAL(J+1,4) =    PRSFCT * OM
          PRSVAL(J+1,5) =    PRSFCT * INS
          PRSVAL(J+1,6) =    PRSFCT * REPLAC
          PRSVAL(J+1,7) =    PRSFCT * FUEL
          PRSVAL(J+1,8) =    PRSFCT * ELECT
          PRSVAL(J+1,9) =    PRSFCT * DEPREC
          PRSVAL(J+1,10) =    PRSFCT * PLTAX
          PRSVAL(J+1,11) =    PRSFCT * PCTAX
          PRSVAL(J+1,12) =    PRSFCT * TAXDIF
          PRSVAL(J+1,13) =    PRSFCT * NETCST
C.
C.                   ALL THE COST, TAXES, ETC. HAVE BEEN COMPUTED
C.                   WRITE OUT THIS YEARS TOTALS
C.
          IF (LINECT.EQ.0) WRITE(LUW,2222)
```

```
               WRITE(LUW,3333) J,PRINC,INTCAP,INTLND,OM,INS,REPLAC,
     1                          FUEL,ELECT,DEPREC,PLTAX,PCTAX,
     2                          TAXDIF,NETCST
               LINECT = LINECT + 1
               IF (SUMCST.LT.0. .OR. PAYBAK .OR. J.LT.MINPBK) GO TO 945
               IF (.NOT. PAYBAK) WRITE(LUW,222)
               PAYBAK = .TRUE.
  945          CONTINUE
               IF (LINECT.LT.MAXLIN) GO TO 940
               LINECT = 0
               WRITE(LUW,9999)
  940          CONTINUE
C.
C.                  END DO LOOP
C.
  950     CONTINUE
C.
C.             AT THIS POINT WE HAVE COMPLETED ONE ITERATION(CASE)
C.
C.
C.             WRITE THE TOTALS
C.
           WRITE(LUW,4444) (TOTALS(J),J=1,13),(METHOD(J,MODDEP),J=1,5)
          IF (PAYBAK) WRITE(LUW,333)
C.
C.             ACCUMULATE THE TOTALS IN THE PRESENT VALUE ARRAY
C.
          LVALUE = LIFSYS + 1
          DO 955 J = 1,LVALUE
          DO 955 K = 1,13
               PRSVAL(LVALUE+1,K) = PRSVAL(LVALUE+1,K) + PRSVAL(J,K)
  955     CONTINUE
C.
C.             IF THE ENTIRE ARRAY IS NOT TO BE PRINTED OUT, BRANCH
C.             TO THE POINT WHERE ONLY THE TOTALS ARE PRINTED.
C.
          IF (.NOT. PRTFLG) GO TO 958
C.
C.             WRITE OUT THE PRESENT VALUE ARRAY STARTING AT THE TOP
C.             OF THE NEXT PAGE.
C.
          WRITE(LUW,444)
  444 FORMAT(1H1,47X,39HS Y S T E M   C O S T   A N A L Y S I S,// 1X,
     1           48X,39HP R E S E N T   V A L U E   C O S T S   , ///)
          WRITE(LUW,2222)
C.
C.
C.             WE CAN NOW WRITE OUT THE ARRAY
C.             FIRST WRITE OUT ALL THE ROWS EXCEPT FOR THE TOTALS
C.             WE USE ONLY ONE IMPLIED DO LOOP AND LET THE FORMAT
C.             TAKE CARE OF ROW ALIGNMENT
```

```
C.
          DO 957 J = 1,LVALUE
               K = J - 1
               WRITE(LUW,3333) K, (PRSVAL(J,L),L=1,13)
  957     CONTINUE
C.
C.             WRITE OUT THE HEADER AT THE BOTTOM BEFORE THE TOTALS
C.
          WRITE(LUW,4444) (PRSVAL(LVALUE+1,J),J=1,13),
     1                          (METHOD(J,MODDEP),J=1,5)
          GO TO 959
  958     CONTINUE
C.
C.             WRITE OUT THE TOTALS OF THE PRESENT VALUES
C.
          WRITE(LUW,4445) (PRSVAL(LVALUE+1,J),J=1,13)
  959     CONTINUE
C.
C.             RESET THE TOTALS ARRAY TO ZERO
C.
          DO 960 J = 1,13
               TOTALS(J) = 0.0
          DO 960 K = 1,40
               PRSVAL(K,J) = 0.0
  960     CONTINUE
          LINECT = 0
          SUMCST = 0.0
          PAYBAK = .FALSE.
 1100 CONTINUE
C.
          OK = .TRUE.
C.
C.             LAST WILL BE THE COLUMN NUMBER PRIOR TO THE LAST COLUMN
C.             WITH MULTIPLE VALUES
C.
          LAST = LSTCOL - 1
          IF (LAST.EQ.0) GO TO 1200
          DO 1000 J = 1,LSTCOL
C.
C.                  IF WE HAVE FOUND A NEW CASE TO COMPUTE BRANCH
C.                  TO THE START
C.
               IF (.NOT.OK) GO TO 800
               INDEX = LSTCOL - J
               IF (INDEX.EQ.0) GO TO 1000
               IF (NBR(INDEX).LE.1 .OR. ICOL(INDEX).GE.NBR(INDEX))
     1              GO TO 1000
               ICOL(INDEX) = ICOL(INDEX) + 1
               OK = .FALSE.
               INDEX = INDEX + 1
               DO 990 K = INDEX,LAST
```

```
                  ICOL(K) = 1
 990           CONTINUE
1000      CONTINUE
1200 CONTINUE
     STOP
1111 FORMAT(1H1, 47X, 39HS Y S T E M   C O S T   A N A L Y S I S,///1X,
    1     22HCAPITAL INVESTMENT = $, F10.0, 8X,
    .     25H           ANALYSIS PERIOD =, I4, 6H YEARS, 15X,
    .     12HCOST OF FUEL, / 1X,
    .     22H      REAL PROPERTY = $, 0PF10.0, 8X,
    .     21HFIRST YEAR OPERATIONS, 29X,
    .     19H  DURING FIRST YEAR, 8X, 3H= $, F8.0, / 1X,
    2     6X, 16H       EQUITY = $, F10.0, 8X,
    .     18H   AND MAINTENANCE, 6X, 3H= $, 0PF8.0, 15X,
    .     28HFUEL COST RATE OF INCREASE =,2PF6.2,8H PERCENT, / 1X,
    3     20HLOAN INTEREST RATE =,2PF6.2, 8H PERCENT, 6X,
    .     25HO AND M ESCALATION RATE =,2PF6.2,8H PERCENT, 11X,
    .     19HCOST OF ELECTRICITY, / 1X,
    4     5X, 15HDISCOUNT RATE =,2PF6.2,8H PERCENT, 6X,
    .     27HFIRST YEAR INSURANCE    = $,3PF6.2,13H PER THOUSAND, 4X,
    .     30H  DURING THE FIRST YEAR    = $, 0PF8.0)
1112 FORMAT(1X,
    5     20H         LOAN PERIOD =, I4, 6H YEARS, 10X,
    .     25HINSURANCE RATE INCREASE =, 2PF6.2, 8H PERCENT, 11X,
    .     24HELECTRICITY COST RATE OF, / 1X,
    6     20H   INCOME TAX RATE =,2PF6.2,8H PERCENT, 6X,
    .     25H           TAX CREDIT   =,2PF6.2,8H PERCENT, 11X,
    .     10H  INCREASE, 17X, 1H=, 2PF6.2, 8H PERCENT, /   1X,
    7     20H REAL PROPERTY TAX =,2PF6.2,8H PERCENT,6X,
    .     27HSYSTEM SALVAGE VALUE    = $,0PF8.0, 15X,
    .     28HCAP. PROP. TAX RATE INCR.  =,2PF6.2, 8H PERCENT,
    3     / 1X,
    .     20H CAP. PROPERTY TAX =,2PF6.2,8H PERCENT, 56X,
    .     28HREAL PROP. TAX RATE INCR.  =,2PF6.2,8H PERCENT
    .     // 1X,
    8     23HANNUAL LOAN PAYMENT = $, 0PF8.0, //)
2222 FORMAT(
    1     10X,20HANNUAL LOAN PAYMENT , 7X,7HOPERATE,11X,
    .     8HREPLACE-,30X,24HPROPERTY TAX       DELTA, /
    2     22X, 8HINTEREST,
    2     10X,3HAND,6X,41HINSUR-   MENT     FUEL    ELECT.  DEPREC-,
    .     22X,16HINCOME       NET  /
    3     1X,52HYEAR  PRINCIPAL CAPITAL     LAND     MAINTAIN    ANCE,
    .     5X,50HCOST      COST     COST   IATION**  REAL    CAPITAL,
    .     6X,16HTAX       COST * /
    4     1X,4H----,3(2X,8H--------),3X,8(9H-------- ),
    .     12H----------- , 11H---------- )
3333 FORMAT(1X,I3,1X,3F10.0,2X,8F9.0,2F12.0)
4444 FORMAT(5X,3(2X,8H--------),3X,8(9H-------- ),
    1     12H----------- , 11H---------- / 1X,
    1     4HTOT.,3F10.0,2X,8F9.0,2F12.0 //, 1X
```

```
     3     9X,43H*  FIRST YEAR NET COST INCLUDES TAX CREDIT.  // 1X,
     4    9X, 29H**  METHOD OF DEPRECIATION - , 5A4 // 1X)
 4445 FORMAT(1X,7HPRESENT, / 1X,
     1    4HVAL.,3F10.0,2X,8F9.0,2F12.0)
 2000 CONTINUE
      WRITE(LUW,5555) IFLAG, MAXPRM
 5555 FORMAT(1X,5(1H*), 17H PARAMETER NUMBER, I3, 18H EXCEEDS MAXIMUM ,,
     .    9H WHICH IS, I3,1H.)
      STOP
 2100 CONTINUE
      WRITE(LUW,6666) NVALUE, REALS(1), MAXVAL
 6665 FORMAT(1X,5(1H*), I3, 37H VALUES WERE SUBMITTED FOR PARAMETER ,
     .    F3.0, 5H ONLY, I3, 15H ARE PERMITTED.)
      STOP
 2200 CONTINUE
      WRITE(LUW,7777) J, MAXITR
 7777 FORMAT(1X,5(1H*), 18HYOU HAVE ASKED FOR, I5,
     .    48H REPORTS, BUT THE MAXIMUM NUMBER ALLOWED IS ONLY, I5, / 1X,
     .    5(1H*), 36H YOU MAY CHANGE THE MAX IF YOU LIKE.)
      STOP
 2300 CONTINUE
      WRITE(LUW,8888) MODDEP,MAXDEP
 8888 FORMAT(1X,5(1H*),18HDEPRECIATION MODE ,I4,16H DOES NOT EXIST./
     1        6X,22HMAXIMUM MODE VALUE IS ,I4)
      STOP
 9999 FORMAT(1H1)
  222 FORMAT(1H+,3X,3H***)
  333 FORMAT(10X,19H***  PAYBACK PERIOD)
      END
/*
//LKED.SYSLMOD DD DSN=A.T80221DS.LOADLIB(COST2),UNIT=SYSDA,DISP=OLD
/*
//
```

```
************************************************************************
```

Appendix H. Part 2 Utilization Instructions

```
************************************************************************
*                                                                      *
*     S Y S T E M   C O S T   A N A L Y S I S   P R O G R A M         *
*                                                                      *
*                   A U G U S T   2,   1 9 7 7                         *
*                                                                      *
*  A M E R I C A N   T E C H N O L O G I C A L   U N I V E R S I T Y *
*                                                                      *
************************************************************************
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THIS DOCUMENT DESCRIBES THE AMERICAN TECHNOLOGICAL UNIVERSITY'S COST
ANALYSIS PROGRAM WHICH WAS DEVELOPED WITH ERDA FUNDS UNDER CONTRACT
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*                                                                      *
*                        I N T R O D U C T I O N                       *
*                                                                      *
************************************************************************
.
THE COST ANALYSIS IS BASED UPON A NUMBER OF PARAMETERS WHICH ECONOM-
ICALLY DESCRIBES THE SYSTEM BEING MODELED.  THESE PARAMETERS HAVE BEEN
PROVIDED WITH DEFAULT VALUES, AND IF THE DEFAULTS ADEQUATELY DESCRIBE
THE SYSTEM BEING MODELED, THEN NO INPUT IS REQUIRED IN PRODUCING A
REPORT.  HOWEVER, IN ALMOST ALL SITUATIONS THE DEFAULT PARAMETERS
WILL NOT EXACTLY DESCRIBE THE SYSTEM, AND CHANGES WILL HAVE TO BE
EFFECTED.  IN ADDITION, SENSITIVITY ANALYSIS IN WHICH ONE OR MORE
PARAMETERS ARE VARIED IS A COMMON REQUIREMENT OF COST EVALUATIONS.
BOTH OF THESE CAPABILITIES HAVE BEEN INCLUDED, AND THE DETAILS OF
IMPLEMENTING THESE FEATURES ARE DESCRIBED BELOW.  CURRENTLY THERE
ARE THREE METHODS FOR CALCULATING DEPRECIATION OF THE SYSTEM.   THE
DEFAULT METHOD IS THE SUM OF THE YEARS METHOD.  THIS METHOD  IS A
DECREASING VALUE METHOD IN WHICH THE DEPRECIATION AMOUNTS DECREASE
OVER THE LIFE OF THE SYSTEM.  THE SECOND OPTIONAL METHOD IS THE
STRAIGHT LINE DEPRECIATION METHOD.  THE THIRD METHOD IS NO DEPRECIATION
COSTS AT ALL AS WOULD BE TYPICAL IN A RESIDENTIAL SYSTEM.  THE MANNER
IN WHICH A PARTICULAR METHOD IS CHOSEN IS DESCRIBED BELOW.
.
IN ADDITION TO THE BASIC OPTIONS GIVEN ABOVE, TWO OTHER OPTIONAL
FEATURES ARE CURRENTLY AVAILABLE WITHIN THE SYSTEM.  FIRST, THERE
IS THE ABILITY TO EASILY ALTER THE OUTPUT UNIT NUMBER TO ALLOW
OUTPUT TO A DIFFERENT DEVICE.  THE SECOND OPTION RELATES TO THE
SENSITIVITY ANALYSIS CAPABILITY.  THE NUMBER OF DIFFERENT CASES
TO BE EXAMINED IN A SENSITIVITY ANALYSIS GROWS MULTIPLICATIVELY, AND
CAN EASILY REACH AN UNMANAGEABLE VALUE.  AS A RESULT, THE SYSTEM HAS
BEEN DEFAULTED TO AN UPPER BOUND OF 100 DIFFERENT CASES ALLOWABLE PER
EXECUTION.  IN SOME INSTANCES THIS NUMBER MAY BE CONSIDERED EITHER
TOO HIGH OR TOO LOW, AND A METHOD FOR CHANGING THIS LIMIT IS PROVIDED.
.
************************************************************************
*                                                                      *
```

```
*               E C O N O M I C    P A R A M E T E R S                 *
*                                                                      *
************************************************************************
.
THE FOLLOWING PARAMETERS ARE USED IN THE PROGRAM.  EACH OF THESE PARAM-
ETERS MAY BE EASILY CHANGED AS EXPLAINED BELOW.
.
 PARAMETER    DESCRIPTION                       MNEMONIC     DEFAULT
  NUMBER                                          NAME        VALUE
.
    1.        CAPITAL INVESTMENT OF THE SYSTEM  CAPINV       5,000,000
              EXCLUDING THE COST OF THE LAND
              IF ANY. (DOLLARS)
.
    2.        DOWN PAYMENT MADE AS A FRACTION   DWNPMT       0.20
              OF THE CAPITAL COST.  A TEN
              PERCENT DOWN PAYMENT WOULD BE
              REPRESENTED BY 0.10
.
    3.        THE INTEREST RATE APPLIED TO THE  IRATE        0.09
              NOTE FOR FINANCING OF THE SYSTEM.
              EXPRESSED AS A DECIMAL FRACTION.
.
    4.        DISCOUNT RATE TO BE APPLIED WHEN  DISRTE       0.12
              COMPUTING PRESENT VALUE COSTS.
.
    5.        THE LIFE OF THE NOTE REFERRED TO  LOANYR       20
              IN PARAMETER 3.  THE VALUE IS
              NORMALLY CONSIDERED TO BE IN
              YEARS, BUT MAY REPRESENT ANY TERM.
.
    6.        THE EXPECTED LIFE OF THE SYSTEM   SYSYR        20
              USUALLY THOUGHT OF AS YEARS.  THE
              TIME SPAN USED FOR THIS PARAMETER
              SHOULD BE COMPATIBLE WITH THAT FOR
              THE LIFE OF THE LOAN (PARAMETER 5).
              THIS VALUE IS USED IN THE
              GENERATION OF THE NUMBER OF PERIODS
              FOR WHICH COSTING IS REPORTED.
.
    7.        FIRST YEAR OPERATION AND MAINTEN- OANDM        75,000
              ANCE COSTS IN DOLLARS.
.
    8.        THE ESCALATION RATE APPLIED TO    OMRATE       0.06
              THE COST OF OPERATING AND
              MAINTAINING THE SYSTEM.  THIS IS
              THE RATE APPLIED TO EACH PERIOD
              OF THE SYSTEM LIFE.
.
    9.        THE COST OF THE ELECTRICITY CON-  DELTAE       40,000
              SUMED BY THE SYSTEM DURING THE
```

	FIRST YEAR OF OPERATION. (DOLLARS)		
10.	THE ESCALATION RATE APPLIED TO TO THE COST OF ELECTRICITY CONSUMED BY THE SYSTEM.	ERATE	0.10
11.	THE COST OF THE FUEL ENERGY CONSUMED BY THE SYSTEM DURING THE FIRST YEAR OF OPERATION.	DELTAF	35,000
12.	THE ESCALATION RATE APPLIED TO THE COST OF FUEL CONSUMED BY THE SYSTEM.	FRATE	0.12
13.	THE INCOME TAX RATE APPLICABLE TO THE ENTITY PURCHASING THE SYSTEM.	TXRATE	0.50
14.	THE TAX CREDIT ALLOWED FOR INVESTMENT IN THE SYSTEM BEING MODELED. THIS CREDIT IS COMPUTED AS A FRACTION OF THE CAPITAL COST AND IS DEDUCTED FROM THE INCOME TAX DURING THE FIRST YEAR OF THE SYSTEM'S LIFE.	TAXCRD	0.20
15.	THE INSURANCE RATE APPLIED TO THE SYSTEM. THIS FRACTION IS APPLIED TO THE CAPITAL INVESTMENT LESS THE LAND COST.	INS	0.01
16.	THE PROPERTY TAX RATE AS APPLIED TO THE CAPITAL INVESTMENT COST.	PCTAX	0.00
17.	THE ESCALATION RATE APPLIED TO THE PROPERTY TAX ON THE CAPITAL INVESTMENT (DOES NOT INCLUDE THE COST OF THE LAND, IF ANY).	PCRATE	0.06
18.	THE ESCALATION RATE APPLIED TO COST OF INSURANCE FOR THE SYSTEM.	INSRAT	0.06
19.	THE COST OF THE LAND PER ACRE FOR THE SYSTEM IF ANY. THIS COST IS IN ADDITION TO THE CAPITAL INVESTMENT IN CAPITAL EQUIPMENT, AND MAY BE SUBJECTED TO A DIFFERENT ESCALATION RATE.	CSTLND	17,500
20.	THE NUMBER OF ACRES OF LAND REQUIRED FOR THE SYSTEM IF ANY.	ACRES	5

```
             THIS PARAMETER TIMES THE CSTLND
             PARAMETER (19) GIVES THE TOTAL
             LAND COST.
   21.       THE NUMBER OF YEARS OVER WHICH    DEPYRS       20
             THE SYSTEM IS TO BE DEPRECIATED.
.
   22.       THE FIRST YEAR REPLACEMENT COSTS  REPLAC       0.00
             IN DOLLARS.
.
   23.       THE SALVAGE VALUE OF THE SYSTEM   SALVAG       250,000.
             IN DOLLARS.  THIS FIGURE IS USED
             IN DEPRECIATION CALCULATIONS AND
             IN THE NET COST CALCULATIONS.
.
   24.       THE REAL PROPERTY TAX RATE AS     PLTAX        0.03
             APPLIED TO ANY LAND PURCHASED
             FOR THE SYSTEM.
.
   25.       THE RATE AT WHICH THE LAND        PLRATE       0.06
             APPRECIATES IN VALUE.
.
   26.       THE ESCALATION RATE APPLIED TO    REPRTE       0.06
             REPLACEMENT COSTS (REPLAC).
.
   27.       THE ESCALATION RATE APPLIED TO    APPLND       0.06
             THE LAND.
.
**********************************************************************
*                                                                    *
*                  O T H E R    P A R A M E T E R S                  *
*                                                                    *
**********************************************************************
.
    A.       THE PARAMETER REPRESENTING THE    DEPMOD       1
             MODE IN WHICH THE DEPRECIATION
             IS COMPUTED.  1 REPRESENTS THE
             SUM OF THE YEARS METHOD WHILE
             2 REPRESENTS THE STRAIGHT LINE
             METHOD.  ZERO REPRESENT NO DEP-
             RECIATION.
.
    B.       THE LOGICAL UNIT UPON WHICH THE   LUW          6
             OUTPJT IS WRITTEN.
.
    C.       THE NUMBER OF COST PARAMETERS.    MAXPRM       27
.
    D.       THE MAXIMUM NUMBER OF SENSITIVITY MAXITR       100
             CASES ALLOWED PER EXECUTION.
.
    E.       THE MAXIMUM NUMBER OF VALUES FOR  MAXVAL       20
             A GIVEN PARAMETER MAY ASSUME
```

	DURING SENSITIVITY ANALYSIS.		
F.	THE MAXIMUM NUMBER OF LINES PER PAGE OF OUTPUT ALLOWED, EXCLUSIVE OF HEADINGS, TOTALS, AND FOOTNOTES.	MAXLIN	30
G.	THE COUNT OF THE NUMBER OF LINES WRITTEN PER PAGE EXCLUSIVE OF HEADINGS, TOTALS, AND FOOTNOTES.	LINECT	0
H.	THE MAXIMUM NUMBER OF METHODS ALLOWED FOR DEPRECIATION. THIS VALUE IS USED ONLY AS A CHECK TO INSURE THAT A MODE SUBSTITUTED FOR THE DEFAULT MODE IS VALID.	MAXDEP	3
I.	THE MINIMUM NUMBER OF YEARS IN WHICH A PAYBACK MAY OCCUR. BECAUSE OF THE MANNER IN WHICH THE TAX CREDIT IS APPLIED THE CHECK WHICH IS MADE TO DETERMINE IF A PAYBACK SITUATION HAS BEEN REACHED MAY FALSELY BE SPECIFIED IN THE FIRST FEW YEARS IF THIS PARAMETER IS GIVEN A LOW VALUE.	MINPBK	100
J.	THE SUM OF THE NET COSTS THUS FAR ACCRUED. WHENEVER THIS SUM ASSUMES A NEGATIVE VALUE AND THE MINPBK PERIOD HAS BEEN REACHED THEN A PAYBACK PERIOD IS ASSUMED TO HAVE BEEN REACHED. THE CURRENT PERIOD IS FLAGGED AS THE PAYBACK PERIOD FOR THE CURRENT ITERATION.	SUMCST	0.0
K.	A BOOLEAN FLAG WHICH IS USED TO INDICATE IF A PAYBACK PERIOD HAS BEEN RECOGNIZED DURING THE CURRENT ITERATION (CASE).	PAYBAK	.FALSE.
L.	A BOOLEAN FLAG USED TO INDICATE IF A NEW CASE HAS BEEN ENCOUNTERED. USED IN CASE DETERMINATION IN SENSITIVITY ANALYSIS.	OK	.TRUE.
M.	A DATA FIELD USED TO REPRESENT THE FIRST FIELD IN THE INPUT STREAM. THIS FIELD REPRESENTS THE TYPE OF ACTION REQUIRED OR THE NUMBER OF THE PARAMETER FOR	IFLAG	--

WHICH A CHANGE IN DEFAULT VALUE IS DESIRED.

N.	A FOUR POSITION ARRAY WHICH IS USED TO HOLD THE DATA VALUES AS READ FROM THE INPUT STREAM.	REALS

PREPARING INPUT SPECIFICATIONS

1. GENERAL

ALL CHANGES TO THE SYSTEM PARAMETERS ARE EFFECTED THROUGH SPECIFICATIONS IN THE INPUT (CARD) FILE. ONE INPUT RECORD (CARD) WILL BE USED TO CHANGE THE DEFAULT SPECIFICATIONS FOR A GIVEN PARAMETER, AND UP TO FIVE FIELDS MAY BE REQUIRED TO COMPLETELY DEFINE A CHANGE FOR ONE PARAMETER (SEE SENSITIVITY ANALYSIS BELOW). IT SHOULD BE NOTED THAT ONLY ONE PARAMETER SPECIFICATION IS ALLOWED PER INPUT RECORD (CARD). FOR A GIVEN PARAMETER IT IS PERMISSIBLE TO SPECIFY SEVERAL PARAMETER ALTERATIONS USING ONE INPUT RECORD FOR EACH SPECIFICATION. IN THESE CASES THE LAST SPECIFICATION ENCOUNTERED WILL TAKE EFFECT. THUS IT IS POSSIBLE TO HAVE THE FOLLOWING RECORDS IN THE INPUT FILE

```
....5....0....5....0....5....0
  1 2000000.
  1 3000000.
  1 4000000.
```

THESE SPECIFICATIONS ALL WILL CHANGE THE DEFAULT VALUE FOR THE FIRST PARAMETER (CAPITAL COST OF THE SYSTEM). IN THE ABOVE EXAMPLE, ONLY THE LAST SPECIFICATION WILL TAKE EFFECT, AND THE CAPITAL COST OF THE SYSTEM FOR THE ANALYSIS WILL BE 4,000,000 DOLLARS (SEE BELOW FOR INSTRUCTIONS FOR CHANGING PARAMETER VALUES).

ALL INPUT RECORDS ARE READ IN THE SAME FORMAT -

```
I3, 4F10.2
```

WITH THE INTEGER READ INTO THE IFLAG DATA ITEM WHILE THE REAL VALUES ARE READ INTO THE REAL ARRAY. THE INTEGER IS USED TO REPRESENT THE NUMBER OF THE PARAMETER BEING CHANGED OR REPRESENTS A FLAG INDICATING OTHER PARAMETER SPECIFICATIONS SUCH AS SENSITIVITY ANALYSIS. THE REAL VALUES(S) REPRESENT THE CHANGED VALUE OF THE PARAMETER OR OTHER PARAMETER SPECIFICATIONS.

IMPORTANT

WHEN PLACING DATA INTO THE INPUT DECK, THE FIRST NUMBER WHICH

REPRESENTS THE PARAMETER NUMBER OR ACTIVITY NUMBER MUST BE INSERTED IN COLUMNS 1 THRU 3 INCLUSIVE AND BE RIGHT JUSTIFIED. ONLY THE REQUIRED NUMBER OF ADDITIONAL PARAMETERS (FOUR MAXIMUM) NEED BE INSERTED AND WILL OCCUPY COLUMNS 4 THRU 13, 14 THRU 23, 24 THRU 33, AND 34 THRU 43. FOR SIMPLICITY THE VALUES INSERTED INTO THESE FIELDS MUST ALWAYS HAVE A DECIMAL POINT (EVEN IF IT REPRESENT AN INTEGER VALUE) AND MAY BE PLACED ANYWHERE WITHIN THE SPECIFIED FIELD.

.

************************** I M P O R T A N T **************************

.

2. CHANGING THE DEFAULT SETTING OF A PARAMETER.

.

PLACE THE PARAMETER NUMBER OF THE PARAMETER BEING CHANGED IN COLUMN 1 THRU 3 (RIGHT JUSTIFIED). PLACE THE NEW VALUE OF THE PARAMETER IN COLUMNS 4 THRU 13 WITH THE DECIMAL POINT IN THE PROPER POSITION. THIS VALUE MAY BE POSITIONED ANYWHERE WITHIN THE COLUMN LIMITS PROVIDED THE DECIMAL POINT IS USED. FOR EXAMPLE, TO CHANGE THE DEFAULT VALUE FOR THE FUEL ESCALATION RATE TO 15 PERCENT, USE THE FOLLOWING INPUT

```
....5....0....5....0....5....0
 12 0.15
```

.

3. SENSITIVITY ANALYSIS.

.

FREQUENTLY IT IS DESIRABLE TO ANALYZE THE ECONOMIC EFFECT OF VARYING ONE OR MORE PARAMETERS FROM AN INITIAL VALUE BY A GIVEN INCREMENT UNTIL SOME UPPER VALUE IS ATTAINED. FOR EXAMPLE, ONE COULD EXAMINE THE OVERALL AFFECT OF DIFFERING INTEREST RATES FROM 8 TO 12 PERCENT IN INCREMENTS OF 0.5 PERCENT. SENSITIVITY ANALYSIS OF THIS TYPE MAY BE SPECIFIED FOR ONE OR MORE PARAMETERS BY ENCODING FIVE DESCRIPTORS IN ONE CARD. THE DESCRIPTORS ARE THE ACTIVITY CODE (999 FOR SENSITIVITY ANALYSIS), PARAMETER NUMBER, INITIAL VALUE, TERMINAL VALUE, AND INCREMENTAL VALUE. THERE IS ONE REPORT PRODUCED FOR EACH DIFFERENT VALUE

INITIAL-VALUE + (N)(INCREMENTAL-VALUE)

WHERE

N = 0, 1, 2, 3, . . . K

AND

K = 1 + (TERMINAL-VALUE - INITIAL-VALUE) / INCREMENTAL-VALUE

.

IN CASES WHEREIN MORE THAN ONE PARAMETER IS SUBJECTED TO THIS TYPE OF SENSITIVITY ANALYSIS, THE TOTAL NUMBER OF REPORTS PRODUCED IS THE PRODUCT OF THE NUMBER OF DIFFERENT POSSIBLE VALUES FOR EACH OF THE PARAMETERS. THAT IS,

.

NUMBER-OF-REPORTS = (K1) (K2) ... (KI)

.

WHERE THE K'S ARE CALCULATED AS INDICATED ABOVE FOR EACH OF THE I DIFFERENT PARAMETERS. FOR EXAMPLE, IF ONE VARIED THE INTEREST RATE FROM 8 TO 12 PERCENT IN INCREMENTS OF 0.5 PERCENT AND ALSO VARIED THE CAPITAL COST FROM 1,000,000 TO 10,000,000 DOLLARS IN

INCREMENTS OF 1,000,000 THEN THE TOTAL NUMBER OF REPORTS PRODUCED WOULD BE

•

$$\left(1 + \frac{0.12 - 0.08}{0.05}\right) \left(1 + \frac{10,000,000 - 1,000,000}{1,000,000}\right) = (9)(10) = 90$$

•

IT IS EVIDENT THAT THE NUMBER OF POSSIBLE REPORTS CAN BECOME RATHER UNMANAGEABLE AND A CHECK HAS BEEN PROVIDED TO INSURE THAT THIS NUMBER DOES NOT BECOME INADVERTENTLY LARGE (SEE ITEM 4 BELOW).

•

PLACE THE ACTIVITY CODE 999 IN COLUMNS 1 THRU 3 OF THE INPUT RECORD. PLACE THE PARAMETER NUMBER OF THE PARAMETER BEING SUBJECTED TO SENSITIVITY ANALYSIS IN COLUMNS 4 THRU 13 WITH THE DECIMAL POINT INCLUDED. PLACE THE INITIAL VALUE FOR THE PARAMETER IN COLUMNS 14 THRU 23 WITH THE DECIMAL POINT IN THE PROPER POSITION. PLACE THE TERMINAL VALUE IN COLUMNS 24 THRU 33 WITH THE DECIMAL POINT INCLUDED. PLACE THE INCREMENTAL VALUE IN COLUMNS 34 THRU 43 WITH THE DECIMAL POINT INCLUDED. THE VALUE OF THE PARAMETER IS VARIED FROM THE INITIAL VALUE BY THE INCREMENTAL VALUE UNTIL THE ENDING VALUE IS EXCEEDED. FOR EXAMPLE, IF IT IS DESIRED TO ANALYZE CAPITAL COSTS FROM 2,000,000 TO 10,000,000 DOLLARS IN 2,000,000 DOLLAR INCREMENTS THEN THE FOLLOWING CARD SHOULD BE CODED

```
....5....0....5....0....5....0....5....0....5....0....5....0
999 1.         2000000. 10000000. 2000000.
```

•

NOTE THAT THE DECIMAL POINTS ARE REQUIRED IN THE LAST FOUR FIELDS AND THAT THE VALUES MAY BE CODED ANYWHERE WITHIN THOSE FIELDS.

•

4. CHANGING THE MAXIMUM NUMBER OF SENSITIVITY CASES.

•

PLACE THE ACTIVITY CODE 998 IN COLUMNS 1 THRU 3. PLACE THE NEW MAXIMUM NUMBER OF CASES ALLOWED IN COLUMNS 4 THRU 13 WITH THE DECIMAL POINT INCLUDED. FOR EXAMPLE, TO CHANGE THE MAXIMUN NUMBER OF CASES ALLOWED TO 150 ONE WOULD USE THE FOLLOWING INPUT

```
....5....0....5....0....5....0....5....0
998 150.
```

•

5. CHANGE TO LOGICAL UNIT NUMBER FOR OUTPUT.

•

ENCODE 997 AS THE ACTIVITY CODE IN COLUMNS 1 THRU 3. PLACE THE LOGICAL UNIT NUMBER OF THE OUTPUT UNIT IN COLUMNS 4 THRU 13 WITH THE DECIMAL POINT IN THE PROPER POSITION. FOR EXAMPLE TO CHANGE THE OUTPUT LOGICAL UNIT NUMBER TO 1 USE THE FOLLOWING INPUT

```
....5....0....5....0....5....0
997 1.
```

•

6. CHANGE THE METHOD OF DEPRECIATION.

•

PLACE THE ACTIVITY CODE OF 996 IN COLUMNS 1 THRU 3. PLACE THE

CODE FOR THE METHOD OF DEPRECIATION IN COLUNMS 4 THRU 13 WITH THE DECIMAL POINT INCLUDED. A VALUE OF 0 WILL RESULT IN NO DEPRECIATION, A VALUE OF 1 WILL RESULT IN THE SUM OF THE YEARS METHOD, AND A VALUE OF 2 WILL RESULT IN STRAIGHT LINE DEPRECIATION. FOR EXAMPLE TO SPECIFY STRAIGHT LINE DEPRECIATION, USE THE FOLLOWING INPUT

```
....5....0....5....0....5....0
996 2.
```

.

7. CHANGE THE MINIMUM PERIOD DURING WHICH PAYBACK WILL OCCUR.

.

A RUNNING NET REAL COST OF THE SYSTEM BEING ANALYZED IS MAINTAINED. WHENEVER THIS NET COST BECOMES NEGATIVE THEN A PAYBACK PERIOD MAY HAVE BEEN REACHED. HOWEVER, BECAUSE OF DEPRECIATION, TAX INCENTIVES, AND OTHER FACTORS OCCURING EARLY IN THE LIFE OF THE SYSTEM, IT MAY APPEAR THAT A PAYBACK PERIOD HAS BEEN REACHED WHEN SUCH IS NOT THE CASE. BY DEFAULT NO PAYBACK PERIOD IS FLAGGED. IF IT IS DESIRED TO HAVE THE PAYBACK PERIOD FLAGGED THEN THE MINIMUM PAYBACK PARAMETER SHOULD BE SET TO A VALUE WHICH WILL AVOID PREMATURE PAYBACK INDICATIONS DUE TO THE INCENTIVES IN THE EARLY YEARS. TO CHANGE THE MINIMUM PAYBACK PERIOD, PLACE THE ACTIVITY CODE OF 995 IN COLUMNS 1 THRU 3. PLACE THE MINIMUM PAYBACK PERIOD IN COLUMNDS 4 THRU 13 WITH THE DECIMAL POINT INCLUDE. FOR EXAMPLE, IF THE MINIMUM PAYBACK PERIOD IS TO BE FIVE YEARS, THEN THE FOLLOWING INPUT WOULD BE USED

```
....5....0....5....0....5
995 5.
```

.

NOTE THAT THE PROGRAM WILL NOT LOOK FOR A PAYBACK PERIOD UNTIL YEAR 5 OF THE ANALYSIS HAS BEEN REACHED AND WILL REPORT THE FIRST AND ONLY THE FIRST YEAR IN WHICH A NEGATIVE OR ZERO NET COST IS ACHIEVED AS THE PAYBACK PERIOD.

.

8. CHANGE THE LOGICAL UNIT NUMBER FOR INPUT.

.

THE LOGICAL UNIT NUMBER FOR INPUT IS INITIALLY 5 AND THE FIRST INPUT RECORDS (IF ANY) MUST BE READ FROM THAT UNIT. IT IS POSSIBLE TO HAVE A STANDARD INPUT FILE WHERE THE THE DEFAULTS FOR SOME PARAMETERS HAVE BEEN SPECIFIED RESIDE ON DISK AND PROVIDE OTHER SPECIFICATIONS IN A DIFFERENT FILE. IT IS ALSO POSSIBLE TO ALTERNATE BETWEEN INPUT DEVICES BY ALTERNATELY READING FROM DIFFERENT LOGICAL UNITS. IT SHOULD BE REMEMBERED THAT THE LAST SPECIFICATION ENCOUNTERED IS THE ONE WHICH WILL TAKE EFFECT. ALSO, SPECIFICATION OF SENSITIVITY ANALYSIS FOR A PARAMETER AND CHANGING THE DEFAULT VALUE FOR THE SAME PARAMETER MAY PRODUCE UNEXPECTED RESULTS. PLACE THE ACTIVITY CODE OF 994 IN COLUMNS 1 THRU 3 OF THE INPUT RECORD AND PLACE THE NEW LOGICAL UNIT NUMBER IN COLUMNS 4 THRU 13 WITH THE DECIMAL POINT INCLUDED. FOR EXAMPLE, TO CHANGE THE INPUT LOGICAL UNIT NUMBER TO 10 USE THE FOLLOWING INPUT

```
....5....0....5....0....5....0
994 10.
```

9. SPECIFY A REPLACEMENT COST FOR A GIVEN YEAR.

REPLACEMENT COSTS FOR THE SYSTEM ARE DEFAULTED TO ZERO FOR EACH YEA IN ORDER TO SPECIFY A REPLACEMENT COST FOR A GIVEN YEAR PLACE THE ACTIVITY CODE OF 993 IN COLUMNS 1 THRU 3 OF THE INPUT RECORD. PLACE THE YEAR IN COLUMNS 4 THRU 13 WITH THE DECIMAL POINT INCLUDED. PLACE THE REPLACEMENT VALUE IN COLUMNS 14 THRU 23 WITH THE DECIMAL POINT INCLUDED. THE VALUE PLACED IN COLUMNS 14 THRU 23 IS THE ACTUAL COST USED IN THAT YEAR THAT IS, THE COST IS NOT SUBJECT TO ANY ESCALATION. FOR EXAMPLE TO SPECIFY THAT A REPLACEMENT COST OF 50,000 DOLLARS IS TO BE PROJECTED FOR YEAR 10 THE FOLLOWING INPUT SHOULD BE USED

```
....5....0....5....0....5....0....5....0....5
993 10.       50000.
```

OF COURSE AS MANY TYPE 993 ACTIVITIES AS NECESSARY MAY BE USED.

10. SPECIFY THAT PRESENT VALUE TABLES ARE TO BE PRINTED.

BY DEFAULT, ONLY THE FUTURE COST TABLE IS PRINTED WITH ONE ROW OF DATA PRINTED FOR EACH YEAR OF ANALYSIS, AND PRESENT VALUE TOTALS FOR THE ANALYSIS PERIOD ARE ALSO PRINTED. IT IS POSSIBLE TO HAVE BOTH FUTURE COST TABLES AND PRESENT VALUE COST TABLES PRINTED. TO SPECIFY THIS OPITON PLACE THE ACTIVITY CODE OF 992 IN COLUMNS 1 THRU 3, AND PLACE 1 IN COLUMNS 4 THRU 13 WITH THE DECIMAL POINT INCLUDED. FOR EXAMPLE, TO SPECIFY THAT PRESENT VALUE TABLES ARE TO BE PRINTED USE THE FOLLOWING INPUT

```
....5....0....5....0....5....0
992 1.
```

```
******************************************************************************
*                                                                            *
*                  P R O G R A M    I N F O R M A T I O N                    *
*                                                                            *
******************************************************************************
```

FOR ADDITIONAL INFORMATION, COMMENTS, SUGGESTED ENHANCEMENTS, OR CORRECTIONS TO THE PROGRAM DESCRIBED ABOVE, PLEASE CONTACT

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END OF DOCUMENT