DOE/SF-10501-009

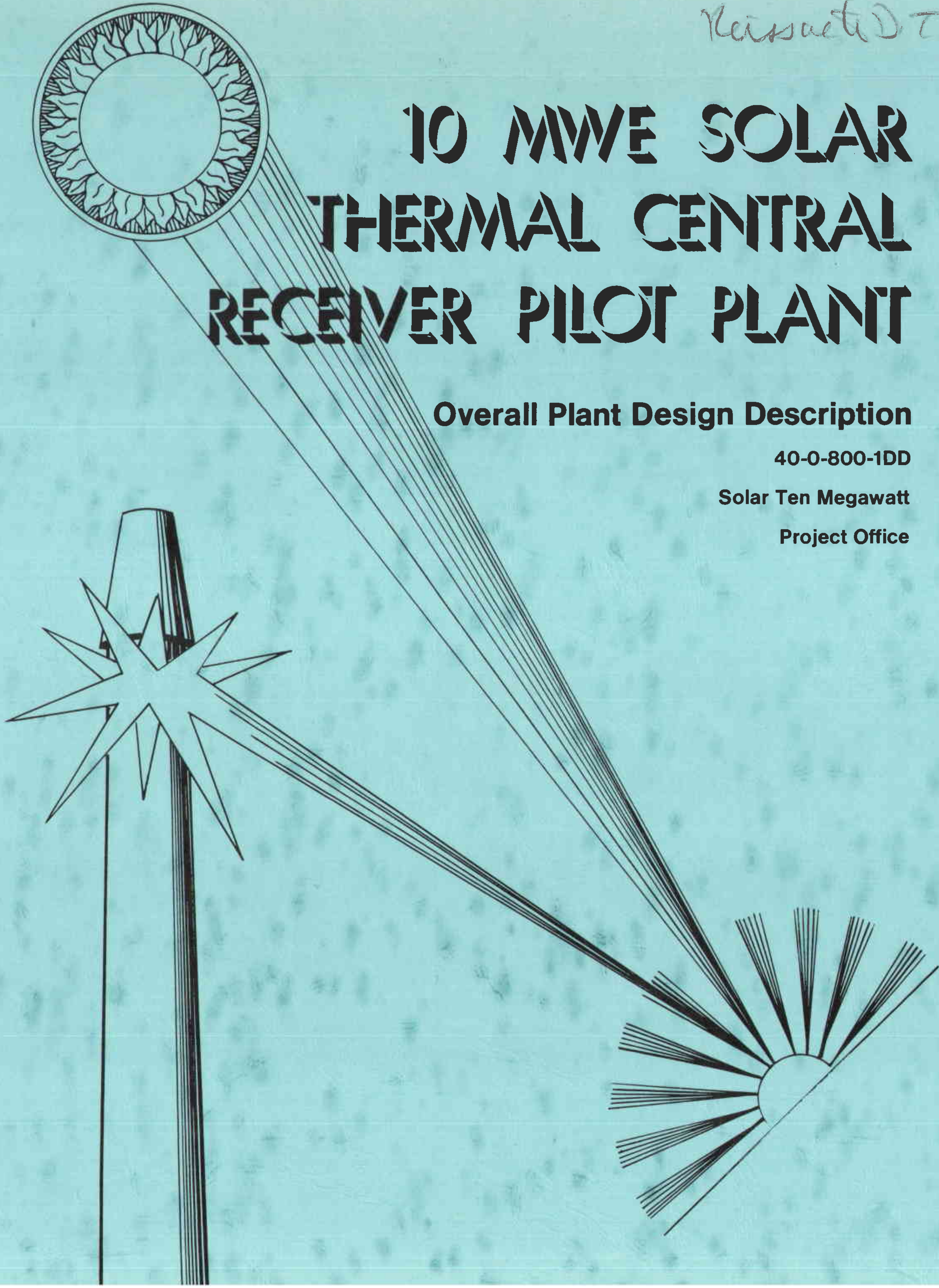
10 MWE SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT

Overall Plant Design Description

40-0-800-1DD

Solar Ten Megawatt

Project Office



40-O-800-1DD

STMPO #053
EXTRA C.K.S.

10-MWe SOLAR
THERMAL CENTRAL
RECEIVER PILOT PLANT
OVERALL PLANT DESIGN DESCRIPTION

MARCH 1978

Department of Energy
San Francisco Operations Office
Solar Ten Megawatt Project Office
9550 Flair Drive, Suite 210
El Monte, California 91731

OCT 6 1978

William F. Manning
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San Francisco Operations Office
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SOLAR 10MWe PILOT PLANT OPDD - CHANGE NOTICE NO. 002

Dear Sir:

Enclosed is copy 2 of CN 002 to the subject OPDD. To enable the OPDD to be a source of current information on the Solar Pilot Plant, you are requested to insert the enclosed change notice pages into your binder.

Sincerely,

A. Klein

A. Klein
Project Design Engineer
Solar Ten Megawatt Project Office

AK/RJ

10-78-236

Enclosures: CN 002 (1 Page)
Table Of Contents (2 Pages)
Section 2 (81 Pages)
Appendix C (Bound Booklet)

OPDD CHANGE NOTICE

Date: OCT 6 1978

Change Notice No: 002

OPDD Title: 10 MWe Solar Thermal Central Receiver Pilot Plant

OPDD Number: 40-0-800-1DD

Affected Section(s) of the OPDD:

Tabel of Contents; Section 2; Appendix C

Design Phase: Conceptual Design

Description of Change(s):

1. Change Table of Contents to reflect issuance of Section 2 and Appendix C.
2. Insert "Section 2"
3. Insert "Appendix C"

JUSTIFICATION OF CHANGE(S):

1, 2, and 3 Initial release and change of these portions of OPDD is with STMPO authority per Project Management Plan (40-F-000 1S)

Cost and Schedule Impacts: None

A. Klein

A. Klein - STMPO
Initiator

APPROVALS:

Project Manager - Solar Facilities Design Integrator

Director - STMPO
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SOLAR TEN-MEGAWATT PROJECT OFFICE
9550 Flair Drive, Suite 210
El Monte, California 91731

May 1, 1978

Assistant Manager for Projects
San Francisco Operations Office
Department of Energy
1333 Broadway
Oakland, Calif. 94612

Subject: Solar 10MWe Pilot Plant Overall Plant Design Description (OPDD)

Dear Sir:

Enclosed is copy 2 of the Solar Pilot Plant Overall Plant Design Description (OPDD). This copy is registered in your name as custodian. All changes and revisions will be forwarded to you for incorporation into the binder.

To enable the OPDD to be a source of current information on the Solar Pilot Plant, you are requested to insert the latest change notice pages and revisions when received.

Thank you for your cooperation.

Very truly yours,

R.W. Wiese

R.W. Wiese
LMEC/DOE
Solar Ten-Megawatt Project Office

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SECTION 1

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1.0 DESIGN REQUIREMENTS

1.0 Design Requirements

1.1 Summary

1.1.1 Application

This Overall Plant Design Description (OPDD) constitutes the principal means to establish, describe, and control the design of the 10 MWe Solar Thermal Central Receiver Pilot Plant. Section 1.0 of the OPDD contains the specific functions and design requirements to be satisfied by the design in accordance with overall project technical requirements.

The central receiver configuration has been selected by the U.S. Department of Energy (DOE) for early large-scale research, development, and demonstration. This pilot plant project will be the first integration of hardware and software in a functional power generating facility whose performance and reliability can be assessed in the context of utility operation.

The principal programmatic objectives are:

(1) To establish the technical feasibility of solar thermal power plants of the central receiver type, including collection of data for retrofit applications of solar boilers to existing power plants fueled by oil or natural gas.

(2) To obtain sufficient development, production, and operating and maintenance data to identify potential economics of commercial solar plants of similar design, including retrofit applications on a comparable scale.

(3) To determine the environmental impact of solar thermal central receiver plants.

Subsidiary objectives are:

(1) To gather operational data that can be analyzed to determine system operating and safety characteristics.

(2) To develop both utility and commercial acceptance of solar thermal central receiver systems.

(3) To stimulate industry to develop and manufacture solar energy systems.

(4) To enhance public acceptance and familiarity with solar energy systems.

The requirements which follow (Sections 1.2 through 1.8) represent an interpretation of the programmatic objectives made by the DOE and the Utility Associates. They are based upon the results of studies and experiments and a recognition of the needs for a pilot electrical generating plant. It is intended that these requirements not be changed unless they collectively or individually fail to achieve or address the programmatic objectives. The development of the detailed requirements for subsystems and components, which are described in the subsequent sections of this OPDD, is the essence of the pilot plant design.

The central receiver solar thermal power plant (schematically represented in Figure 1.1) consists of five major subsystems: (1) the collector subsystem, (2) the receiver subsystem, (3) the thermal storage subsystem, (4) the electric power generating subsystem, and (5) the master control subsystem.

The Utility Associates participation in the 10 MWe Solar Central Receiver Pilot Plant is defined in Cooperative Agreement No. EG-77-A-03-1482, which incorporates the Project Management Plan as Appendix C. The Cooperative Agreement specifies that the Utility Associates are responsible for the design, construction, and ownership of the Electric Power Generating Subsystem (EPGS), as well as operation of the entire plant through all test phases. Management of the project shall be accomplished by mutual agreement of a Steering Committee composed of members representing both Department of Energy and the Utility Associates. The Associates are also responsible for coordinating and providing input to the SFDI regarding interfaces between the EPGS and the balance of the plant.

The collector subsystem (CS) is a 360-deg array of sun-tracking mirrors (heliostats) which reflect the sun's energy to a receiver mounted on a tower. It includes the heliostats themselves, their pedestals and foundations, local controls and drive mechanisms, and a subsystem control console remotely located in the centralized Plant Control Building.

The receiver subsystem (RS) includes all of the hardware and software necessary to convert feedwater into superheated steam by utilizing redirected solar energy from the collector subsystem. It consists of a tower-mounted water boiler (steam generator), support tower, feedwater pumps, piping, valves, instrumentation and controls necessary for water/steam circulation and flow control. A control console for the Receiver Subsystem is located in the Plant Control Building. Feedwater is pumped through a riser to the steam generator, where it is first heated in preheater panels before being evaporated and superheated in a single pass through the tubes of individual boiler panels. The panels of joined vertical tubes are in an outward-facing cylindrical array. Heat is transferred to the tube panels by radiation of reflected solar energy from the surrounding

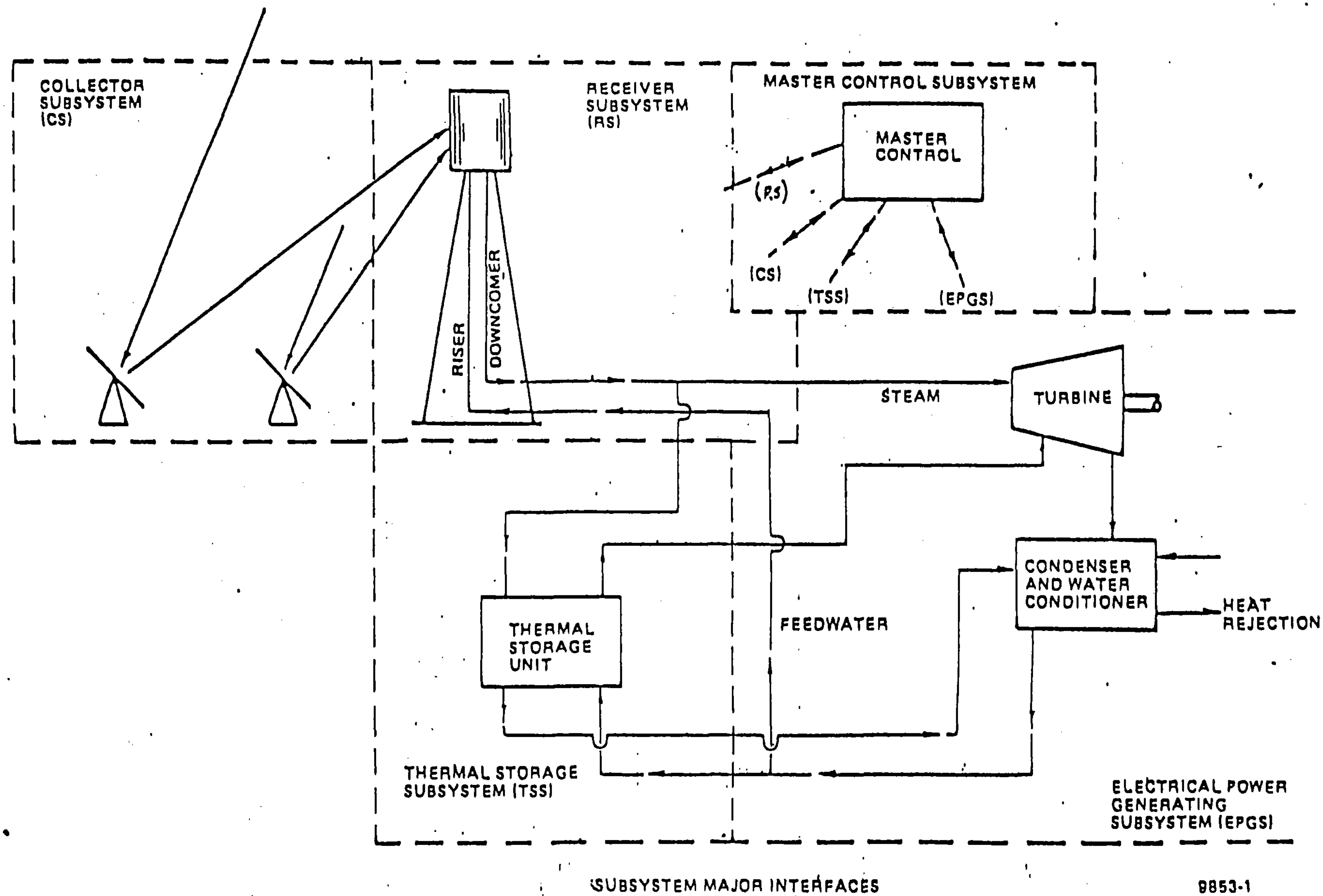

Figure 1.1. Central Receiver Thermal Power Plant Block Diagram

mirror field to the outer surface of the cylinder. Equipment to collect, distribute, and assure that dry steam is delivered to the turbine is provided within this system. The steam is routed through a downcomer to the base of the tower where it is introduced directly to a turbine generator to produce electricity, or to the thermal storage system, or to both simultaneously.

The thermal storage subsystem (TSS) is a reservoir of heat transfer-thermal capacitance medium which serves as a heat sink for receiver steam. Energy is stored as sensible heat, providing a heat source to generate admission steam for the turbine, thus allowing electric power generation in the absence of sunlight. The TSS consists of tanks, heat exchangers, piping, valves, pumps, instrumentation, and a control console located in the Plant Control Building.

The electric power generating subsystem (EPGS) utilizes conventional power plant equipment such as turbine, generator, condenser, and wet cooling-tower. It includes ancillary equipment, condensate polishing equipment, feedwater heaters, pumps, instrumentation, and a control console located in the Plant Control Building.

The master control subsystem (MCS) is the equipment and software required for integration and automatic control of the plant, and for gathering and processing plant evaluation data. It is located in the Plant Control Building. The MCS is an overall command, control, and Data Acquisition System (DAS) which performs control management, supervision functions as well as data collection and display functions. Its purpose is to integrate the independent controls of the other four subsystems (CS, RS, TSS, EPGS) and the balance of plant to achieve effective single console control and evaluation capability. Thus, the MCS consists of the plant supervisory controls, the DAS, and the data displays and consoles.

The pilot plant also includes the following two systems which support and connect the major systems:

The beam characterization subsystem (BCS) measures the flux delivered by individual heliostats and is used for heliostat alignment and calibration. It consists of heliostat image targets, flux sensing equipment, and software which controls the ordering, processing, and storing of the measurement data.

The plant support subsystem (PSS) consists of the ancillary equipment and structures required for operating the plants major systems. These include electrical power and mechanical systems such as water, nitrogen, and compressed air. The PSS also includes fire protection and plant security provisions, communications, and facilities for administration and maintenance.

The pilot plant occupies a 130-acre site on land owned by Southern California Edison Company adjacent to the Coolwater Generating Station in Daggett, 12 miles southeast of Barstow in San Bernardino County, California. The pilot plant is a joint undertaking of the U.S. Department of Energy (DOE) and the Associates.

1.1.2 Definitions

The following definitions shall apply to this design description:

Associates - Collectively, the organizations associated with the U. S. Department of Energy in sponsoring the 10 MWe Solar Thermal Central Receiver Pilot Plant. Individually, the Associates are the Southern California Edison Company, the Los Angeles Department of Water and Power, and the California Energy Commission.

1.1.3 Abbreviations

The following abbreviations shall apply to this design description:

BCS	Beam Characterization Subsystem
CPU	Central Processing Unit
CS	Collector Subsystem
DAS	Data Acquisition System
EPGS	Electrical Power Generation System
MCS	Master Control Subsystem
OCS	Operational Control System
OPDD	Overall Plant Design Description
PCS	Peripheral Control System
P&ID	Piping and Instrumentation Diagram
PSS	Plant Support Subsystem
RS	Receiver Subsystem
TSS	Thermal Storage Subsystem

1.2 Overall Plant Design Requirements

1.2.1 Plant Rating and Sizing

1) The 10 MWe Solar Thermal Central Receiver Pilot Plant shall deliver 10 MWe of electric power to the Southern California Edison Co. distribution grid. This power level shall be the minimum net output of the plant after subtracting all plant operating requirements and when operating solely from insolation for a period of at least 4 hours on the least favorable day of the year. This is the "Plant Design Worst Day" (minimum energy available to the site on a clear day), as defined by the environmental conditions in Appendix C.

2) The pilot plant shall deliver the rated net electric power output of 10 MWe when operating solely from insolation for a period of at least 8 hours on the most favorable day of the year. This is the "Plant Design Best Day" (maximum energy available to the site on a clear day), as defined by the environmental conditions in Appendix C.

3) The maximum thermal storage charge rate (thermal power absorbed into the TSS) shall be equivalent to the thermal power required to operate the turbine generator at a 10 MWe net electric power outlet level. The TSS charge rate will not be capable of accepting the maximum thermal power output of the Receiver Subsystem when the turbine generator is out of service, which will require defocusing of a portion of the collector field to reach the specified charge rate.

4) The thermal storage discharge rate (thermal power discharged from the TSS) shall be capable of delivering the thermal power required to operate the turbine generator at a 7 MWe net electric power output level.

1.2.2 Plant Energy Storage Capacity

The TSS capacity shall be equivalent to the thermal energy required for the turbine generator to produce 28 MWHe of net electrical energy output, when operating on admission steam only.

1.2.3 Plant Design Life

The pilot plant and its subsystems and components shall be designed to meet a 30-year plant lifetime expected in a utility usage context. The requirements for design are established by the environmental constraints and the operational life cycle exposures as detailed in Appendices B and C, respectively.

1.2.4 Plant Availability

The pilot plant shall be designed to accept solar energy and supply power, in response to a demand, at least 90% of the time it could normally be functioning.

1.2.5 Plant Design Criteria

The pilot plant systems, components, and subsystems shall be designed and demonstrated (by analysis, test, inspection, or other means as appropriate) to conform to Codes and Standards specified in Appendix A, which are accepted by regulatory jurisdictions and by knowledgeable practitioners of the disciplines involved.

1.3 Major Plant Subsystem Requirements

The plant shall be capable of operation with a single operator, utilizing either the MCS or manual operation at the major subsystem control level independent of the MCS.

The solar facilities shall be designed to accommodate the diurnal and seasonal variations in insolation as presented in Appendix C.

1.3.1 Collector Subsystem (CS). The collector subsystem shall be comprised of an array of individually controlled reflectors (heliostats) which continuously direct the available solar insolation onto an elevated receiver. The heliostats are located in a surround-field array.

1.3.2 Receiver Subsystem (RS). The receiver subsystem shall conduct water from the ground level to the top of a tower where a once-through externally heated steam boiler is located that is the focus for the redirected solar energy. The dry superheated steam shall be returned to the ground level within this subsystem for delivery to other subsystems.

The receiver boiler shall be designed to accommodate a peak incident heat flux of at least 0.3 MW_{th}/m^2. Radient flux sensors will be installed on the receiver to verify that the required peak heat flux is achieved.

1.3.3 Thermal Storage Subsystem (TSS). The thermal storage subsystem shall transfer energy from steam to oil for sensible heat storage in an oil-rock containment vessel. Retransfer from oil back to steam shall also be accomplished within this subsystem, which shall be capable of performing both transfer operations simultaneously. The thermal storage subsystem shall be sized to include auxiliary energy needed by other subsystems as well as that energy stored for reconversion to power for the grid.

1.4 Overall Plant Operation Requirements

1.4.1 Environmental Conditions

The pilot plant will be exposed to the environmental conditions at the Barstow-Daggett site. These conditions are provided within Appendix C.

Within the conditions existing at the site, selected environmental factors have been identified for the purposes of plant, subsystem, and component design, which are also contained within Appendix C.

1.4.1.1 Operating Conditions. The plant and its subsystem will provide the performance and implement the operating modes of this OPDD when exposed to the operating conditions of Appendix C.

1.4.1.2 Survival Conditions. The plant and its subsystems shall be capable of withstanding the conditions defined in Appendix C without damage and shall be returned to service within the normal elapsed start-up time following a return to operating conditions.

1.4.2 Operating Modes

The pilot plant shall be capable of execution of the following operating modes:

1.4.2.1 Steady-State. The following eight steady-state modes of plant operation shall be available. The capacity shall be provided to operate at a minimum steady state power output level of 2 MWe net. Mode 1, 2, 3 and 7 shall also be capable of providing at least 10 MWe net power as specified in Paragraph 1.2.1 while Mode 4 and 6 shall be capable of providing at least 7 MWe net power as specified in Paragraph 1.2.2.

1) CS-RS driving the EPGS (TSS is not involved)

2) CS-RS driving the EPGS and charging the TSS (normal solar power operation)

3) CS-RS driving the EPGS while the TSS also discharges to share in driving the EPGS (low solar power operation)

4) CS-RS charging the TSS and TSS discharging to drive the EPGS (intermittent cloudiness)

5) CS-RS charges TSS only (thermal storage charging)

6) TSS discharges to drive the EPGS (extended operation) at 7 MWe net (maximum)

7) CS-RS charging TSS and driving T-GS and TSS discharging to drive EPGS simultaneously (all subsystems in operation).

8) Overnight shutdown and hold of all plant subsystems (subsystem conditioning)

1.4.2.2 Mode Transitions. The plant shall perform the startup and shutdown procedures. The plant shall be capable of transitioning between operating modes in a preprogrammed manner.

1.4.2.3 Transients. The pilot plant will be both exposed to transient conditions and required to respond to transient demands.

1) The plant will be exposed to transients resulting from external conditions, defined in Appendix C, such as cloud passage, excess winds, earthquake, power loss, etc.

2) The plant will be operational in a mode where the demand change does not exceed TBD MWe/min over the acceptable range of plant net power output for that mode.

1.5 Overall Plant Test and Evaluation Requirements

The test and evaluation requirements of the pilot plant encompass the design, installation, and operation of the plant. Testing is required for a 2-year experimental period to verify the technical feasibility of equipment and systems. Data acquired during the following 3 years of the pilot plant operation will be used to demonstrate and verify the technical performance of the plant, define actual operating and maintenance requirements, confirm commercial system cost projections, and provide directions to technical improvement and major cost reduction efforts. Detailed requirements are listed in Appendix D.

1.5.1 Plant Test and Evaluation

The pilot plant shall be equipped with additional systems, equipment, instrumentation, and data acquisition facilities necessary to test and evaluate the plant performance and operational characteristics in a pilot or experimental context. Design life requirements of paragraph 1.2.3 do not apply to this type of evaluation equipment.

1.6 Plant Safety Requirements

1.6.1 Plant Operations

Plant systems shall be designed to prevent creation of unsafe or potentially hazardous conditions within or outside the facility. The design shall consider potential risks generated by the unique character of this installation as a solar central receiver facility.

1.6.2 Plant Protection System

The plant protection system shall be designed, installed and maintained such that no single component and/or system failure or design feature will cause an accident that results in major injury or death to personnel or excessive damage to equipment or property. The plant shall be designed to minimize the possibility of human error which can lead to an accident hazardous to equipment or personnel. Detailed requirements are listed in Appendix E.

1.6.3 Plant Controls

Upon detection of an unsafe condition, the plant shall automatically sequence to a safe condition.

1.6.4 Codes and Standards

The plant shall be designed, constructed, maintained, and operated in accordance with nationally and locally recognized and accepted Codes and Standards applicable to the disciplines involved. Appendix A establishes the applicability of such Codes and Standards.

1.7 Plant Maintenance Requirements

1.7.1 Routine Maintenance

Plant systems shall be designed to enable routine maintenance with a minimum loss of operating time.

1.7.2 Employee Skills

Plant systems shall be designed to permit maintenance by power plant operating employees.

1.7.3 Receiver Tower Crane

The receiver tower shall be equipped with a crane sized for maintenance including replacement of the absorber panels.

1.7.4 Receiver Tower Elevator

The receiver tower shall be equipped with a service elevator for equipment transportation.

1.7.5 Heliostat Cleaning

Heliostat mirror cleaning equipment and facilities shall be provided as required.

1.8 Facility Services Requirements

1.8.1 Site

1.8.1.1 Area. A 130-acre site shall be provided near SCE's Coolwater Generator Station, Barstow, California. This site shall be available as required solely for plant purposes for a period of at least 5 years following initiation of plant operation.

1.8.1.2 Roads, Parking Lots, and Walkways. An all-weather access road from the public road to the site entrance, and hard-surfaced parking lots in the administrative and warehouse areas shall be provided. Walkways between the parking lots and the buildings and between the buildings shall also be provided.

1.8.1.3. Drainage. Drainage or collection shall be provided for:

1) Normal and storm drainage from the solar collector areas and roads, walkways, parking lots, and buildings in the administrative and warehouse areas.

2) A liquid waste collection system for acid, oil, or other waste not allowed in the sanitary drainage.

1.8.1.4 Area Lighting. Lighting shall be provided at the pilot plant perimeter for security and in working and access areas.

1.8.1.5 Security. Site perimeter fencing shall be provided to control site access. Additional localized control fencing shall be provided where required.

1.8.1.6 Sewage. Sewage drainage shall be provided from all site areas to a sewage treatment system for the pilot plant.

1.8.1.7 Helistop. A helistop (i.e., heliport without refueling provisions) shall be provided near or at the plant site.

1.8.2 Buildings

The following buildings shall be provided:

1) An administration building with an area of approximately 3,000 $ft.^2$. This building shall contain areas and facilities for plant management visitor control, and technical support for the pilot plant.

2) A plant control building with facilities and space for operation of the plant. A central room approximately 25 ft. by 45 ft. within the building shall permit centralized control of the plant through the MCS. This building shall also provide space for switchgear and associated electrical equipment.

3) A building of approximately 6000 $ft.^2$ area shall house warehouse, assembly, and maintenance functions.

4) The necessary foundations and structures to support and house the turbine-generator and associated electrical and steam and feedwater equipment.

5) A security building at the site entrance.

6) A Visitor's Center near or at the plant site.

1.8.3 Utilities

1.8.3.1 Power. Normal and emergency power shall be provided as follows:

1) Generate own normal power during generator operation.

2) Site to be provided with limited power for emergencies and off periods.

1.8.3.2 Water. Water systems shall be provided as follows:

1) A well (potable) water supply to the site for all plant uses.

1.8.3.3 Auxiliary Systems. The following shall be provided:

1) A plant compressed air supply for the entire pilot plant. A complete distribution system shall interconnect all pilot plant systems and buildings.

2) An instrument air supply for the entire pilot plant. A complete distribution system shall interconnect all pilot plant systems and buildings.

3) An inert gas (gaseous nitrogen) supply and distribution system.

4) A mirror cleaning fluid treatment system.

SECTION 2

OPDD

SECTION 2 - DESIGN DESCRIPTION

Revised 15 August 1978

2.1 SUMMARY

The Pilot Plant hardware complement is divided into three major groups: the Solar Facilities System, which includes the Collector, Receiver, Storage, and Beam Characterization Subsystems; the Electrical Power Generation System (EPGS); and the Common Benefit Facilities (CBF), including the Master Control and Plant Support Subsystems. Each of these is described separately in this OPDD section. Their characteristics are derived from the subsystem features which collectively satisfy Section 1 requirements.

2.2 SOLAR FACILITIES SYSTEM

The Solar Facilities System consists of four subsystems: the Collector Subsystem (CS): the Beam Characterization Subsystem (BCS); the Receiver Subsystem (RS); and the Thermal Storage Subsystem (TSS). Normally, operation of the different subsystems is coordinated by the Master Control Subsystem (MCS) within the Common Benefit Facilities (CBF). Solar Facilities System status data are supplied to the MCS for that purpose, However, each subsystem is also capable of monitoring its own operation to preclude conditions hazardous to equipment or personnel.

2.2.1 Collector System (CS)

The CS is an array of heliostats which reflect the solar radiation to a single location where it produces steam. Heliostat position is controlled by either an operator or the MCS through the Heliostat Array Controller (HAC). The CS performance is capable of extrapolation to a commercial power generation system size of 100 MW_e by expansion of the array field in accordance with scaling laws.

2.2.1.1 General System Description

The CS consists of (1) the heliostat array; (2) mounting pedestals and positioning drive motors; (3) pedestal foundations; (4) field located control and instrumentation electronics, including necessary buffer or signal processing hardware for system interfaces; and (5) all cabling, conduit, etc. to the common points specified in the Interface Control Drawing, ICD ________________.

The heliostats must reflect the sunlight with combined beam and tracking errors of less than 3 mr standard deviation. Slew rates about the drive unit axes exceed______degrees/min to permit rapid stowage when required. Individual heliostat fundamental vibration frequencies are greater than 1 Hz to preclude dynamic coupling with the controls system, and to minimize wind-induced vibrations.

The maximum heliostat weight is governed by cost, transportation and structural requirements. Reflector shape limitations are imposed by the array lay-out, shadowing and blocking constraints, and servicing requirements. The heliostats are spaced to permit access by service vehicles and maintenance personnel. The foundation design includes consideration of soil stratigraphy, preservation of vegetation, and geological phenomena. Soil bearing characteristics are identified in the Geological Survey listed under Application Documents, paragraph________.

Single-point failures that disable the automatic mode of system operation have been eliminated wherever practical. In addition,

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the CS is designed to provide malfunction indication and fault isolation information on critical components. Critical components are those components that, because of failure risk, downtime, or effect on overall pilot plant performance, materially affect CS availability, or safety with respect to the reflected beam in the surrounding air space or on the ground within the collector field.

The system is designed for 99% availability based on reliability and maintainability averaged over a one year period of scheduled operating time.

The drawing and specification schedule as required to define the collector system is shown in Table ____.

2.2.1.2 Major Interfaces

Figure 2-1 shows the major interfaces with other Pilot Plant facilities. Within the Solar Facilities, interfaces exist with the RS and the BCS. The CS also interfaces externally with various subsystems in the Common Benefit Facilities and EPGS. A non-active interface also exists between the CS and the physical site through the heliostat siting and foundation considerations. Detailed interface requirements are specified in Interface Control Drawings.

2.2.1.2.1 Collector/Receiver System Interface

The CS will concentrate at least 95% of the redirected energy onto the absorber whenever the sun is ____ radians above the horizon. The RS absorber is a vertical cylinder ____m diameter and ____m high. The Absorber center line is ____ m above ground level. Individual heliostats track the sun and concentrate the redirected energy according to a preselected aiming point strategy.

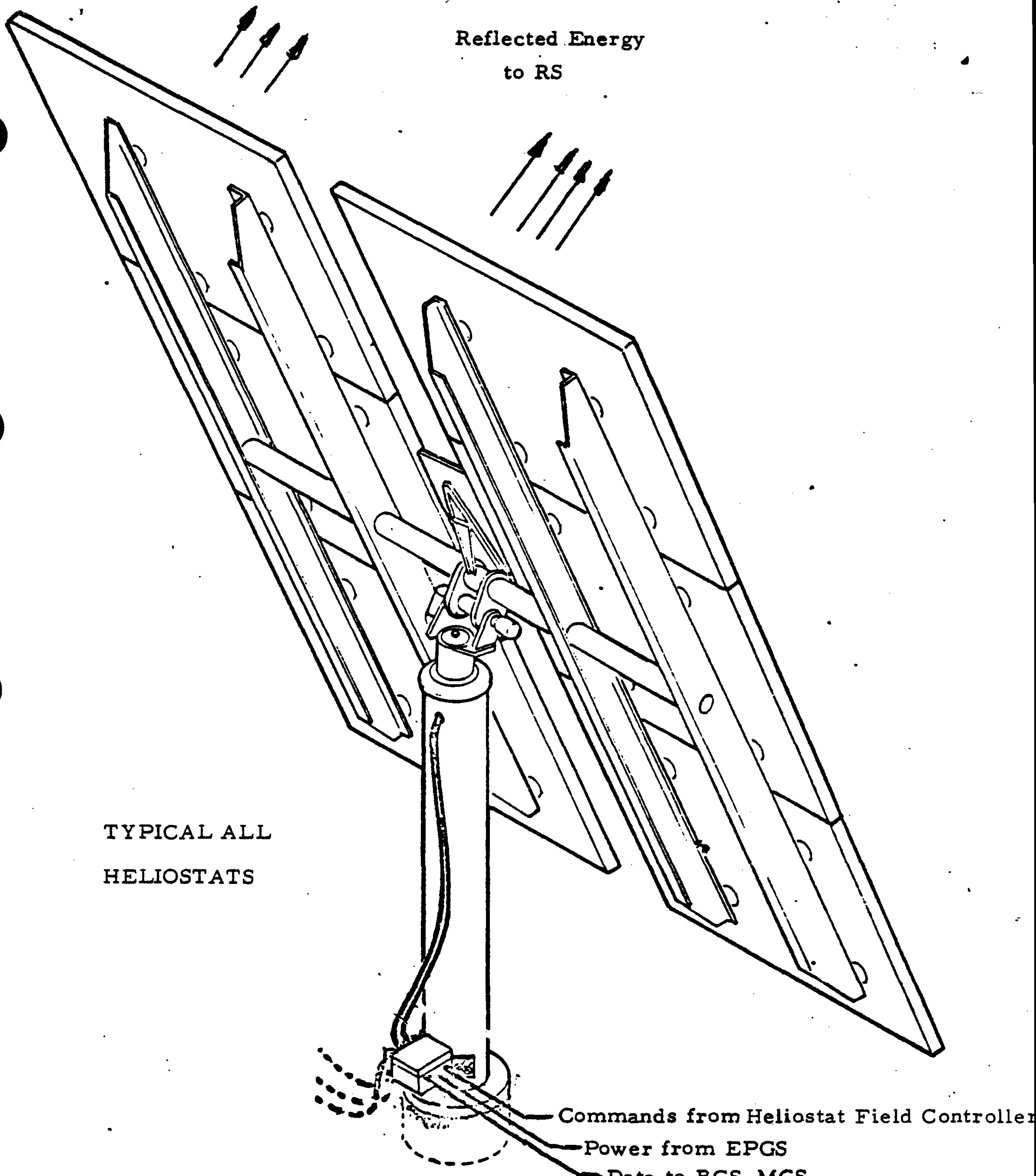


Figure 2-1

Major Collector System Interfaces

2.2.1.2.2 Collector/Beam Characterization System (BCS) Interface

The HAC will be responsible for selecting heliostats and moving them so as to track the BCS target. It furnishes the BCS all relevant data, e.g., heliostat number (or coordinates) and sun position, and requests characterization. The BCS will acknowledge the request and gather the necessary data. It will then release the heliostat to the HAC which will then bring the next heliostat to bear on the BCS target. The BCS will process the data to determine pointing corrections, beam figure, and diagnostic information for use in adjusting heliostat mirrors. These will be transmitted to the HAC at an appropriate time. They will also be transmitted to the DAS along with additional data, as appropriate, for archiving.

2.2.1.2.3 Collector/Common Benefit Facilities Interface

A two way digital data communication grid is used to interconnect the HAC with the MCS. Commands, status information, functional data, and information requests are transferred on that link.

2.2.1.2.4 Collector/Electrical Power Generating System Interface

The CS System and the EPGS are interconnected by the power grid. The EPGS supplies _____ kVa at 240V, 3-phase, to the CS from two independent power sources.

2.2.1.3 Collector System Arrangement

The heliostats are arranged in a radial, fan shaped geometry completely surrounding the RS which is elevated on a tower. Individual heliostats are mounted on posts attached to concrete foundations. Utilities, data, and command links to each heliostat are routed in underground conduits. The total area of the collector field is ______ acres. The collector field layout is a scaled version of an optimized commercial plant collector field which was sized to produce the necessary design point power.

2.2.1.4 Collector System Performance Characteristics

(a) The CS reflects solar radiation onto the elevated Absorber with a beam pointing error of______mrad, standard deviation, whenever the sun is more than_____radians above the horizon, under the normal operational environmental conditions specified in Appendix C.

(b) The CS will concentrate______MW_{th} radiant energy on the absorber at noon local sun time on the clear day of summer solstice, for a solar insolation given by the environmental data in Appendix C, with a flux density not exceeding 0.3 MW_{th}/m^2.

(c) The CS normally operates in three modes: (1) STAND-BY, wherein the receiver intercepts negligible flux; (2) TRACK and (3) STOW.

(d) The system is capable of emergency defocusing (DE-FOCUS) at a rate equal to or greater than that which would linearly reduce peak incident radiation on the receiver to less than______% of initial value within______seconds. In addition, the system includes the special commands of INCREASE, DECREASE, DIVE, and CANCEL, all of which allow rapid responses to emergencies.

(e) The system is also designed in such a manner that reflected beams do not pose a safety hazard and normally unradiated portions of the receiver subsystem are not exposed to heat fluxes greater than_____KW/m^2 at any time.

(f) Average reflectance of clean heliostat mirrors exceeds 91% over an air mass 2 solar spectrum and within a______mrad cone. A mirror module life of 30 years is required, so surface degradation rate has been minimized. The optical spreading due to surface waviness and specular dispersion is less than_____mrads. The heliostat structural supports are designed to prevent reflective surface deflection from exceeding______mrad standard deviation under the normal operational wind and temperature conditions specified in Appendix C. An override provision is included in the drive unit to permit manual feathering of the reflector at the heliostat. Limit switches prevent damage to the heliostat if it is driven beyond the normal operating limits.

2.2.1.5 Design Environmental Conditions

Environmental conditions representative of the site characteristics are defined in Appendix C. Design allowable stresses are commensurate with performance requirements to ensure a 30 year life. In addition to site-related environmental conditions, hardware is required to survive transportation environments which are defined in the individual subsystem and component specifications. All components are designed for transportability, within applicable Federal and State regulations, by highway and railroad carriers using standard transport vehicles and materials handling equipment.

2.2.1.6 Collector System Design Description

2.2.1.6.1 Heliostat Field Lay-out

The physical arrangement and boundaries of the heliostat array are optimized to concentrate the required solar energy on the absorber in the most cost effective manner. The arrangement reflects a balanced consideration of heliostat shading, blocking, and geometric parameters to produce an optimal heliostat field layout.

The principal objective in defining the Pilot Plant collector field is to simulate as closely as possible the characteristics of a commercial power plant collector field; this includes both the heliostat packing and relative geometry between the heliostats and the absorber. The optimized commercial collector field is laid out in a radial stagger arrangement which is simulated in the Pilot Plant array by simple circles. The most accurate simulation requires the adjacent circles have the same number of heliostats but such an approach causes inner circles to become progressively compressed until an unacceptable density occurs. To adjust for this, the Pilot Plant collector field is split into circular zones. The zone boundary allows for a decompression by lessening the number of heliostats per circle in the inner zone. Six zones are used for the Pilot Plant. The total number of heliostats in the Pilot Plant array is_________. The general configuration is depicted in Figure 2-2. Detailed field dimensions and individual heliostat location coordinates are defined in Plot Plan Drawing_________.

2.2.1.6.2 Heliostat Design

The heliostat is made up of two segments separated by the mounting post and associated hardware. Each segment is composed of three second-surface, low iron, float glass mirrors_________inches thick by _________inch by_________inch. The mirrors are attached to a composite structure consisting of a material with low thermal coefficient of expansion and a higher strength backing to provide rigidity for mounting to the pedestal support. The thinnest obtainable glass is desired to minimize transmission loss, but handling problems limit individual panel size. Panel size is also influenced by focusing requirements. All flat panels must be canted so the centroid of the projected spot from each one falls on the heliostat aiming axis. The resulting image size is determined by the initial panel size and the spread of the sun's reflected image. The required average specular reflectivity of the mirrors is_______.

Heliostat layout drawings are shown in Figures_______to _____________.

2.2.1.6.3 Support Pedestal

(SFDI to supply brief description of construction and major design features resulting from performance and environmental requirements.)

2.2.1.6.4 Heliostat Drive Mechanisms

Each heliostat incorporates azimuth and elevation drive mechanisms to move the heliostats about their axes of rotation. The drive mechanisms consist of motors, drive trains, position feedback transducers,

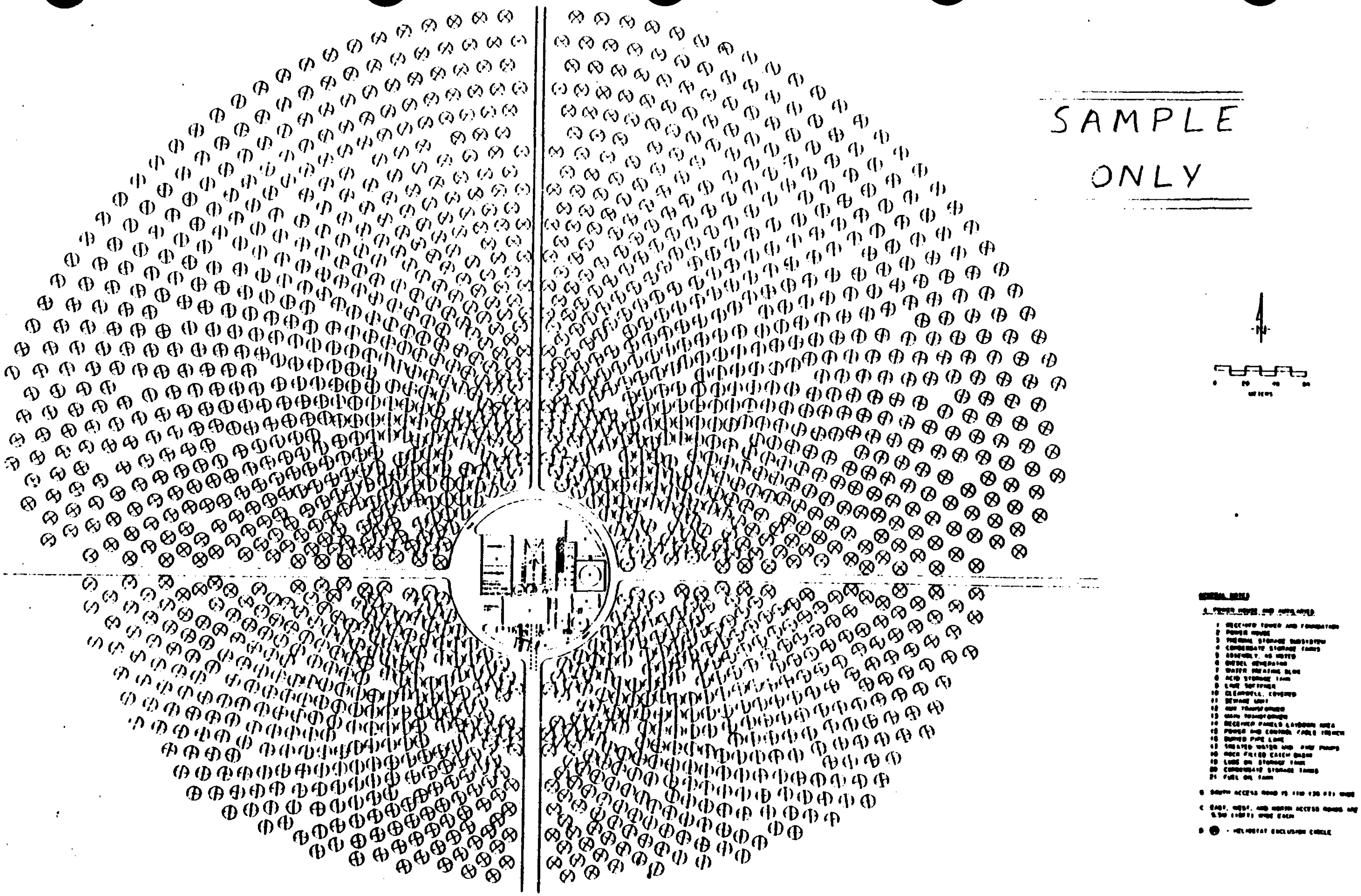


Figure 2-2 SOLAR TEN MEGAWATT CENTRAL RECEIVER
COLLECTOR FIELD LAYOUT

reflector support bearings, and structural housings. The azimuth and elevation drive trains are schematically identical. The________V, 3-phase, ________-frame, ________-pole AC torque motor drives an input ________: reducer, whose output shaft is coupled to a_______: output stage reduction.

The three most critical factors involving sizing of the drives are static load capacity, torsional stiffness, and fatigue life. The elevation drive is more critical with regard to stowage load, while the azimuth drive is more critical in torsional stiffness. Finally, the elevation drive has more critical life characteristics due to the higher average loading combined with a large daily rotation. Detailed design performance requirements are contained in Heliostat Drive Specification_________.

2.2.1.6.5 Controls and Instrumentation

The CS control system is a distributed type. For purposes of cost reduction, redundancy, safety and operational simplicity, the collector field is divided into sector or cells, each of which contains a field-located controller. Individual heliostat controllers interface with the field controller for that sector. The field controller supervises command and data traffic between that sector and the HAC; it may also perform some of the data processing functions. Control/data functions performed at each control level are shown in Figure 2-3. All electrical power and control/data busses are routed underground to individual heliostats.

2.2.1.6.6 Applicable Documents

The equipment, material, design, and construction of the CS complies with all Federal, State, Local, and user standards, regulations, codes, laws, and ordinances which are currently applicable for siting in Barstow, California and to the using utility, the Southern California Edison Company. These include, but are not limited to, the government and non-government documents itemized below.

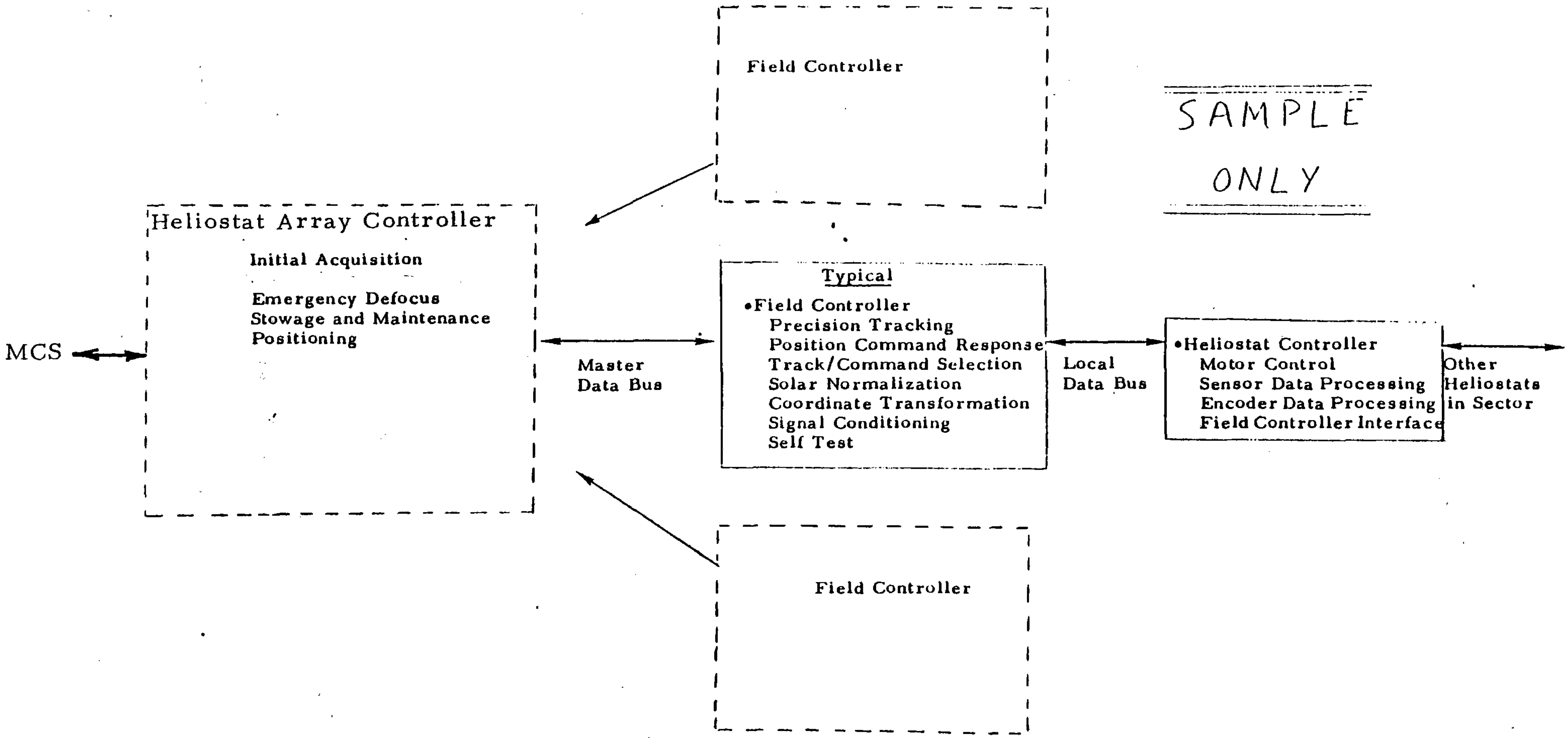


Figure 2-3 Functional Description of Collector System Controls

2.2.1.6.6.1 <u>Drawings</u>

Main Assembly Drawing	XXXX
Pedestal Assembly Drawing	XXXX
Heliostat Wiring Drawing	XXXX
Heliostat Drive Motor Specification Drawing	XXXX
CS/RS ICD	XXXX
CS/EPGS ICD	XXXX
CS/MCS ICD	XXXX

2.2.1.6.6.2 <u>Specifications</u>

Heliostat Mirror Specification	XXXX
Heliostat Azimuth and Elevation Drive Motor Specification	XXXX
Heliostat Control Specification	XXXX

2.2.1.6.6.3 <u>Standards</u>

NFPA Bulletin No. 78 (ANSI C5.1), Lighting Protection Code

National Electrical Code, NFPA 70-1975 (ANSI C1-1975)

2.2.2 Receiver Subsystem (RS)

The RS provides a means of transferring the redirected solar flux from the CS into steam for (1) generating electrical power with a conventional turbine-generator, and (2) charging the Thermal Storage Subsystem (TSS). With the exception of the Feedwater Pumps, all elements of the RS are located on a tower surrounded by the CS. Fluid flow through the RS is shown schematically in Figure 2-4.

2.2.2.1 General Subsystem Description

The RS consists of a Central Tower Assembly and Feedwater Pumps. The Central Tower Assembly has seven major components: the Tower; the Absorber and Absorber Support Structure, both of which are mounted on the Tower; a Water Riser; a Steam Downcomer; Thermal Insulation; and Controls and Instrumentation for hardware operation.

The Feedwater Pumps move water up the Riser in the Central Tower Assembly to the Absorber. The water then flows through the Absorber where it is converted to steam which leaves the Tower via the Downcomer.

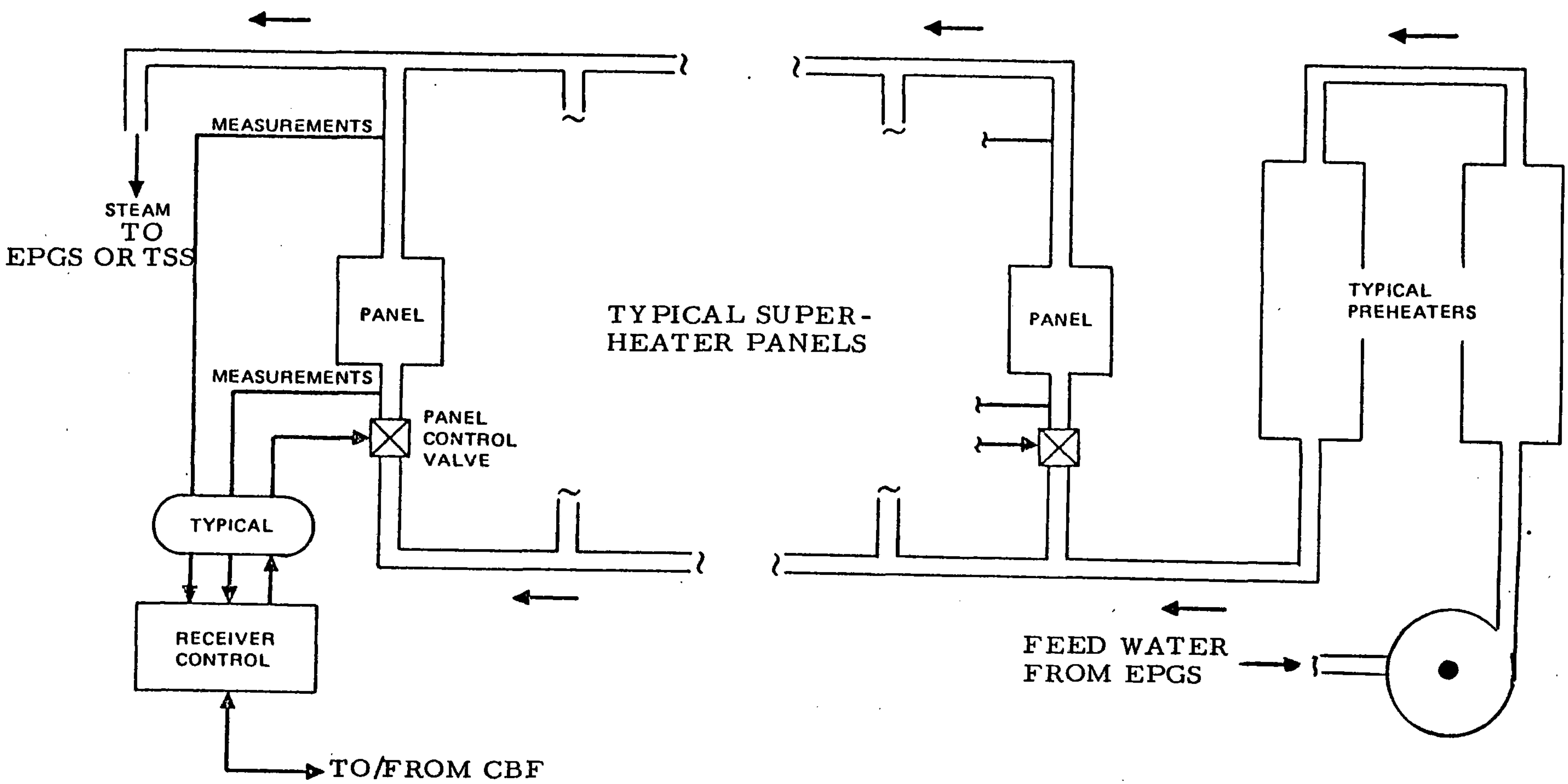
The drawing and specification schedule as required to define the receiver system is shown in Figure ____.

2.2.2.2 Major Interfaces

Figure 2-5 shows the Absorber and Feedwater Pumps, which are the active Receiver Subsystem components, and their major interfaces with other Pilot Plant systems. Interfaces exist with the CS, TSS, EPGS and CBF. Interface signals to the CBF are used by the Master Control Subsystem (MCS) to coordinate operation of the heliostat array controller, feedwater pump controller, TSS charge/discharge controller, and the Beam Characterization Subsystem. A nonactive interface also exists between the Central Tower Assembly and its foundation at grade level.

RECEIVER FLOW SCHEMATIC

FIGURE 2-4



2.2.2.2.1 Receiver/Collector Subsystem Interface

The incident solar power on the absorbing surfaces of the Receiver will be dependent on the variable solar insolation and the performance of the Collector Subsystem. However, the absorbing surfaces will not be subjected to more than _ MW_{th} of concentrated solar energy. The energy will be distributed in nonuniform, but predictable, manner such that peak solar flux will not exceed 0.3 MW_{th}/m^2. The nonabsorbing areas of the Receiver (i.e., tower and support structures) may be exposed to a maximum _ KW_{th}/m^2.

2.2.2.2.2 Receiver/Electrical Power Generation Subsystem Interface

The Receiver Subsystem is designed to provide thermal energy in the form of superheated rated steam for the Electrical power Generation Subsystem (EPGS) at the base of the tower, when supplied with pressurized, preheated, and chemically treated feedwater per Table 2-1. Power for pumps and controls is provided by the EPGS.

2.2.2.2.3 Receiver/Thermal Storage Subsystem Interface

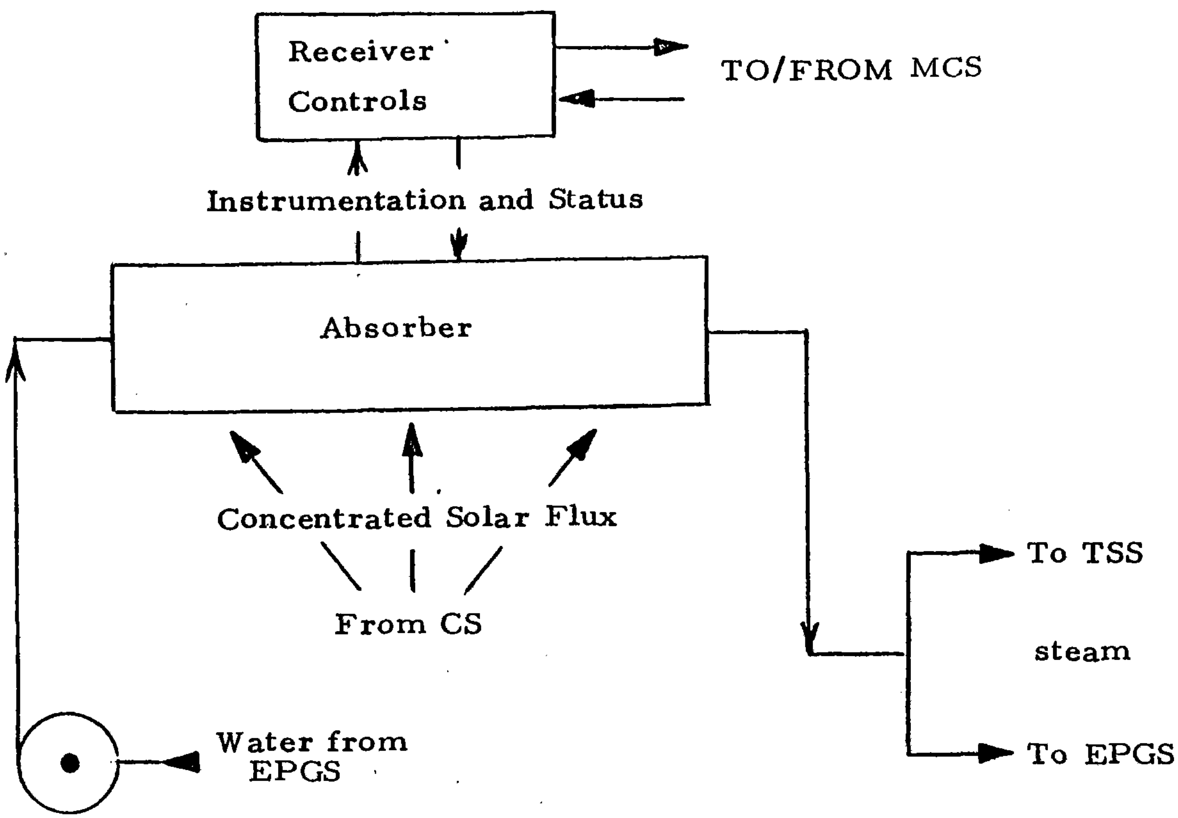
The Receiver is designed to also provide thermal energy in the form of superheated derated steam for the Thermal Storage Subsystem (TSS) at the base of the tower.

2.2.2.2.4 Receiver/Master Control/Heliostat Array Controller Subsystem Interface

a. The Receiver Subsystem includes a complete control, alarm, and instrumentation subsystem sufficient to permit control of the Receiver Subsystem, identify failure events, protect the Receiver Subsystem, and permit evaluation of the subsystem's performance so as to quantify such factors as error budgets and energy losses.

MAJOR RECEIVER SUBSYSTEM INTERFACES

Figure 2-5



SAMPLE

Table 2-1

Feedwater Purity

Factor	Recommended Maximum Limit	Typical Concentrations
Total solids	0.050 ppm	0.020 ppm
Silica as SiO_2	0.020 ppm	0.002 ppm
Iron as Fe	0.010 ppm	0.003 ppm
Copper as Cu	0.002 ppm	0.001 ppm
Oxygen as O_2	0.007 ppm	0.002 ppm
Hardness	0.0 ppm	0.0 ppm
Carbon dioxide	0.0 ppm	not measured
Organic	0.0 ppm	0.002 ppm
Lead	0.0 ppm	---
pH	9.3 - 9.5	9.45

b. Control and alarm functions are independent. The subsystem control console is integrated into and compatible with the operational controls console (OCS) in the Master Control Subsystem (MCS). The subsystem controls are capable of manual, stand-alone operation for all required control and alarm functions (i.e., independent of MCS).

c. The subsystem controls interface with the MCS through the interface defined by Interface Control Document (ICD) _____ such that the MCS can automatically achieve integrated control and alarm of all pilot plant subsystems including the Receiver Subsystem.

d. The MCS performs the data collection function for subsequent evaluation of the Receiver Subsystem through this interface. The data crossing each of plant subsystem interfaces are of two generic types:

Overall Interface Signals	Evaluation Interface Signals
Control Commands	Evaluation Data Requests
Operational Data Requests	Evaluation Data Outputs
Operational/Alarm Data Outputs	

2.2.2.3 Receiver Subsystem Arrangement

The Central Tower Assembly supports theAbsorber above the Collector field. The Absorber consists of structurally identical panel subassemblies arranged in an approximately cylindrical configuration. Panels on the south side of the Absorber are used as preheaters and those on the north side as superheaters. The heliostats surrounding the base of the tower direct their collected solar flux onto the full 360° surface of the Absorber.

At the top of the tower is a crane which is used for hardware assembly and maintenance. Various supporting subsystems such as the Receiver Start-up Flash Tank and the BCS are mounted at different places within the tower. Detailed component arrangements are shown in System Arrangement Drawings _____ through _____.

2.2.2.4 Receiver Subsystem Performance Characteristics

The overall Receiver Subsystem performance range is sufficient to satisfy the Pilot Plant operating modes described in Section 1.0. Table 2-2 summarizes the required performance. The Receiver design provides for a smooth and safe transition between any two modes of plant operation. The calculated Absorber thermal losses corresponding to rated performance are given in Table 2-3.

2.2.2.4.1 Steady State

The Receiver will deliver, at the base of the tower, rated dry superheated steam when the plant operating mode requires turbine or thermal storage (or any combined) charging power.

2.2.2.4.2 Start-Up

Start-up is accomplished following a signal of anticipated sunrise from the Master Control. Following this signal, the Receiver controls perform sufficient checks to ensure that it can operate in a manner consistent with normal safety requirements, and automatically regulates its own operation to ensure peak efficiency during any mode of operation.

Morning start-up is accomplished such that rated steam can be supplied to the plant prior to the sun reaching ______ radians of elevation during any day of the year.

2.2.2.4.3 Transients

The Receiver control and instrumentation system responds to transient conditions (i.e., solar flux or feedwater temperature or

Table 2-2

Receiver Subsystem Performance Requirements

Quantity	Design	Minimum	Maximum
Rated Steam (Modes 1, 2, 3, 7)			
Feedwater			
Inlet temperature, $^oF(^oC)$	400 (204)		
Inlet pressure, psia(MPa)	2000 (13.8)		
Flow rate, lb/hr x 10^3 (Kg/sec)	134.5 (16.94)		
Steam			
Outlet temperature, $^oF(^oC)$	960 (516)	878 (470)	1042 (561)
Outlet pressure, psia (MPa)	1515 (10.45)	1415 (9.76)	1615 (11.14)
Flow rate, lb/hr x 10^3 (Kg/sec)	134.5 (16.94)		
Derated Steam (Modes 4, 5)			
Feedwater			
Inlet temperature, $^oF(^oC)$			
Inlet pressure, psia (MPa)			
Flow rate, lb/hr x 10^3 (Kg/sec)			
Steam			
Outlet temperature, $^oF(^oC)$	660 (349)	578 (303)	742 (394)
Outlet pressure, psia (MPa)	1515 (10.45)	1415 (9.76)	1615 (11.14)
Flow rate, lb/hr x 10^3 (Kg/sec)			

Table 2-2 (Cont'd)

Receiver Subsystem Performance Requirements

Quantity	Design	Minimum	Maximum
Absorber absorbed heatflux, Btu/in^2-sec (MW$_t$/m^2)	0.18 (0.3)		
Non-Absorber surfaces absorbed heat flux, Btu/in^2-sec (MW$_t$/m^2)			0.0018 (0.003)
Heat Flux distribution on Absorber panels			
Power incident on Absorber, Btu/sec x 10^3 (MW$_t$)			
Absorber power/flow, Btu/lb/sec (MW$_t$/Kg/sec)			
Absorber efficiency, %			
Annual average efficiency, %		85	
Absorber surface absorptivity, %		90	
Activation time, sec			
Cold start up			
Warm start up			
Hot start up			

TABLE 2-3

ABSORBER HEAT LOSSES (MW_t)

Item	Max Rated Steam	Max Derated Steam
IR Radiation		
Convection		
Reflected Insolation		
Total	(TBD)	
Absorbed Energy		
Percent Loss		

feedwater pressure variations) by adjusting fluid flow within the Receiver steam generator so as to maintain peak thermal efficiency and proper performance.

2.2.2.4.4 Emergencies

The Receiver Subsystem will respond to emergency conditions (i.e., loss of feedwater flow, loss of solar energy, failure of one or more receiver flow control valves) so as to avoid adverse effects on the Receiver components or components of other subsystems. A hardwired connection to the CS permits emergency defocus when necessary. The Receiver control system keeps the Master Control Subsystem continuously apprised of the Receiver's condition and performance characteristics.

2.2.2.4.5 Shutdown

Upon command of the Master Control Subsystem, the Receiver will begin a coordinated stable shutdown.

2.2.2.4.6 Absorber Absorptivity

The effective solar absorptance of the Absorber surface is at least 0.95 at operating temperature. Coatings used to enhance the absorptivity have a one-year minimum life. The directional absorptivity characteristics of such coating must be within 2% of its maximum value for all angles of incident solar flux.

2.2.2.4.7 Thermal Efficiency

The annual average efficiency of the Receiver subsystem is at least 85%. The annual average is defined as the ratio of the annual thermal power out of the Receiver, at rated and/or derated steam conditions while the sun is at elevations greater than ________ radians, to the annual incident solar power onto the absorbing surfaces of the Receiver.

2.2.2.5 Design Environmental Conditions

Design environmental conditions, such as seismic, wind loads, rain, and transportation, are defined in Appendix C. All hardware components are designed and packaged so that conditions described in Appendix C do not induce conditions which exceed the structural capability of the hardware. In addition, all components are designed to withstand handling/hoisting loads of up to 2 g's, considering the number, locations, and type of hoisting points. Components shall be designed for transportability within applicable Federal and State regulations by highway and railroad carriers using standard transport vehicles and materials handling equipment.

To preclude fatigue by fluctuating wind loads, all structural components are designed so that stresses are below the endurance limits. Applied pressures are assumed to be in-phase over the structures.

Subsystem components are protected from electrostatic charging and discharging associated with sand and dust storms. Lightning protection is provided for various Solar Facilities subsystems. Tower-located hardware is protected from lightning threats by a 90-degree cone of protection per NFPA 78.

Detailed operating environment design restrictions, such as electrical transients, electromagnetic radiation, materials, etc., are contained in the appropriate specifications listed under Applicable Documents for each component description.

2.2.2.6 Receiver Subsystem Design Description

The primary functions of the Central Tower Assembly are to elevate and support the Absorber, Feedwater Riser, Steam Downcomer, and all necessary auxiliary equipment, which includes: (1) a combined freight and equipment elevator operating inside the tower structure; (2) a crane at the top of the tower; and (3) attachment points and work platforms for the Beam Characterization Subsystem. The Tower is constructed of steel and elevates the horizontal center line of the Absorber ________ feet above the finished grade of the Collector Subsystem.

The Tower extends______feet above grade to the interface with the Absorber Support Structure.

All of the collected solar energy cannot be accurately aimed at or restricted to the Absorber, therefore, the operating conditions for the Central Tower Assembly include spill-over impingement of______Btu/ft^2/sec (________MW_t/m^2) over a region extending down to Tower Station________.

The Tower is designed to: (1) provide a 30-year useful life; (2) permit shop fabrication and field erection; (3) permit ease of attachment to a steel reinforced concrete foundation; (4) accommodate lightning protection equipment; and (5) accommodate aircraft warning lights.

The Tower structure and all attached components are designed to withstand the forces and loads induced by the environmental conditions given in Appendix C. With a weight of______tons above Tower station ________, the horizontal deflections do not exceed________inches at the mid-point of the Absorber envelope for a maximum operational wind speed of ________mph at________feet elevation. Wind speeds at other elevations are given in Appendix C. The practices recommended in ASCE Paper 3269, Volume 126, and the Uniform Building Code 1976, Volume l, are used in the design for winds. The structures are designed such that stresses are below the endurance limits of fatigue caused by the fluctuating wind loads given in Appendix C. The Tower is also designed to withstand the earthquake environment given in Appendix C without structural damage or yielding.

Critical components of the Central Tower Assembly, which include but are not limited to the Absorber panel rear surfaces, Feedwater Riser, and Steam Downcomer are appropriately insulated to prevent over-cooling and/or overheating.

The Tower is supported on a square concrete foundation. The foundation mat is_______ft. thick and ________ft. on a side, and is located_________ft. below finished grade in an open excavated area. Concrete walls and pedestals extend_______ft. upwards to meet the steel Tower at an elevation________ft. above grade.

2.2.2.6.1.1 through___________.

(The SFDI shall supply a detailed description of the analysis and design of the Central Tower Assembly.)

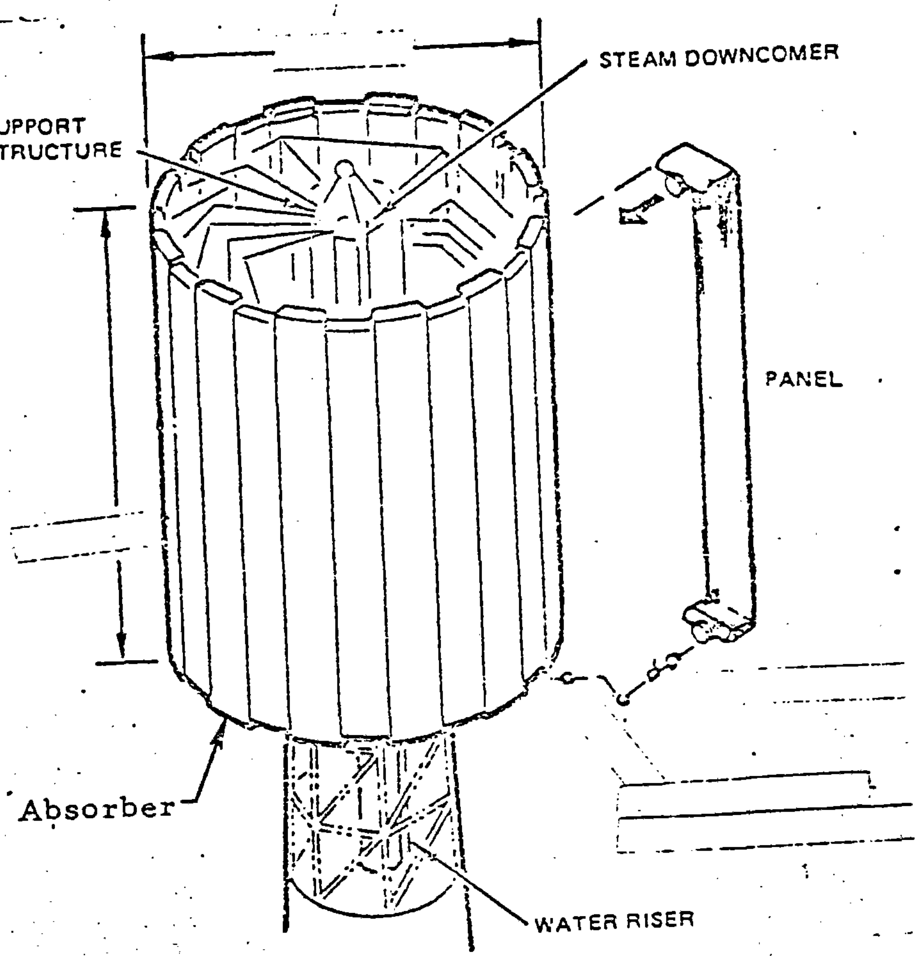
2.2.2.6.2 Absorber

The functions of the Absorber are to: (1) convert the incident solar energy reflected from the Collector Field into the maximum amount of thermal energy in steam; (2) contain the water/steam for further distribution; and (3) secondarily, but necessarily, protect the structure and control components located behind the absorber panels from overheating by incident solar energy.

Detailed design of the Absorber accounts for the collector field aim strategy. The Absorber design is based on exterior solar heating distributions which result from a customized 3-point high-low aim strategy for the collector field. This aim strategy produces a peak heat flux of ________ Btu/in^2-sec.

The Absorber (Figure 2-6) consists of______preheater and _______boiler panel assemblies mounted on a central core steel support structure to form a single, essentially circular (_______sides) cylinder, which is______feet in diameter and_____feet long. The support structure is located at the top of a_______foot high steel tower which is completely surrounded by the Collector Field. The weight of the Absorber and its components (including the water/steam) is_______pounds.

The preheater and boiler panel assemblies are structurally identical and include a tube bundle, inlet and outlet manifolds, backup structure, and insulation. The major difference in the panels is that flow control is provided on the boilers but not on the preheaters. The preheater panels are connected with the Receiver feedwater riser and the boiler panels. The boiler panel exit steam manifolds are connected with the Receiver steam downcomer.



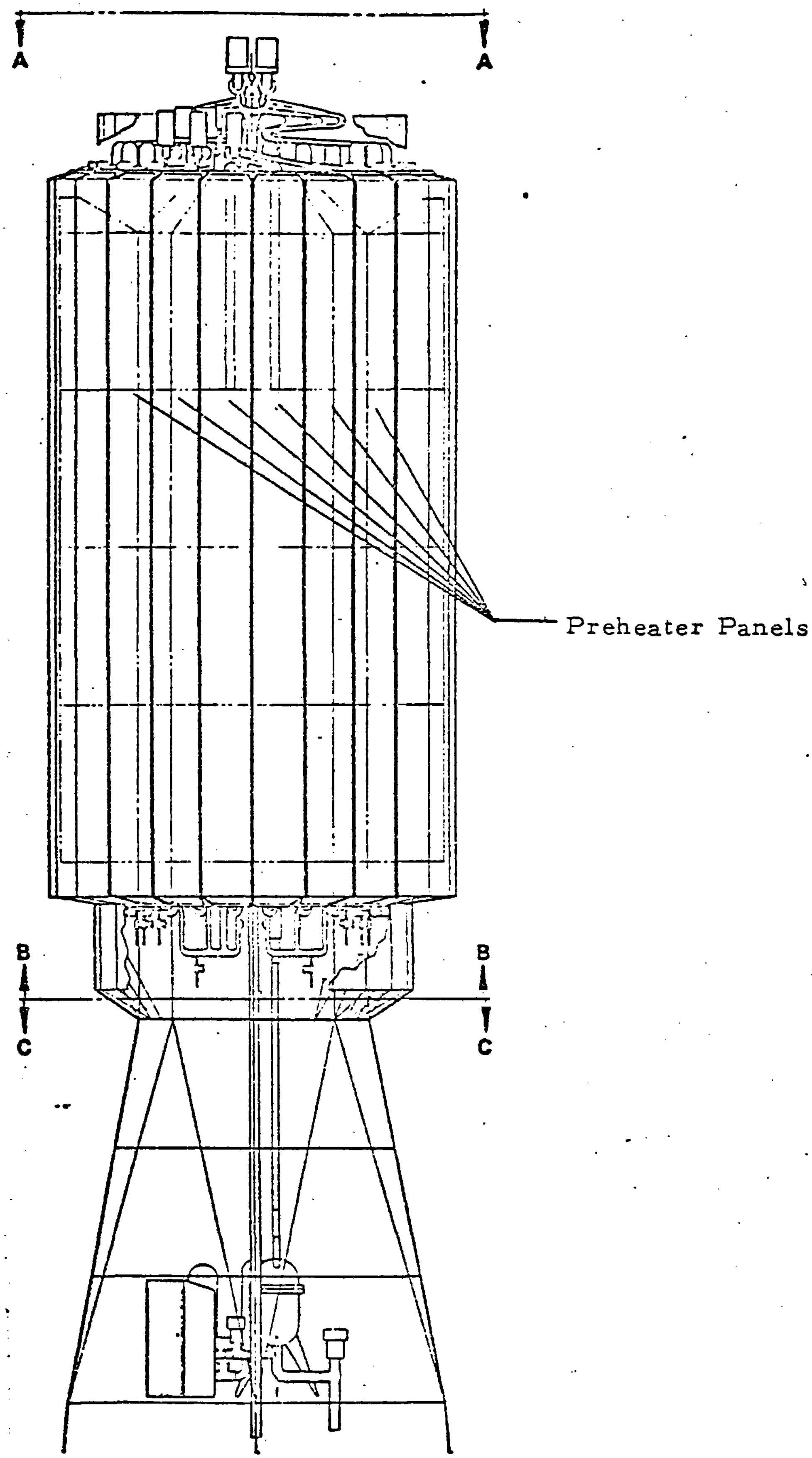
Pilot Plant Absorber

Figure 2-6

The preheater panels are located on the southerly facing exterior of the Receiver (Figure 2-7 and 2-8). The modular panel design provides for easy maintenance in that a panel may be removed for repair, if necessary, and replaced with another panel. A schematic portraying the installation of a typical panel is given in Figure 2-9. The time required to replace a panel is approximately 12 hours.

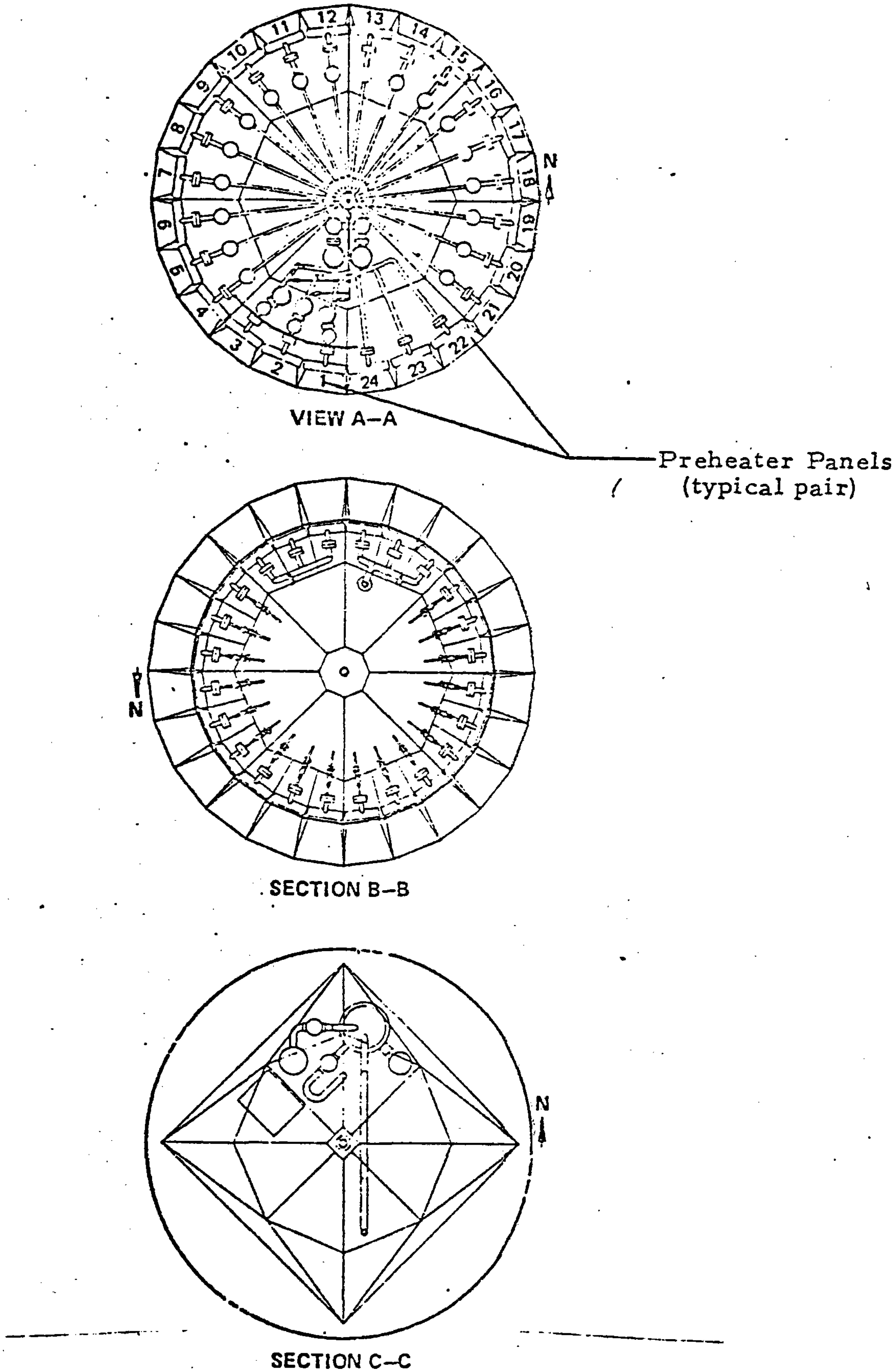
The tube bundles used in the preheater panels consist of multiple Incoloy 800 tubes which are_____feet (________m) long and have additional length provided at both ends for bending over to protect the inlet and outlet (Figure 2-10). Each panel tube bundle is mounted to a backup structure to: (1) maintain panel shape; (2) fasten the tube bundle to the central core support structure properly while allowing for thermal growth; and, (3) provide support for wind and seismic loads. The panels are permitted unrestrained lateral and vertical thermal expansion through the use of sliding clips and channels. Each panel is insulated on the back in order to minimize thermal losses and provide thermal protection for the central core support structure and control components. Full-length longitudinal welds are used between adjacent tubes on each panel to provide: (1) structural integrety; and, (2) good thermal contact between tubes. All panel tubes are welded to the manifolds at both ends to provide leak integrity.

The preheater panels heat the system feedwater prior to its introduction into the boiler panels; however, the water must exit the preheaters in a subcooled state to avoid unstable two-phase flow at the boiler panel inlets. The water temperature at the preheater outlets varies throughout the year as a function of the solar heating of the panels. Figure 2-11 shows the preheater panel duty (percentage of total Absorber area heat flux incident on the preheaters) throughout the diurnal cycle for different seasons. The water temperature at the preheater panel outlets as a function of feedwater inlet temperature for the anticipated preheater duty is given in Figure 2-12. Preheater inlet temperatures are set to provide a minimum of 50^{o} subcooling to prevent two-phase flow to the boiler panels.



Pilot Plant Receiver Unit External View (Looking North)

Figure 2-7



Pilot Plant Receiver Unit Cross Sections

Figure 2-8

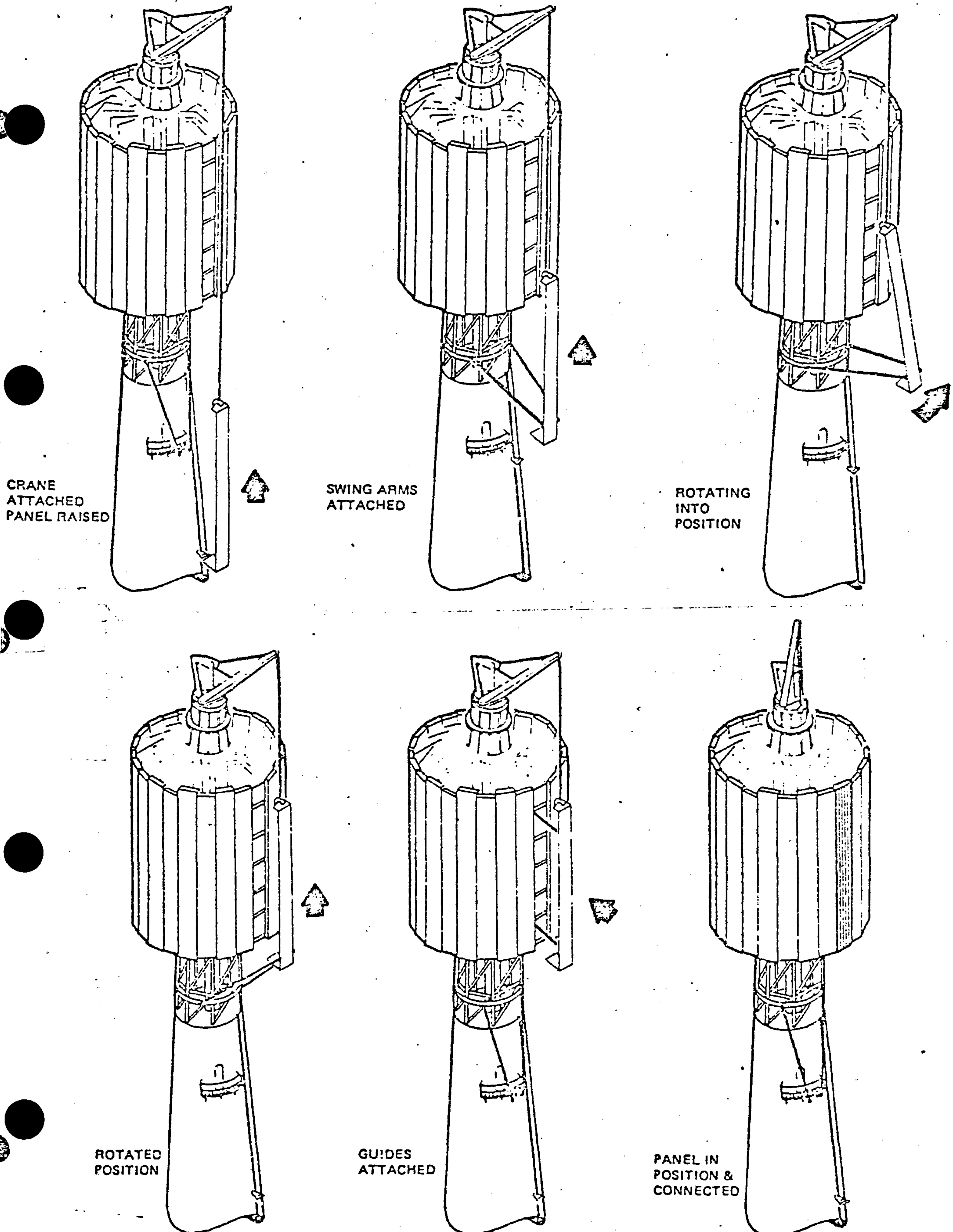
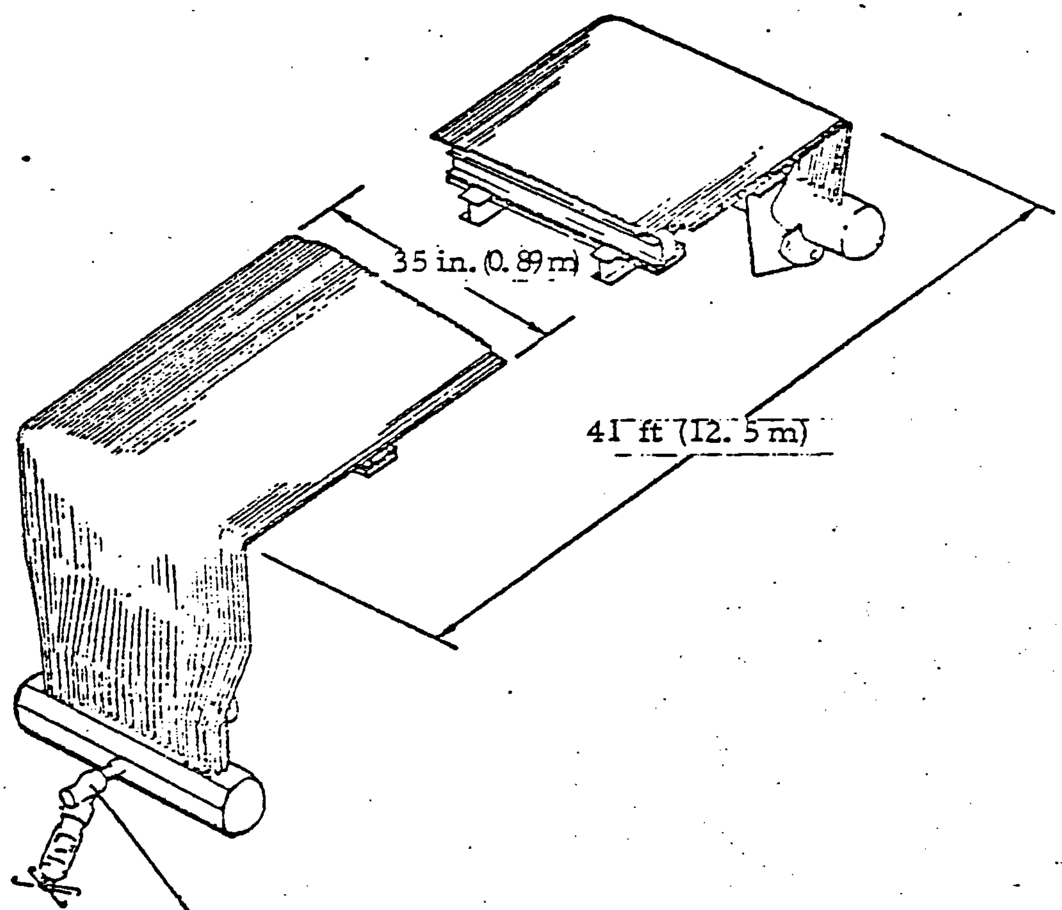

CRANE
ATTACHED
PANEL RAISED
SWING ARMS
ATTACHED
ROTATING
INTO
POSITION
ROTATED
POSITION
GUIDES
ATTACHED
PANEL IN
POSITION &
CONNECTED

Figure 2-9

SAMPLE



Pilot Plant Absorber Panel

Figure 2-10

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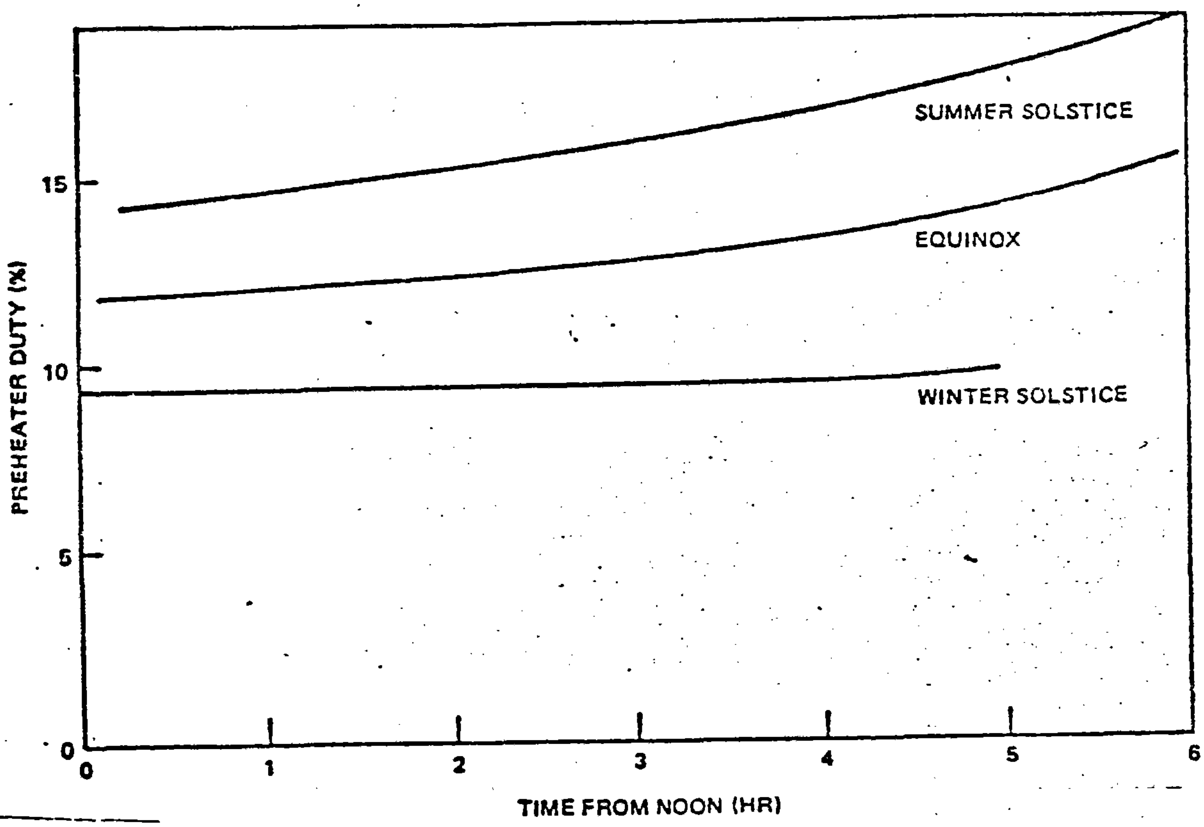


Preheater Duty

Figure 2-11

SAMPLE

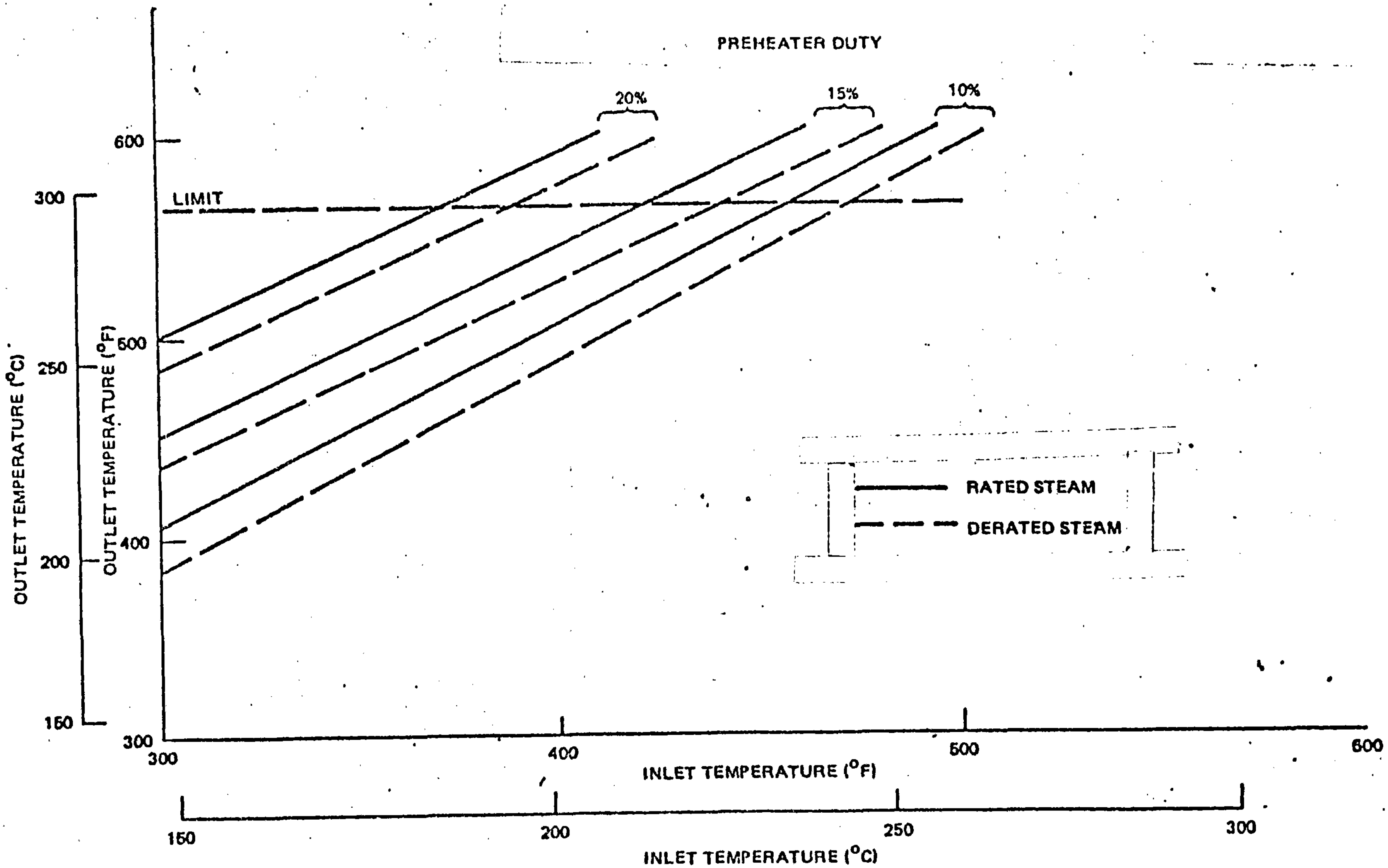


Figure 2-12

Preheater Performance

The intake manifolds of 3 of the preheater panels are connected in parallel to the Receiver feedwater riser (Figure 2-13). Each of the above panels is connected in series to a second preheater panel to make 3 pairs (Figure 2-8, View A-A). In each pair, feedwater rises upward through one panel and down in the second panel as its temperature increases due to solar heating. The heated water from the second panel of each pair is collected and distributed to a ring manifold. The ring manifold supplies the preheated water to the inlets at the bottom of the boiler (superheater) panels.

The boiler (superheater) panels are of the "once-through" type and are used to convert water from the preheater panels into superheated steam. The boiler panels are structurally identical to the preheater panels but have flow control valves not found on the preheater panels.

The boiler panels are connected in parallel. Flow control is provided through modulating flow control valves at the inlet to each boiler panel in conjunction with temperature sensing of the exiting steam at the top. Superheated steam is produced as the feedwater flows upward through the boiler tubes and exits at the top.

A cyclone steam separator is connected at the exit of each boiler panel to insure drying of the steam. The separators are equipped with level sensors to signal excessive water or to initiate shutdown. Water from the cyclone separators is collected in a moisture trap (tank).

The dried steam from all panels is then collected in a steam downcomer collection manifold, which is connected at the top of the Receiver steam downcomer. The steam downcomer collection manifold is provided with two redundant safety relief valves in conformance with the ASME Boiler Code. In addition, a remotely controlled vent valve is included in the panel design which may be activated under emergency conditions.

SAMPLE

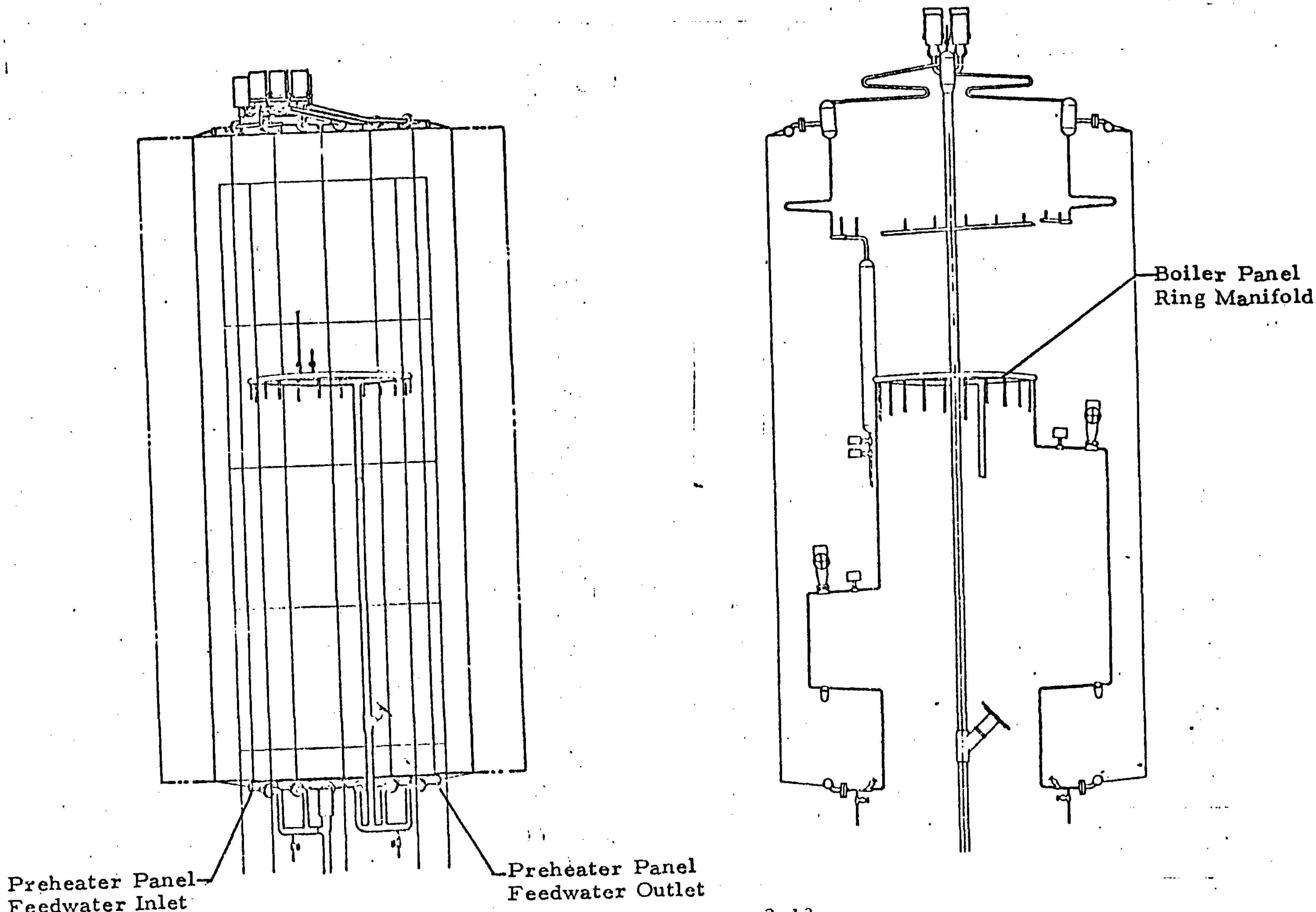


Figure 2-13

Absorber Feed System

The Absorber is designed to survive thermal and structural loads both instantaneously and over the 30-year life of the plant for all operating modes, as defined in Appendix B. The basic design requirement is imposed by the location of the peak solar heat flux, which occurs on northerly facing surfaces (Figure 2-14). Since this location produces the highest heat flux on the Absorber, the resulting temperature distributions produce the most critical thermal strains within the Absorber tubes.

The 30-year plant service life and cyclical variation of the solar heating require the use of materials in the panels which have high ductility and resistance to thermal shock. High strength and thermal conductivity in the metals used in construction are additional requirements. Panel materials also have good corrosion reistance which is enhanced by system feedwater demineralization and filtering. The requirement of the Absorber to absorb 90% of the incident solar energy is met by special surface preparation (paint).

Water flow through the Absorber is controlled by an instrumentation and flow control subassembly consisting of sensors, signal conditioning equipment, control electronics, valves, filters, and plumbing. This subassembly controls the water/steam flow within the Absorber as directed by the plant operator or the Master Control Subsystem

2.2.2.6.2.1 through____________

(The SFDI shall supply a detailed description of the analysis and design of the Absorber.)

2.2.2.6.3 Feedwater Pumps

Two redundant feedwater pumps are located upstream of the Feedwater Riser inlet. Each pump is capable of increasing the feedwater pressure from______psia to______psia at a maximum flow rate of 167,500 lb/hr and a peak power consumption of________hp.

Each pump is electric motor driven through a variable speed hydraulic coupling to automatically control the inlet pressure level

SAMPLE
ONLY

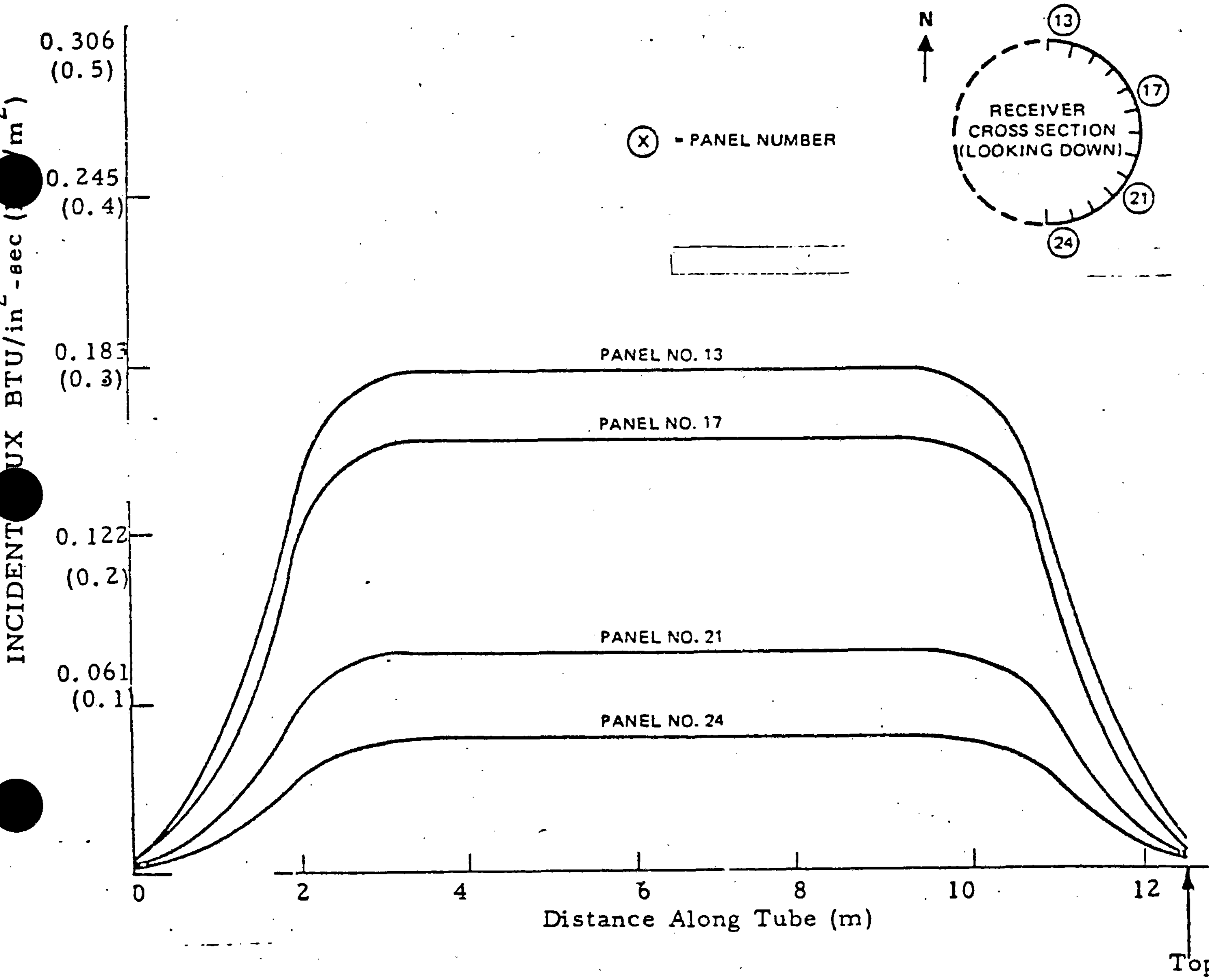


FIGURE 2-14, PILOT PLANT ABSORBER INCIDENT HEAT FLUX PROFILES to the Absorber at______psia. Feedwater flow is used as a feed forward signal to ensure rapid response to changes in flow requirements.

The characteristics of each pump are as follows:

Type	Centrifugal, double-case barrel-type
Capacity	______________gpm
Inlet Pressure	______________psia
Developed Head	______________feet
Drive Motor	______________hp
Full-Load Rotation	______________rpm
Efficiency	______________%
Brake Horsepower	______________hp

2.2.2.6.3.1 through__________.

(The SFDI shall supply a detailed description of the analysis and design of the Feedwater Pumps.)

2.2.2.6.4 Receiver Subsystem Startup Flash Tank

The Receiver Subsystem startup flash tank is used to establish flow through the Receiver Subsystem during (1) the cleanup mode which precedes startup, and (2) the startup operating mode before the generation of steam at rated conditions. The operational characteristics involving the flash tank during the Receiver Subsystem prestart and startup modes are described in OPDD Section 4.

The flash tank is sized for______lb/hr which corresponds to the minimum flow required for stable Receiver Subsystem operation. The above flow corresponds to approximately_______% of maximum flow at equinox noon.

The flash tank design and construction conforms to ASME Section VIII, Unfired Pressure Vessel Code.

2.2.2.6.4.1 through ________.

(The SFDI shall supply a detailed description of the analysis and design for the RS Startup Flash Tank.)

2.2.2.6.5 Receiver Subsystem Instrumentation and Controls

The instrumentation and controls subassemblies provide the information and control necessary to (1) provide specified steam outlet conditions under the highly transient diurnal and seasonal variations in solar insolation; (2) evaluate Receiver Subsystem performance; and (3) protect the Receiver Subsystem.

The instrumentation and controls assemblies include data sensors and control electronics. The control electronics receives command signals from an operator or the Master Control Subsystem and translates these signals into specific actions in the Receiver. The Receiver Subsystem control system performs these functions during prestart checks, startup, daytime operation, normal shutdown, emergency shutdown, and night-time standby. The set points and operating conditions for each of these phases are given in OPDD Sections 3 and 4. A schematic showing the arrangement of components is given in________. The valves shown in the Piping and Instrumentation Diagram (P&ID) of Appendix F and their related functions are summarized in_______. Detailed component characteristics are given in individual specifications.

The Receiver Subsystem control system maintains a constant steam outlet temperature by controlling the feedwater flow rate. The steam discharge temperature at each boiler panel is measured and compared with appropriate set point values by control electronics.

Receiver Subsystem inlet and exit pressure, and inlet temperature, are regulated by other control elements such as the turbine stop valve, feedwater heater controls, and feedwater pump speed regulators.

2.2.2.6.5.1 through ____________

(The SFDI shall supply a general description of the rationale and design for instrumentation and control of major hardware pieces.)

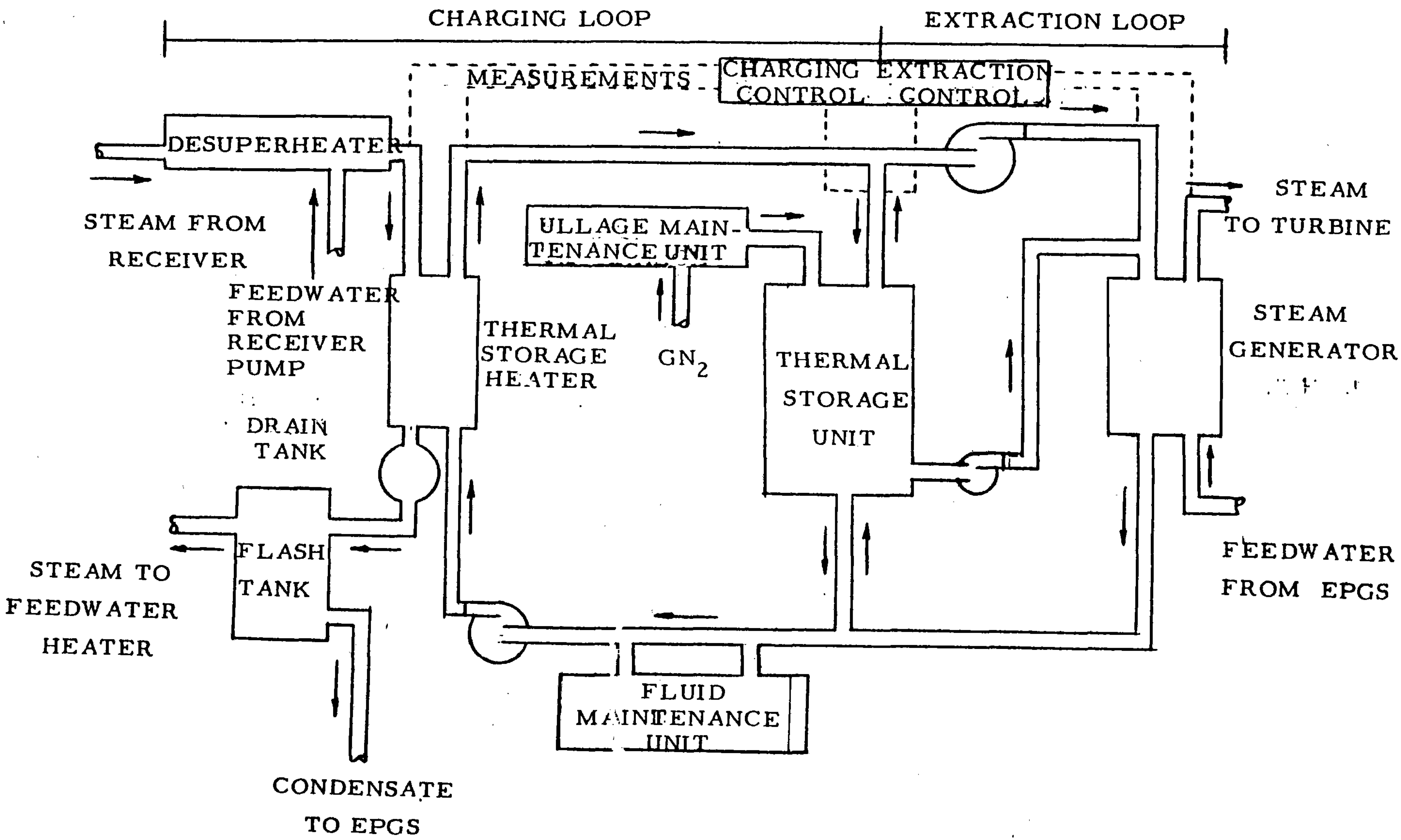
2.2.3 Thermal Storage System (TSS)

The Thermal Storage System (TSS) provides a means of (1) transferring a portion of the thermal output from the Receiver System (RS) to stored thermal energy, and (2) subsequently transferring the stored thermal energy to steam in a form suitable for generating electrical power with a conventional turbine-generator. The TSS buffers the Electrical Power Generation System (EPGS) from excessive variations in solar insolation, extends the power plant's generating capacity into periods of low or no insolation, and provides seal steam for the turbine and blanketing steam for the deaerator. A schematic of the fluid flow loops within the TSS is shown in Figure 2-15.

2.2.3.1 General System Description

The TSS consists of nine major components which include: (1) the Thermal Storage Unit (TSU), which is a tank that stores and discharges thermal energy via a heat transfer fluid; (2) the Ullage Maintenance Unit (UMU), which provides a controlled pressure range and gas composition above the surface of the fluid in the TSU; (3) the Fluid Maintenance Unit (FMU), which removes suspended and dissolved impurities from the heat transfer fluid; (4) the Desuperheater, which reduces the temperature of the steam from the RS; (5) the Thermal Storage Heater (TSH), which transfers heat from the RS steam to the heat transfer fluid (drain and flash tanks are included as part of the TSH); (6) the charging loop consisting of pumps and associated equipment which connect the TSH and TSU; (7) the Steam Generator, which transfers thermal energy from the heat transfer fluid to feedwater to generate steam for the turbine; (8) the extraction loop, consisting of pumps and associated equipment connecting the TSU and steam Generator; and (9) the TSS Control Assembly, consisting of instrumentation and controls.

Steam from the RS flows to the TSH where it heats the heat transfer oil circulating from the TSU. The heated oil is then distributed



THERMAL STORAGE SYSTEM FLUID FLOW LOOP SCHEMATIC

FIGURE 2-15

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to the TSU and/or Steam Generator. Steam produced in the Steam Generator is used to drive the turbine-generator set, while heat transfer oil exiting the Steam Generator is circulated back to the TSU and/or TSH. RS steam which exits the TSH as high temperature condensate is collected in the drain tank and is then flashed to the TSS Flash Tank. The portion of this condensate which flashes to steam circulates to the high pressure feedwater heaters within the EPGS; the condensate from the TSS Flash Tank circulates either to the Condenser hot well or Deaerator within the EPGS.

The complete TSS drawing and specification schedule is shown in Figure _____.

2.2.3.2 Major Interfaces

Major interfaces exist between the TSS and other pilot plant systems including the RS, EPGS, and MCS. The TSS Charging and Extraction loop instrumentation and controls are coordinated with the MCS to direct and control: (1) steam from the RS to the Desuperheater; (2) feedwater from the RS feedwater pump to the Desuperheater; (3) steam from the steam Generator to the turbine-generator set; (4) feedwater from the EPGS to the Steam Generator; and (5) TSS Flash Tank steam and condensate to the EPGS. A schematic of the above interfaces is shown in Figure 2-16. The TSS components and equipment are designed to provide mechanical attachment to concrete foundations for mechanical support. Mechanical and electrical connections between the TSS and RS, EPGS, and MCS are designed in accordance with Interface Control Document drawings found in _______.

2.2.3.3 Thermal Storage System Arrangement

The TSS is located in the immediate vicinity of the RS and EPGS because of the close coupling of these systems. The equipment and components of the TSS provide for safe and reasonable ingress, egress, and access for inspection, maintenance, and repair. Detailed component arrangements are shown in the Plot Plan drawing ______ and System Arrangement Drawings ______.

2.2.3.4 Thermal Storage System Performance Characteristics

The TSS operates in a safe, stable and flexible manner for: (1) all normal plant operating modes described in Section 1.0; (2) transitions between allowable combinations of these modes, described in OPDD Section 4; and (3) emergency conditions described in OPDD Section 5. Table 2.4 summarizes the overall performance characteristics of the TSS.

2.2.3.4.1 Desuperheater

Inlet and exit conditions for the steam and/or feedwater in the Desuperheater are as follows:

Quantity	Design	Min.	Max.
Inlet Steam			
Temperature, °F(°C)			
Pressure, psia (MPa)			
Flow Rate, lb/hr(Kg/sec)			
Feedwater			
Temperature, °F(°C)			
Pressure, psia (MPa)			
Flow Rate, lb/hr(Kg/sec)			
Outlet Steam			
Temperature, °F(°C)			
Pressure, psia (MPa)			
Flow Rate, lb/hr(Kg/sec)			
Turn Down Ratio			

2.2.3.4.2 Thermal Storage Heater (TSH)

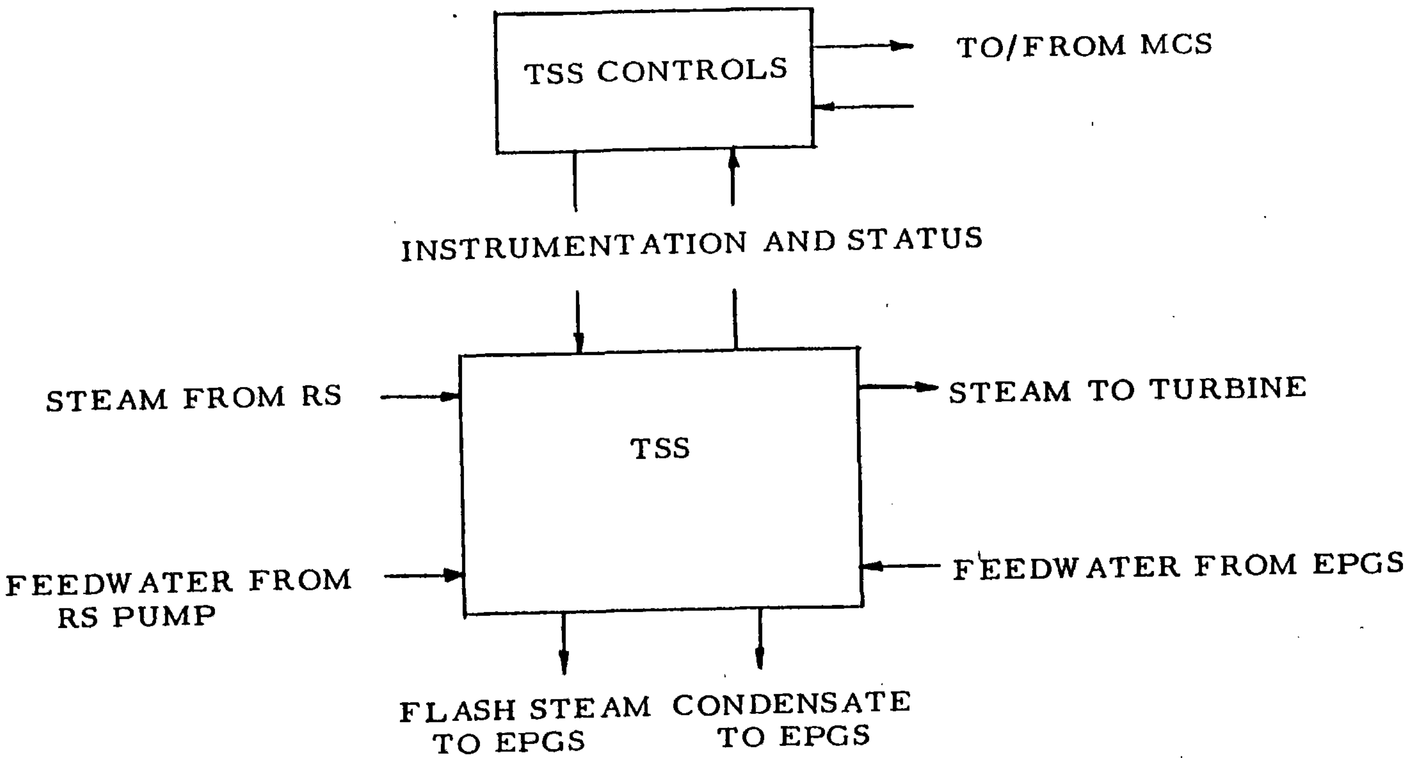
The TSH provides the following conditions for the steam/water and heat transfer oil flow:

Quantity	Design	Min.	Max.
Steam/Water			
Inlet			
Temperature, °F(°C)			
Pressure, psia (MPa)			
Flow Rate, lb/hr(Kg/sec)			
Outlet			
Temperature, °F(°C)			
Pressure, psia (MPa)			
Flow Rate, lb/hr(Kg/sec)			
Heat Transfer Oil			
Outlet			
Temperature, °F(°C)			
Pressure, psia (MPa)			
Flow Rate, lb/hr (Kg/sec)			
Duty, Btu/hr (MW_t)			
Life Expectancy, Years			
Other: Must meet highway transportation limits			

The TSH is capable of completely condensing all steam and of heating the heat transfer fluid to a minimum of ______ °F under maximum steam flow rates of _____ lb/hr, based on an inlet temperature of ______ °F for the heat transfer fluid.

2.2.3.4.3 Thermal Storage Unit (TSU)

The TSU employs a combination of heat transfer oil and crushed rock/sand for storing thermal energy. A sharp temperature differential (thermocline) is used to store both hot and cold media in the same tank.



MAJOR THERMAL STORAGE SYSTEM INTERFACES

FIGURE 2-16

Table 2-4

Thermal Storage System Performance Requirements

Quantity	Design	Min.	Max.
Extractable Capacity After 36 hr. Hold, Btu (MW_t-Hr)			
Net			
Turbine Warm Start			
Total			
Storage Temperature, $^oF(^oC)$			
Average			
Degradation During Extraction			
TSU Thermal Losses*, % of Extractable Capacity			
Thermal Rates, Btu/hr(MW_t)			
Charging			
Extraction			
Hot Standby Demand			
Fluid Temperature, $^oF(^oC)$			
Extraction Steam Thermal Rate, Btu/hr(MW_t)			
Night-Time Standby Demand			
Fluid Temperature, $^oF(^oC)$			
Turbine Seal Steam, Btu/hr(MW_t)			

* Over a 36 hr. period after fully charging the TSS

Table 2-4 (Cont'd)

Quantity	Design	Min.	Max.
Night-Time Standby Demand (Cont'd)			
Deaerator Shell Blanketing, Btu/hr (MW_t)			
Deaerator Pressure Pegging, Btu/hr(MW_t)			
Receiver Subsystem Freeze Protection, Btu/hr(MW_t)			
Net Energy to Grid, MW_e-Hr	28		
Time at 7 MW_e Maximum Power to Grid, Hr.	4		

When thermal energy is added to the TSU, cool heat transfer oil is removed from the bottom of the tank, heated in the TSH with steam from the RS, and circulated back to the top of the TSU. For heat extraction, warm heat transfer oil is removed from the top of the TSU, pumped to the Steam Generator where it heats incoming feedwater which is converted into superheated steam, and is then circulated back to the bottom of the TSU.

The TSU has an extractable capacity of _____ Btu (_____ MW_t - Hr). The extractable capacity consists of _____ Btu (_____ MW_t - Hr) to provide a warm turbine startup, and _____ Btu (_____ MW_t - Hr) to permit the turbine-generator to supply power for auxiliary equipment and deliver $7MW_e$ net to the utility grid for a period of 4 hours after turbine startup is completed. The extractable energy is available following a full charge of the TSU and a subsequent 36 hour hold period. The charging rates of the TSU vary from _____ Btu/hr (_____ MW_t) to _____ Btu/hr (_____ MW_t); the extraction rates vary from _____ Btu/hr (_____ MW_t) to _____ Btu/hr (_____ MW_t).

The maximum allowable heat loss is _____% of extractable energy over a 36 hour hold period which begins after fully charging the TSU. Night-time turbine seal steam and deaerator blanket and pegging steam is also provided at a minimum temperature of _____ ^oF at a rate of _____ Btu/hr (_____ MW_t) for at least _____ hours.

2.2.3.4.4 Ullage Maintenance Unit (UMU)

The UMU primary requirements are to: (1) maintain a controlled pressure range in the ullage gas above the surface of the heat transfer oil in the TSU, and (2) remove volatilized products of degradation from the ullage space and thus provide an inert atmosphere within the TSU. Provisions are also included to vent water vapor during initial system start up. Detailed requirements of the UMU are dependent upon the particular heat transfer oil used in the TSU.

2.2.3.4.4.1 through________

(The SFDI shall provide a summary of key performance parameters which shall include but not be limited to: (1) TSU ullage pressures; (2) ullage gas composition limits; (3) ullage gas temperature limits; (4) makeup inert gas capacity; and, (5) TSU venting limits. Reference shall be made as appropriate to set points which are described in detail in OPDD Section 3).

2.2.3.4.5 Fluid Maintenance Unit (FMU)

The requirements for the FMU are highly dependent on the heat transfer oil used in the TSS. The primary requirements of the FMU are to: (1) remove polymerized compounds formed due to pyrolysis of the heat transfer oil; (2) remove suspended solids from the heat transfer oil; and (3) provide fresh makeup heat transfer oil to the TSS as required. The maximum steady state concentration of polymerized matter in the bulk fluid is _____%. The filtration portion of the FMU removes suspended particulates greater than _____ micrometers in size.

2.2.3.4.5.1 through ________

(The SFDI shall supply additional detailed performance characteristics for the particular FMU selected. The characteristics shall include but not be limited to: (1) polymerization rate, kinematic viscosity, and/or gel permeation chromatography data/analyses for the heat transfer oil; (2) the sources and corresponding sizes of suspended particulate matter in the heat transfer oil; (3) makeup heat transfer oil quantities and rates; (4) ancillary equipment (e.g., feed pumps condensers, evaporators) power and fluid flow conditions, including fluid velocities and corresponding pump sizes.)

2.2.3.4.6 Steam Generator

The Steam Generator produces steam under the following conditions:

Quantity	Design	Min.	Max.
Heat Transfer Oil			
Inlet			
Temperature, ^{o}F (^{o}C)			
Pressure, psia (MPa)			
Flow Rate, lb/hr(Kg/sec)			
Outlet			
Temperature, ^{o}F (^{o}C)			
Pressure, psia (MPa)			
Flow Rate, lb/hr(Kg/sec)			
Feedwater Inlet			
Temperature, ^{o}F (^{o}C)			
Pressure, psia (MPa)			
Flow Rate, lb/hr(Kg/sec)			
Steam Outlet			
Temperature, ^{o}F			
Pressure, psia			
Flow Rate, lb/hr			
Hot Standby Thermal Rate, Btu/hr (MW_t)			

The feedwater inlet and steam outlet temperatures and pressures are defined by: (1) the turbine admission valve inlet conditions, and (2) the pinch point limitations occurring within the Steam Generator between the heat transfer oil and water/steam. The flow rates above correspond to the fluid outlet temperature and pressure conditions which must be maintained. Maximum flow rates correspond to the requirement for the turbine-generator set to provide 7 MW_e net power to the utility grid while operating solely from TSS steam. The minimum flow rates correspond to the threshold of controlled flow during turbine startup using TSS steam or when the turbine is operating from both RS and TSS steam simultaneously.

2.2.3.4.6.1 through _______

(The SFDI shall supply additional detailed performance data for the Steam Generator which shall include but not be limited to: (1) turbine admission steam conditions; (2) pinch point considerations within the Steam Generator; (3) nighttime seal and blanketing steam requirements; and (4) reference to OPDD Section 3 as appropriate for set points.)

2.2.3.4.7 Charging Loop

The TSS charging loop is designed for the following operating conditions:

Quantity	Design	Min.	Max.
Flow Rate, lb/sec.			
Temperature, °F			
Pressure, psia			

The velocity of the heat transfer oil through the charging pump is _____ ft/sec which results in a pump size of ____ inches.

2.2.3.4.8 Extraction Loop

The TSS extraction loop is designed for the following operating conditions:

Quantity	Design	Min.	Max.
Flow Rate, lb/sec			
Temperature, °F			
Pressure, psia			

The velocity of the heat transfer oil through the extraction pump is _____ft/sec. which results in a pump size of ____ inches.

2.2.3.4.9 Thermal Storage System Instrumentation and Controls

The TSS control subsystem provides safe, stable, flexible control of the TSS in support of: (l) the plant steady state operating modes described in Section 1.0; (2) transitions between allowable combinations of plant steady state modes described in detail in OPDD Section 4; and (3) operations required in the event of emergencies as described in OPDD Section 5. In addition to the overall plant operations listed above, the TSS control subsystem provides controls under the following conditions:

(a) Normal Operations

1. Startup
   - (a) Initial startup of the TSS after construction
   - (b) Cold startup after many days shutdown
   - (c) Warm startup within a few days of previous operation
2. TSS Charging
   - (a) Steam Flow Control
   - (b) Steam Pressure Control
3. TSS Extraction
   - (a) Steam Flow Control
   - (b) Steam Pressure Control
4. Simultaneous TSS Charging/Extraction
5. TSS Shutdown/Standby
   - (a) Shutdown following charging
   - (b) Shutdown following extraction
   - (c) Hot standby
   - (d) Nighttime standby
   - (e) Idle standby

The TSS control subsystem provides for transitions between allowable combinations of the above in response to either manual command or command from the MCS. The control subsystem is capable of stand alone operation.

(b) Emergency Shutdown

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1. Failures external to the TSS which cause sudden, unacceptable changes in steam input and/or power output.
2. Loss of electrical power
3. Component failures within the TSS

2.2.3.4.10 Thermal Storage Heater Drain Tank

Steam condensed in the TSH is drained to a device within which the water level is actively controlled, and eventually to a flash tank.

2.3.3.4.10.1 through________

(The SFDI shall supply additional performance characteristics pertaining to: (1) fluid capacity; (2) fluid temperature; (3) pressure (design and operating); (4) corresponding steady state plant operating modes and transitions between modes for the above.)

2.2.3.4.11 Thermal Storage Heater Flash Tank

Condensate drained from the TSH drain tank is circulated to a flash tank which produces flash steam for feedwater heating and deaeration within the Electrical Power Generating System (EPGS). Excess steam is circulated to the condenser. The condensate is drained from the flash tank to the feedwater deaerator or condenser depending on the particular plant steady state operating mode.

2.2.3.4.11.1 through________

(The SFDI shall supply additional performance characteristics pertaining to: (1) tank capacity; (2) condensate and steam temperatures; (3) tank pressure (design and operating); (4) condensate/steam velocities; and (5) corresponding steady state plant operating modes and transitions between modes for the above.)

2.2.3.5 Design Environmental Conditions

Design environmental conditions, such as seismic, wind loads and rain are specified in Appendix C. All hardware

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is designed and packaged so that the conditions described in Appendix C do not induce a condition which exceeds the structural capability of the hardware. Components are designed for transportability within applicable Federal and State regulations for highway and railroad carriers using standard transport vehicles and materials handling equipment. To preclude fatigue by fluctuating wind loads, all structural components are designed such that induced stresses are below endurance limits specified in __________. Detailed operating environment design restrictions, such as electrical transients and electromagnetic radiation, are contained in the appropriate specifications listed under Applicable Documents for each major item of equipment.

2.2.3.6 Thermal Storage System Design Description

The TSS employs sensible heat storage using dual liquid and solid storage within the same tank (TSU). A sharp temperature differential (thermocline) is used in the TSU to provide a working fluid (heat transfer oil) of high temperature to obtain energy at constant extraction rate independent of the total energy stored.

The fluid streams crossing the boundaries of the TSS are shown in Figure _____. A schematic diagram showing all major equipment, lines, and control components in the TSS is shown in Figure______. Process flow conditions at various points in the TSS for the plant steady operating modes are shown in schematics in OPDD Section 4.

Major equipment items are designed, fabricated, and inspected in accordance with the documents cited under the description of each piece of equipment. Piping is designed, fabricated, and inspected in accordance with the American National Standard Code for Pressure Piping. All components are ASME code stamped where applicable.

2.2.3.6.1 Desuperheater

The purpose of the Desuperheater is to reduce the temperature of steam circulating from the RS to the TSS when it is being supplied at rated conditions of 950° and 1465 psia at the Desuperheater inlet. The Desuperheater provides steam for the TSH at a temperature no higher than 650°F to minimize degradation of the heat transfer oil. When steam at the inlet to the Desuperheater is below 650°F, the Desuperheater is inoperative. The Desuperheater is shown in Figure _____.

2.2.3.6.1.1 through________

(The SFDI shall provide additional design analysis, design description, and applicable documents for the Desuperheater.)

2.2.3.6.2 Thermal Storage Heater (TSH)

The TSH is used to transfer the thermal energy contained in incoming steam from the Desuperheater to the heat transfer oil which is stored in the TSU. The TSU functions over a wide range of fluid flow rates under repeated daily thermal cycling for the life of the plant. The TSH is designed to minimize: (1) corrosion; (2) erosion; (3) flow induced vibration of any of its parts; (4) decomposition of the heat transfer oil; and (5) degradation of the heat transfer oil. The TSH is shown in Figure _____. The TSH is designed, fabricated and inspected in accordance with the ASME Boiler and Pressure Vessel Code - Section VIII, Unfired Pressure Vessels.

2.2.3.6.2.1 through _____

(The SFDI shall provide additional design analysis and description of the TSH which shall include but not be limited to: (1) number of units; (2) capacity; (3) fluid flow configuration; (4) fluid flow inlet/outlet conditions; (5) number and sizes of tubes; (6) overall heat transfer coefficient; (7) heat transfer area; (8) shell diameter; (9) exchanger length; (10) type of tube pitch; (11) pitch/diameter ratio; (12) weight; (13 control equipment. These paragraphs shall list applicable documents.)

2.2.3.6.3 Thermal Storage Unit (TSU)

The TSU uses a sharp temperature differential (thermocline) to store both hot and cold storage media in a single tank.

The TSU is a single cylindrical tank, axis vertical, installed above ground. The tank is ____feet in diameter by ____feet high with a capacity of ____gallons. The tank is fabricated of ASTM _____ Grade_____ structural steel by field welded construction. Thermal insulation is used on the top and sides of the tank to minimize heat losses to the atmosphere. The TSU is shown in Figure _____.

The storage media consists of heat transfer oil and rock/ sand. The heat transfer oil is (to be specified by the SFDI as Caloria HT-43 or its equivalent determined on the basis of initial and replenishment cost over the life of the plant). The rock/sand mixture consists of one inch by No. 4 coarse aggregate with 6 mesh silica sand. The packed bed fraction is less than 0.3.

2.2.3.6.3.1 through _____

(The SFDI shall provide additional design analysis and description.)

2.2.3.6.4 Ullage Maintenance Unit (UMU)

The UMU provides a controlled pressure, oxygen free atmosphere (ullage) above the fluid level in the TSU. Oxygen is removed from this region to: (1) minimize fire hazards, and (2) minimize long term oxidation of the heat transfer oil. The ullage pressure is controlled within a specified band in order to prevent under- or overpressurization of the TSU as the oil is cooled or heated. The gaseous mass released from the ullage space during charging or hold of the TSU is replaced during extraction. The TSU ullage pressure is maintained between zero and _____ psig. A pressure below ambient is not permitted in order to prevent air/oxygen from entering the TSU. The UMU is shown in

Figure _____.

2.2.3.6.4.1 through _______

(The SFDI shall provide additional design analysis and description of the UMU which shall include but not be limited to: (1) type of inert gas used; (2) TSU pressure levels, tolerances, and limit values; (3) disposition of gaseous products evacuated from the TSU ullage; (4) equipment description and performance characteristics for hardware used to control over- and underpressurization of TSU; this item shall include power requirements, fluid flow conditions, storage volume capacities, sizing conditions, sizing, and inert gas makeup provisions. Applicable documents shall be listed in these paragraphs).

2.2.3.6.5 <u>Fluid Maintenance Unit (FMU)</u>

The FMU (1) removes polymerized material formed by pyrolysis, (2) removes suspended solid particles larger than 180 micrometers, and (3) provides fresh additions to the TSU heat transfer oil. The FMU does not permit contact of the heat transfer oil with air because of the potential for unacceptable oxidation at the higher temperature of the oil. The FMU is located at (to be specified by the SFDI) and a schematic of it is given in Figure _____.

2.2.3.6.5.1 through _______

(The SFDI shall provide additional design analysis and description of the FMU which shall include but not be limited to: (1) the equipment, associated power, fluid flow conditions, and physical description of hardware used to remove polymerized matter; (2) filter sizes and locations to remove suspended particulates; (3) disposition of waste material; (4) heat transfer oil considerations including degration rates, volatiles fraction formation, polymerized materials fraction accumulation and maximum permissible concentration in the oil; (5) heat transfer oil makeup provisions including daily processing amounts and duration).

2.2.3.6.6 Thermal Storage Heater Drain Tank

The TSH drain tank collects high temperature condensed steam from the TSH. Active controls are provided in order to maintain the water level within the drain tank. The drain tank is sized for a flow of ____ lb/hr and is designed, fabricated, and constructed in accordance with the ASME Boiler and Pressure Vessel Code-Section VIII Unfired Pressure Vessels. The drain tank is shown in Figure _____.

2.2.3.6.6.1 through ______

(The SFDI shall provide additional design analysis and description which shall include but not be limited to: (1) sizing conditions, and (2) tank sizing. Applicable documents shall be listed in these paragraphs.)

2.2.3.6.7 Thermal Storage Heater Flash Tank

The TSH flash tank accepts high temperature condensed steam from the drain tank and distributes flashed steam and condensate to components within the EPGS. Pressure within the flash tank is maintained at _____ psia maximum by a back pressure control valve in the steam outlet line. The flash tank is shown in Figure _____. The flash tank is designed, fabricated, and inspected in accordance with the ASME Boiler and Pressure Vessel Code-Section VIII Unfired Pressure Vessels.

2.2.3.6.7.1 through _____

(The SFDI shall provide additional design analysis and description which shall include but not be limited to: (1) sizing conditions, and (2) tank sizing. Applicable documents shall be listed in these paragraphs.)

2.2.3.6.8 Thermal Storage Steam Generator

The Thermal Storage Steam Generator uses heat extracted from the TSU by the heat transfer oil to convert water into steam for use by the EPGS. The steam generator operates over a range of flow rates for the feedwater/steam and heat transfer oil. The inlet and outlet conditions of both fluids are closely maintained to meet turbine inlet steam conditions and pinch point limitations within the steam generator.

The steam generator provides turbine admission steam to permit plant operation at 7 MWe net to the utility grid. In addition, the steam generator provides steam for plant nighttime standby for: (1) EPGS deaerator shell blanketing; (2) EPGS deaerator pressure pegging; and (3) RS freeze protection. The steam generator is itself designed to be maintained in a hot standby condition during normal turbine operation to minimize possible diurnal solar transient effects on the turbine. The steam generator is designed to minimize; (1) corrosion; (2) erosion; (3) flow induced vibration of any of its parts; (4) decomposition of the heat transfer oil; and (5) degradation of the heat transfer oil. The steam generator is shown in Figure ____. Design, fabrication, and inspection of the steam generator is in accordance with the ASME Boiler and Pressure Vessel Code-Section VIII Unfired Pressure Vessels.

2.2.3.6.8.1 through ______

(The SFDI shall provide additional design analysis and description of the steam generator which shall include but not be limited to: (1) number of units; (2) capacity; (3) fluid flow configurations; (4) fluid flow inlet/outlet conditions; (5) number and sizes of tubes; (6) overall heat transfer coefficients; (7) heat transfer area; (8) shell diameter; (9) exchanger length; (10) type of tube pitch; (11) pitch/diameter ratio; (12) weight; (13) control equipment. Applicable documents shall be listed in these paragraphs.)

2.2.3.6.9 Charging Loop

The TSS charging loop consists of pumps, motors, piping, and controls required to circulate the elevated temperature heat transfer oil between the Thermal Storage Heater and the TSU.

Two redundant charging pumps are located ______ (to be specified by the SFDI). Each pump is capable of handling heat transfer oil at a maximum flow rate of _____ lb/s at a temperature of 601°F and a peak power consumption of _____ hp. Each pump is driven by a dual speed electric motor.

The characteristics of each charging pump are as follows:

Type	Centrifugal
Capacity	_____ gpm
Inlet Pressure	_____ psia
Developed Head	_____ ft
Drive Motor	_____ hp
Full-Load Rotation	_____ rpm
Efficiency	_____ %
Brake Horsepower	_____ hp

A charging loop schematic is shown in Figure _____ (to be provided by the SFDI).

2.2.3.6.9.1 through _____

(The SFDI shall provide additional design analysis and description for the complete charging loop. Applicable documents shall be listed in these paragraphs.)

2.2.3.6.10 Extraction Loop

The TSS extraction loop consists of pumps, motors, piping, and controls required to circulate the elevated temperature heat transfer oil between the TSU and the Steam Generator. In addition, an auxiliary pumping subsystem is provided to extract lower temperature heat transfer oil from the TSU to make turbine seal steam during nighttime standby of the turbine-generator.

Two redundant extraction pumps which handle the elevated temperature heat transfer oil are located ________(to be specified by the SFDI). Each pump is capable of handling heat transfer oil at a maximum flow rate of _____lb/s, at a temperature of 601°F, and a peak power consumption of ______hp. Each pump is driven by a single speed electric motor.

The characteristics of each extraction pump are as follows:

Type	Centrifugal
Capacity	______gpm
Inlet Pressure	______psia
Developed Head	______ft
Drive Motor	______hp
Rotation	______rpm
Efficiency	______%
Brake Horsepower	______hp

The auxiliary pump (for producing turbine seal steam) characteristics are as follows:

Type	
Capacity	______gpm
Inlet Pressure	______psia
Developed Head	______ft
Drive Motor	______hp
Rotation	______rpm
Efficiency	______%
Brake Horsepower	______hp

A charging loop schematic is shown in Figure ______.

2.2.3.6.10.1 through________

(The SFDI shall provide additional design analysis and description for the complete extraction loop and auxiliary pumping equipment used to produce turbine seal steam during nighttime standby. Applicable documents shall be listed in these paragraphs.)

2.2.3.6.11 Thermal Storage System Instrumentation and Controls

The overall instrumentation and controls subassemblies include: (1) data sensors; (2) control electronics; (3) a flow distribution network comprised of flowmeters, flow control valves, and stop-check valves; and (4) components within the UMU and FMU which are independent of the TSU charging and extraction loops.

The Thermal Storage Unit Controller is the major assembly which provides control for the: (1) charging loop; (2) extraction loop; and (3) Desuperheater.

Charging loop controls maintain the temperature of the heat transfer oil at the exit of the TSH at the nominal set point value of 580°F. Constant oil temperature is maintained by means of modulating flow control valves used in conjunction with the charging pumps. Additional measurements of TSH steam and heat transfer oil temperature, pressure and flow rate are obtained to provide the charging controller with data on incoming energy to the TSH and proper pump operation.

Extraction loop controls provide for the automatic response of the TSU extraction loop to variations in demand for admission steam to operate the turbine. Nominal steam conditions at the exit of the steam generator are 530°F and 400 psia at a maximum flow rate of______lb/hr. Measurements of incoming heat transfer oil and exiting steam temperature, pressure, and flow rate are provided to the extraction controller to maintain the correct oil and steam flow rates.

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Desuperheater controls maintain the steam at the Desuperheater outlet at 650°F. The controls regulate the mixing of incoming steam from the RS at 950°F and variable pressure with feedwater from the RS feedwater pumps. Incoming steam conditions are measured and transmitted to a controls computer which determines the incoming steam thermal energy and corresponding feedwater flow rate to achieve a steam condition of 650°F at the Desuperheater outlet.

Further details on the plant operating modes supported by the TSS and the corresponding set points for the controls subassemblies are given in OPDD Sections 3 and 4. A schematic showing the arrangement of the TSS instrumentation and controls is given in Figure _____. The valves shown in Figure______and their related functions are summarized in ______. Detailed component characteristics are given in individual specifications.

2.2.3.6.11.1 through______

(The SFDI shall provide additional design analysis and description of the TSS Instrumentation and Controls.)

2.2.4 Beam Characterization Subsystem (BCS)

(This section to be provided by SFDI)

2.3 ELECTRICAL POWER GENERATING SYSTEM

(To be provided by SCE)

2.4 COMMON BENEFIT FACILITIES

The Common Benefit Facilities consist of the Master Control Subsystem (MCS) and the Plant Support Subsystems (PSS). The characteristics of these equipments, designed and provided in accordance with the requirements of OPDD Section 1, are described in the following sections.

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2.4.1 Master Control System

The Master Control System (MCS) is a computerized supervisory system which responds to operator or automatic direction to provide integrated Plant control. The MCS controls the function of Plant start-up, shutdown, load following, mode changes, and emergency actions.

2.4.1.1 General System Description

The MCS consists of plant supervisory controls, data acquisition hardware, three separate Central Processing Units (CPU's), data displays, tape storage and the control consoles. A simplified block diagram of the basic MCS configuration is shown in Figure 2-17. There are three major subsystems: the Operational Control Subsystem (OCS), the Data Acquisition Subsystem (DAS) and the Peripheral Control Subsystem (PCS). Each subsystem has its own CPU and associated software. The purpose of the MCS is to integrate the independent controls of the CS, RS, TSS, and EPGS. Features of the MCS include:

- Provision of additional CPU capabilities to include off-line software development and data reduction enhancement, without disturbance to control and DAS capabilities
- Backup of operational control capabilities
- Single MCS operational interface at an MCS control board for plant control
- MCS operator interfaces achievable via conversational software languages
- In the event of MCS failure, control of each subsystem remains "status quo" or "as otherwise predetermined".

Separate and functionally-independent lines are used for control and for alarm circuits. Protective functions use separate inputs from those for the subsystem process control, and may act automatically to assure a "fail-safe" condition.

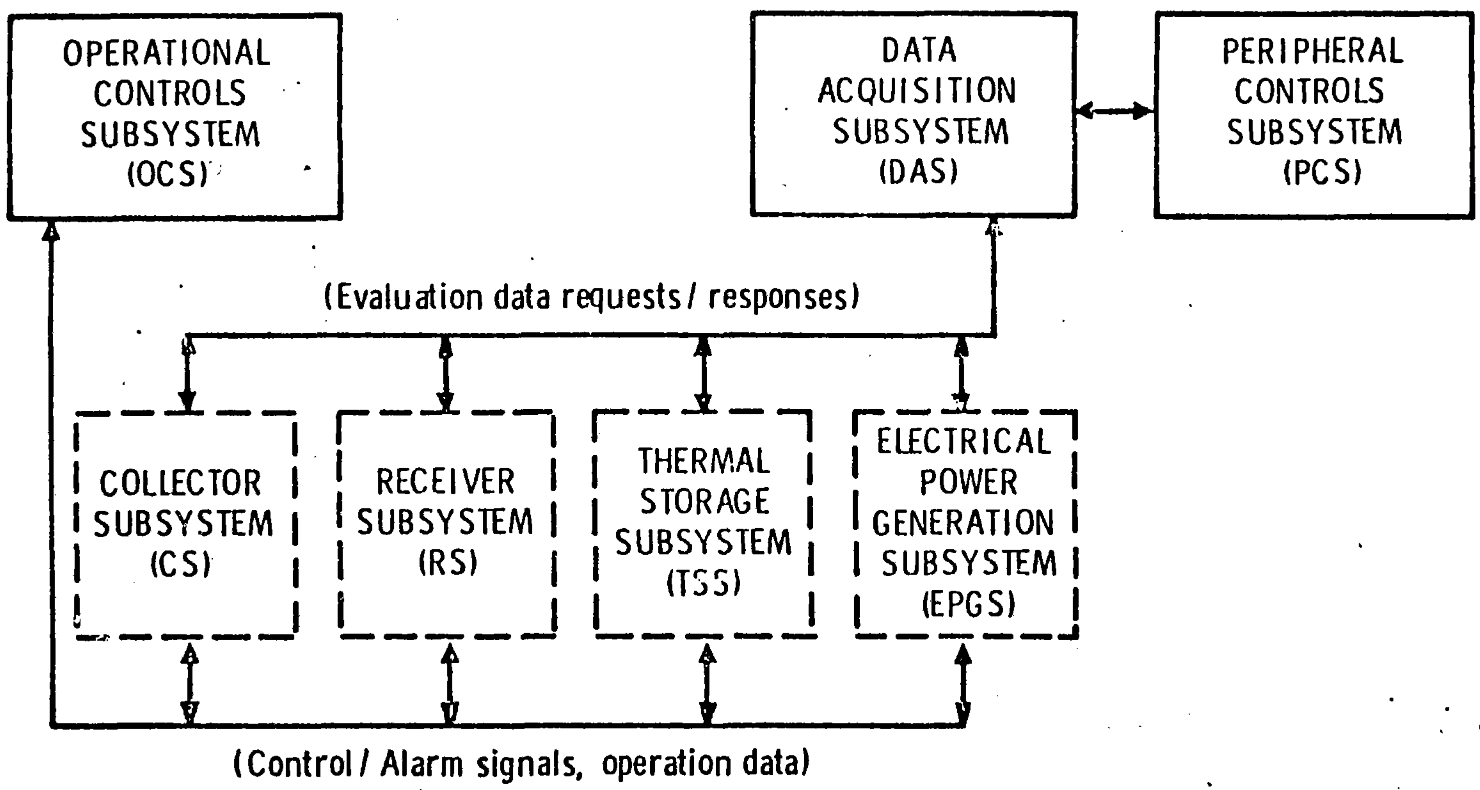

Figure 2-17 Simplified MCS Concept

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2.4.1.1.1 Operation

The CS, RS, TSS and EPGS each has a distinct console separate from the MCS consoles although all are located in the same control center. All are independent and capable of independently performing all operational functions for the respective systems under manual direction. The MCS adds an automatic or non-manual operating capability by virtue of the OCS.

In the manual mode of operation, the MCS is not required. The operator manipulates the systems in the most logical sequence he can determine. Control will automatically revert to manual in the event of an OCS failure.

2.4.1.1.2 Major Interfaces

Supervisory control is provided by the OCS with a single console which interfaces with both plant and other MCS subsystems as shown in Figure 2-18. The OCS is able to operate without the DAS or the PCS. As such it has an interface with the CS, RS, TSS and EPGS for data acquisition. Additional interfaces are required to obtain grid demand and weather data.

Within the MCS, control over evaluation data is provided by the DAS which has its own interfaces to each Plant subsystem and MCS subsystem. The DAS is able to function without the OCS or PCS in its role of data acquisition and storage. The DAS and PCS together are able to function without the OCS in the role of data requests and displays. The DAS requires an interface with weather data independent of the OCS.

The PCS serves as a controller for the evaluation displays, as a software development computer, and as an on-site simulation computer. In the event of an OCS failure, the PCS computer can be used as back-up, utilizing the OCS operator console. It has no direct interfaces outside the MCS.

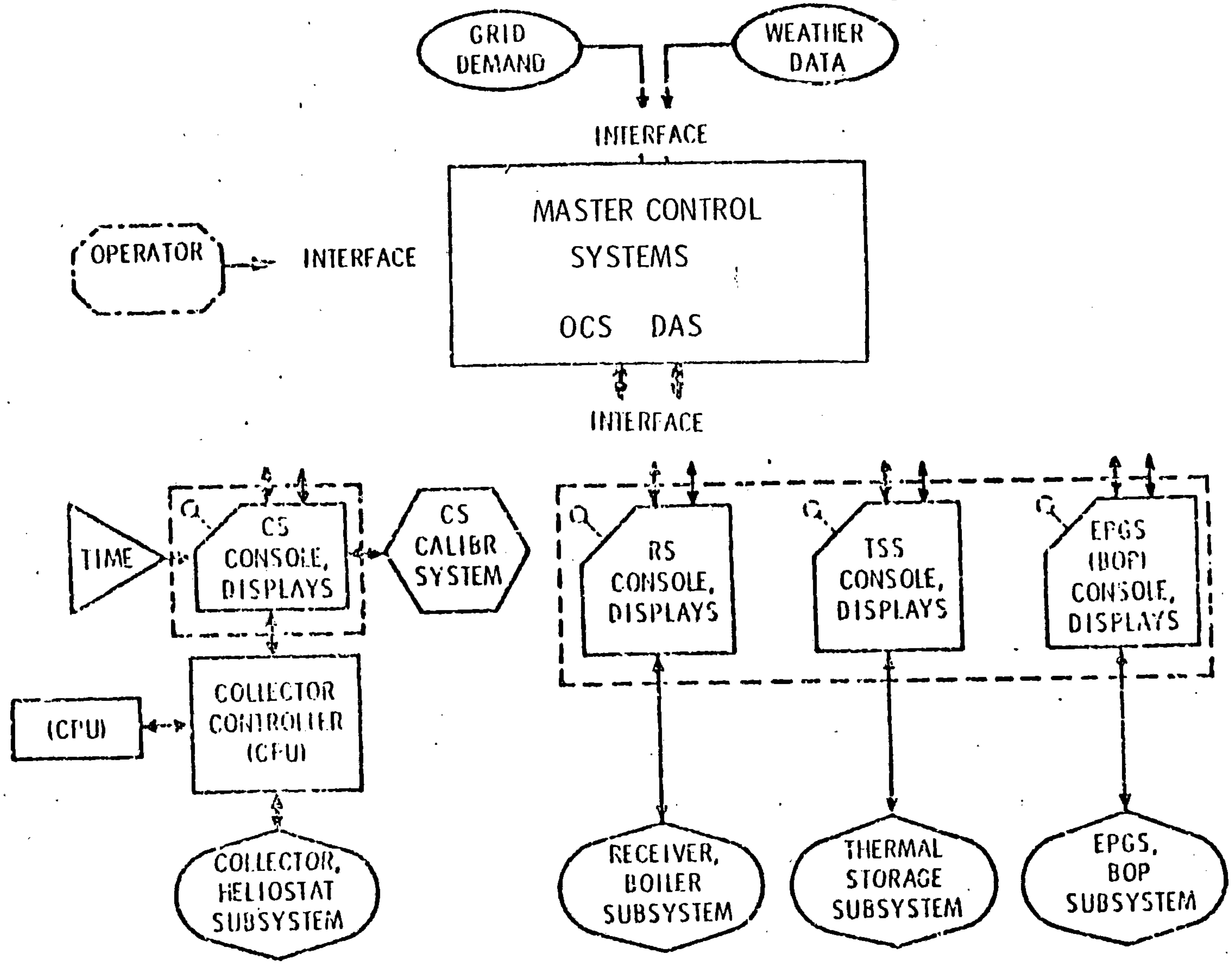


Figure 2-18 Master Control System Major Interfaces

The data crossing each of the Plant system interfaces are of two generic types. These include three sets of interface signals for Plant operation and two sets for subsystem and overall system performance evaluation, as follows:

Operational Interface Signals

Control Commands

Operational Data Requests

Operational/Alarm Data Outputs

Evaluation Interface Signals

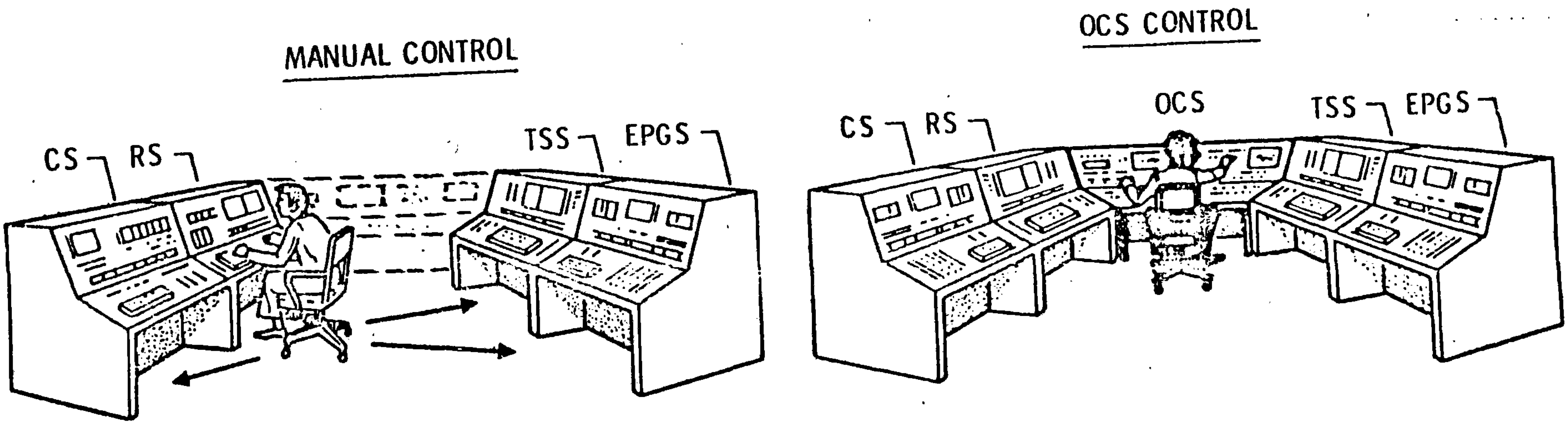
Evaluation Data Requests

Evaluation Data Outputs

Each of these sets of signals is further designated as either continuous (i.e., automatically generated at regular preprogrammed intervals) or on-demand by an operator (i.e., issued upon request or over selectable intervals). Examples of specific Plant subsystem interface signals corresponding to these sets and subsets are contained in Appendix ____. Individual signals are independent of each other except as request/-response combinations.

2.4.1.2 Master Control System Arrangement

All necessary operational control for the Solar Pilot Plant is centralized in a single control room arranged in a configuration to duplicate, as much as practical, the anticipated commercial plant equipment layout. The operational control area in the control room is envisaged as that area within which a single seated control operator will operate the plant with respect to a plant control console which surrounds him. The overall Plant Control Console consists of five sections: a central OCS control section and four subsystem control sections. The OCS operator's console contains alphanumeric key boards for data and computer communication; function selection switches and push buttons; color CRT displays; peripheral controls as appropriate; hard copy printers; and other equipment necessary to perform OCS functions. The physical arrangement is shown in Figure 2-19



- NO MCS REQUIRED
  - CASCADE CONTROL ONLY
  - OPERATOR COORDINATES SUBSYSTEMS
- OPERATOR UTILIZATION
  - BY OPERATOR CHOICE, OR
  - DURING MCS FAILURE

- OCS CONTROL MANAGEMENT & SUPERVISION
  - COORDINATED & CASCADE CONTROL
  - OCS COORDINATES SUBSYSTEMS
- OPERATOR UTILIZATION
  - MONITORS OCS AUTOMATIC CONTROL OF PLANT, OR
  - MANUALLY CONTROLS PLANT USING OCS CONSOLE

Figure 2-19 MCS Control Console Arrangement which includes a summary of how the consoles are utilized in automatic and manual modes of plant operation. The functional arrangement of major hardware elements within the MCS is shown in Figure 2-20.

2.4.1.3 Master Control System Performance Characteristics

The primary requirements imposed on the MCS are simplicity, reliability and cost effectiveness in both design and operation. These are achieved by use of standard control practices, a single operational console, use of off-the-shelf equipment designs, separation of OCS from DAS/PCS functions, a flexible set of operating modes, and incorporation of a capability for plant operation independent of the MCS. For purposes of discussion, performance requirements are divided into three categories: Functional, Operating, and Availability. Detailed numerical performance requirements are contained in the MCS Performance Specification____________.

2.4.1.3.1 Functional Features

Major functional performance characteristics of the MCS are as follows:

a. Primary operation is fully automatic with operator override capability

b. Flexible computer operating set-point control

c. Operating and evaluation data acquisition capabilities both on demand and continuous

d. Separation between control and evaluation (DAS) capabilities

e. Utilization of generally similar, interchangeable units for all MCS and CS computer functions.

f. In the event of MCS failure, control of each subsystem must allow safe operation.

g. Single console control during both automatic and manual operations.

h. Elimination of single point failures through redundant elements wherever it is cost effective.

i. Multiple analog data channels connected to a single high speed digital channel.

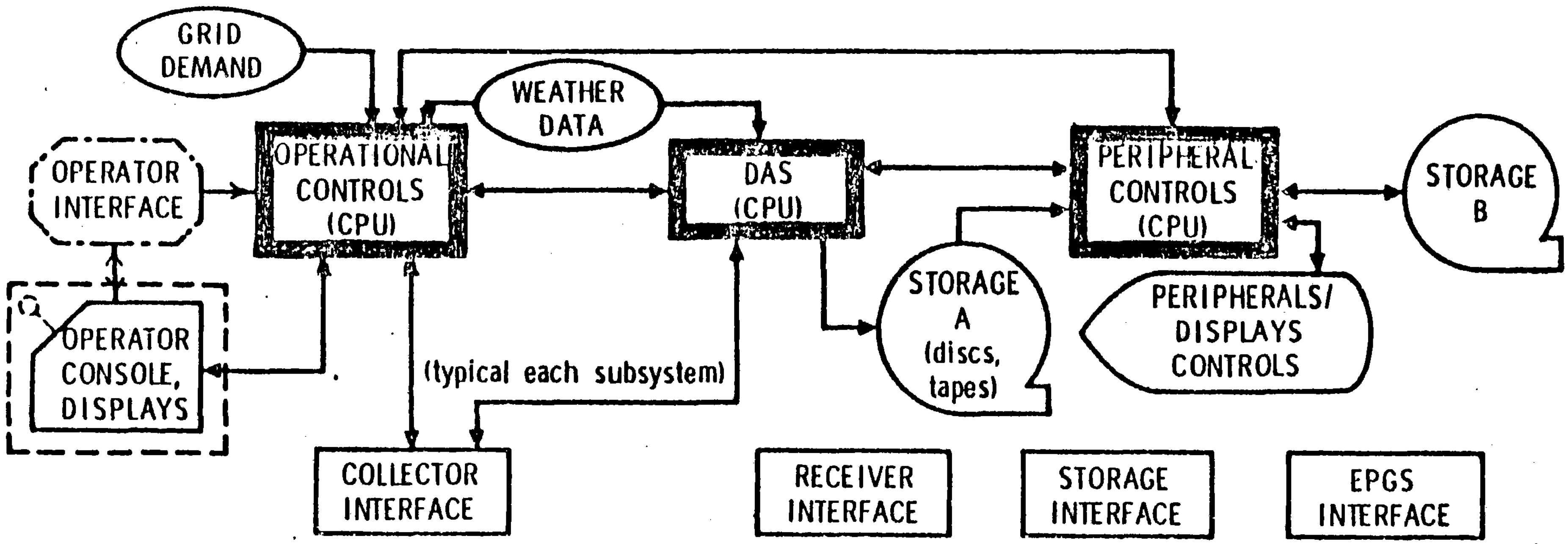


Figure 2-20 MCS Functional Arrangement

2.4.1.3.2 Operating Features

Major operating performance characteristics of the MCS are as follows:

a. Operational alerts or alarms of Plant or significant subsystem upset conditions.

b. Automatic safety or protective actions prudently isolated from system control.

c. Separation of Plant operational controls from DAS and evaluation peripheral controls.

d. Failure of the MCS must not prevent normal operation of the plant.

e. Provision for operation in three modes: fully automatic, fully manual, and manual operation using the OCS console.

2.4.1.3.3 Availability

The availability of the MCS is a direct result of the overall plant availability requirement which is______. This level of availability is achieved through a combination of modularity and interchangeability of components, redundancy and scheduled maintenance activities.

2.4.1.4 Design Environmental Conditions

All MCS equipment is designed to survive the offsite environmental conditions defined in the appropriate subsystem specifications. Onsite environmental conditions are defined in Appendix C.

2.4.1.5 Master Control System Design Description

The MCS consists of three major subsystems, the OCS, DAS and PCS. The DAS is provided in the Pilot Plant for engineering evaluation of operations and would not be a part of the planned commercial size plant. The overall Plant control system provides three modes of control: Fully automatic, Manual, and OCS-manual. The system can perform start-up and shutdown procedures in any of the control modes. It is also capable of transitioning the plant operation from start-up to any of the steady state plant operating mode described in OPDD Section 4; from any of these to shutdown; from any steady state mode to any other; and from any condition to emergency shutdown. The roles of different MCS subsystems are described in the following paragraphs both in an overall perspective and with respect to the individual CS, BCS, RS, TSS and EPGS systems.

2.4.1.5.1 Operational Control Subsystem (OCS)

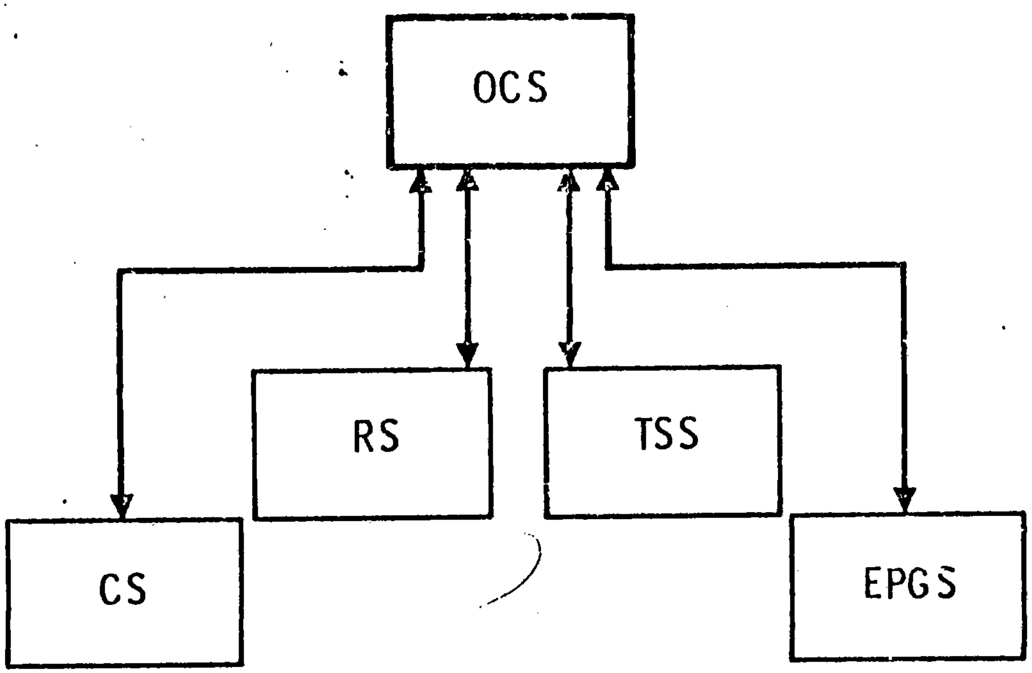
The relationship of the OCS to the CS, RS, TSS and EPGS is shown in Figure 2-21. A summary of the major control functions of the OCS is also shown. In the coordinated control mode, the OCS is automatically supervising Pilot Plant operation according to pre-programmed instructions.

The OCS is capable of generating continuous (i.e., either discrete or over selectable intervals) commands in order to accomplish the modes, mode transitions, or emergency control. The capability is also provided to issue on-deman data requests. Responses to commands and data requests are transmitted back to the OCS console. As with the continuous data and commands, responses will be such as to provide visual and/or printed indication of all sensing devices which are on-line changeable by the operator.

2.4.1.5.2 Data Acquisition Subsystem (DAS)

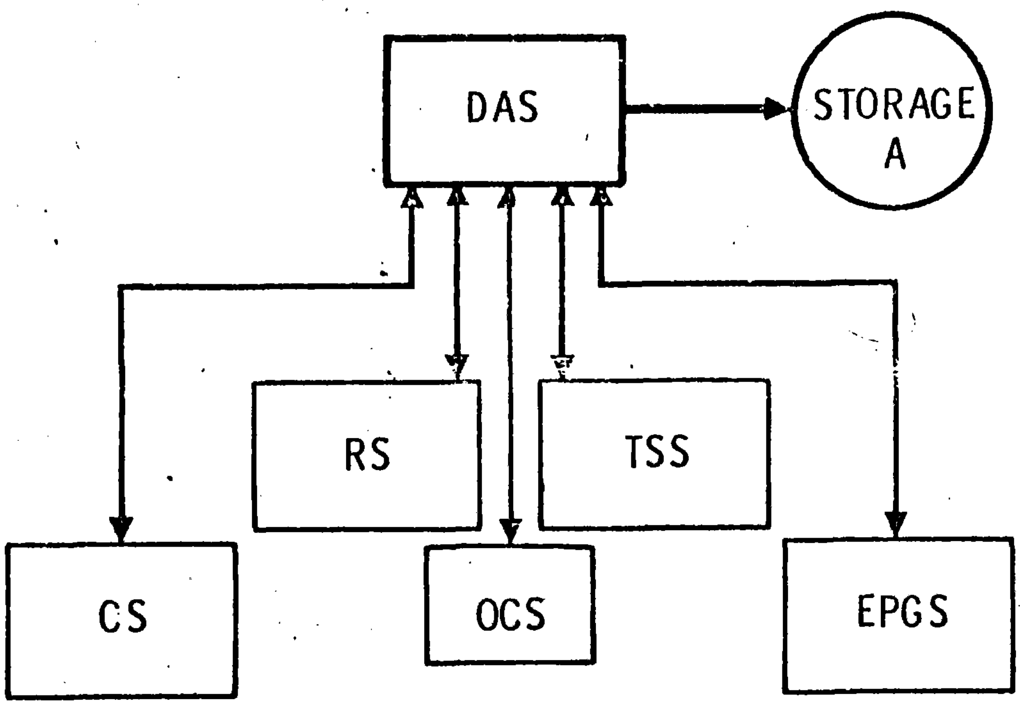
The relationship of the DAS to the OCS as well as CS, RS, TSS and EPGS plant systems is shown in Figure 2-22. Major functions of the DAS as an MCS subsystem are also given. The DAS is capable of requesting, receiving, processing and storing engineering data for evaluation of Pilot Plant operation.

The DAS capability provides for both continuous and on-demand (priority) requests for selected engineering data to evaluate subsystems and/or overall Pilot Plant performance corresponding to any of the operational modes or mode transitions defined in OPDD Section 4. Responses to data requests are transmitted back to the DAS CPU for processing and storage. Examples of the data requests and corresponding responses



- OCS
  - MANAGES & SUPERVISES PLANT AND SUBSYSTEMS
  - COORDINATES ALL SUBSYSTEMS
  - CARRIES OUT PRE-DETERMINED CONTROL STRATEGIES (i.e., mode control)
  - COMPUTES / STORES SUBSYSTEM AND TOTAL PLANT PERFORMANCE
  - DISPLAYS PLANT STATUS, ALARMS & ABNORMALITIES
- SEPARATE LINES TO & FROM EACH SUBSYSTEM
  - NO CROSS-TALK BETWEEN SUBSYSTEMS
- REQUIRED OPERATIONAL DATA COLLECTED BY OCS DIRECTLY

Figure 2-21 Operational Control System.



- DAS MAIN PURPOSE
  - CREATE ARCHIVAL DATA FILES IN STORAGE A FOR ALL ANALYSIS & EVALUATION
    - OFF-SITE
    - ON-SITE
- COLLECT & RECORD ALL PLANT & SUBSYSTEM DATA (including OCS)
  - EVALUATION
  - CONTROL
  - ALARM
  - ENVIRONMENT
- SATISFIES ENGINEERING EVALUATION REQUIREMENTS
  - NOT ORIENTED FOR OPERATION NEEDS
- PERFORMS MINIMAL DATA MANIPULATION
  - CONVERSION AND FORMATTING FOR 3 DATA TYPES (raw, on-site PCS displays, off-site analysis)
- SEPARATE LINE TO EACH SUBSYSTEM (no cross-talk)

Figure 2-22 Data Acquisition Subsystem

pertaining to each interface are contained in Appendix______. With the exception of request/response combinations, all such data are independent of each other.

The DAS processing capability also includes scanning of input signals, converting the signals as necessary into digital data, formatting for appropriate storage, and sending the resulting data into read-write storage for subsequent evaluation.

2.4.1.5.3 Peripheral Control System (PCS)

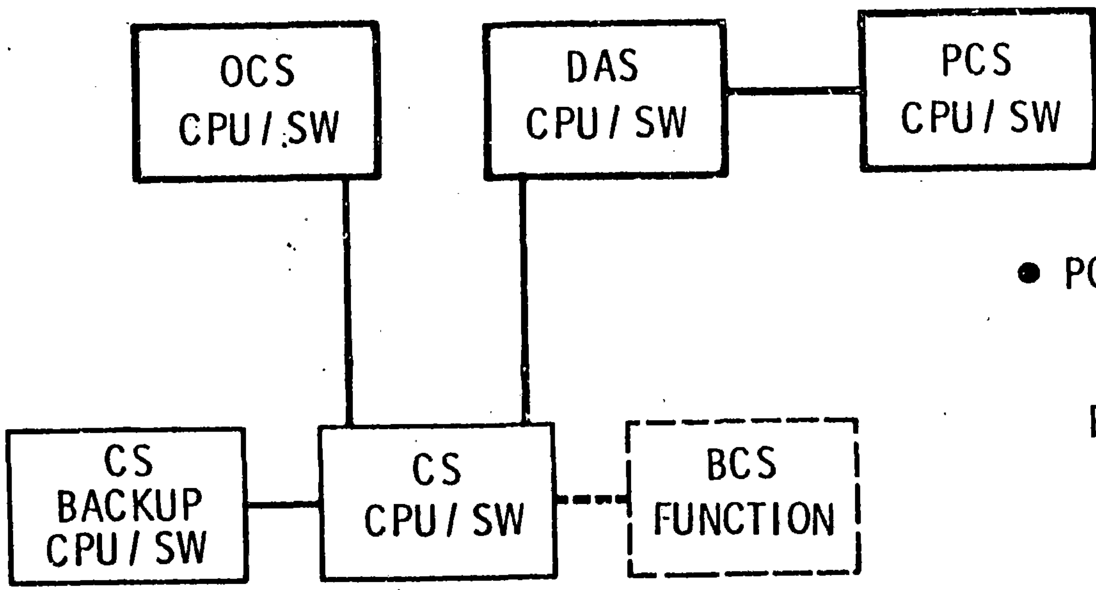
The PCS is a multi-purpose MCS subsystem capable of driving the engineering displays, use as a software development aid, and Pilot Plant control simulation exercises. The PCS CPU can also perform as a back-up to the OCS CPU. In case of an OCS CPU failure, a manual switch to the PCS CPU is possible without affecting the DAS operation.

The primary mode of the PCS is driving the engineering displays for purposes of real-time or subsequent evaluation of the subsystems or Pilot Plant. In this mode, the PCS is capable of reading data from DAS storage, processing the data for special-purpose displays, and displaying selected critical variables on either a CRT or hard copy printers.

The PCS provides a programming mode for on-site development of MCS or CS software. Capability to make MCS and CS operational software improvements is provided entirely on-site without impact to the real-time plant controls. The relationship of the PCS to other MCS subsystems when used for software development, is shown in Figure 2-23.

A third mode is provided in the PCS to accept and exercise a digital simulation of the subsystem controls. This mode is intended for use during MCS on-site checkout and for usage during integration of the Pilot Plant.

(Subsequent detailed sections to be provided by SFDI)



- PCS USED FOR ALL ON-SITE SOFTWARE (SW) DEVELOPMENT & MAINTENANCE OF ALL PILOT-PLANT COMPUTERS
  - OCS
  - DAS
  - PCS
  - CS

- COMMONALITY REQUIRED AMONG COMPUTERS

Figure 2-23 PCS as Used for Software Development

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2.4.2 <u>Plant Support Subsystems (PSS)</u>

(to be provided by SFDI)

2.5 <u>Facility Services</u>

(to be provided by SFDI)

SECTION 3

SECTION 4

SECTION 5

SECTION 6

APPENDIX A

APPENDIX A

CODES AND STANDARDS

The following listing enumerates portions of codes and standards that are to be applied in the design and construction of the 10-MWe Solar Pilot Plant. This list is provided as a convenience for the reader; the omission of a code, standard, or specification, or of a portion of one of these, is not necessarily to be construed as nonapplicability.

A.1 OSHA TITLE 29 PART 1910 – OCCUPATIONAL SAFETY AND HEALTH STANDARDS

Subpart	Applicable Section and Reference
A	General – All Sections
B	Adoption and Extension of Established Federal Standards – 1910.11, 1910.12, 1910.17, and 1910.18.
D	Walking – Working Surface – 1910.21, 1910.22, 1910.23, 1910.24, 1910.25, 1910.26, 1910.27, 1910.28, 1910.29, and 1910.31.
E	Means of Egress – 1910.35, 1910.36, 1910.37, and 1910.39.
F	Powered Platforms, Manlifts, and Vehicle-Mounted Work Platforms – 1910.66, 1910.67, and 1910.69.
G	Occupational Health and Evironment Control – 1910.94, 1910.95, and 1910.99.
H	Hazardous Materials – 1910.101, 1910.102, 1910.104, 1910.106, 1910.107, 1910.110, and 1910.115.
L	Fire Protection – 1910.156, 1910.157, 1910.158, 1910.159, 1910.160, 1910.161, 1910.163, and 1910.165a.
M	Compressed Gas and Compressed Air Equipment – 1910.166, 1910.167, 1910.168, and 1910.170.
N	Materials Handling and Storage – 1910.176, 1910.178, 1910.179, 1910.180, 1910.184, and 1910.189.

O	Machinery and Machine Guarding — 1910.211, 1910.212, 1910.215, 1910.219, and 1910.221.
S	Electrical — All Sections Applicable 1910.308 and 1910.309.
Z	Toxic and Hazardous Substances — 1910.1000.

A.2 OSHA TITLE 29 PART 1926 — SAFETY AND HEALTH REGULATIONS FOR CONSTRUCTION

Subpart	Applicable Section and Reference
A	General — All Sections.
B	General Interpretations — 1926.10, 1926.13, 1926.14, 1926.15, and 1926.16.
C	General Safety and Health Provisions — 1926.20, 1926.27, 1926.28, 1926.31, and 1926.32.
D	Occupational Health and Environmental Controls — 1926.52, 1926.53, 1926.57, and 1926.58.
F	Fire Protection and Prevention — 1926.150, 1926.151, 1926.152, 1926.153, 1926.154, and 1926.155.
	Signs, Signals, and Barricades — 1926.200, 1926.202, and 1926.203.
H	Materials Handling, Storage, Use, and Disposal — 1926.250 and 1926.251.
I	Tools (hand and power) — 1926.300 and 1926.305.
K	Electrical — 1926.400, 1926.401, 1926.402, 1926.403, 1926.404, and 1926.405.
L	Ladders and Scaffolding — 1926.450, 1926.451, and 1926.452.
M	Floors and Wall Openings, and Stairways — 1926.500, 1926.501, and 1926.502.
N	Cranes, Derricks, Hoists, Elevators, and Conveyors — 1926.550, 1926.552, and 1926.554.
P	Excavations, Trenching and Shoring — 1926.650, 1926.651, 1926.652, and 1926.653.

Q Concrete, Concrete Forms, and Shoring — 1926.700, 1926.701, and 1926.702.

R Steel Erection — 1926.750 and 1926.751.

V Power Transmission and Distribution — 1926.950, 1926.951, 1926.952, 1926.954, and 1926.960.

X Effective Dates — 1926.1050.

A.3 CALIFORNIA ADMINISTRATIVE CODE (CAL/OSHA)

A.3.1 OSHA Standards Adopted

Some OSHA Standards were adopted by the California Standards Board as standards under the code. The applicable standards adopted with the section referenced to Title 8 of California Administrative Code are as follows:

OSHA Ref	General Industry Standards	Title 8 Ref
1910.97	Non-Ionizing Radiation	6001
1910.145	Spec. for Accident Prevention — Signs and Tags	6003
	Construction Standards	
1926.54	Non-Ionizing Radiation	1801
1926.151	Fire Prevention	1803
1926.351	Arc Welding and Cutting	1804
1926.352	Fire Prevention	1805
1926.553	Base-Mounted Drum Hoists	1806
1926.554	Overhead Hoists	1807
1926.555	Conveyers	1808
1926.752	Bolting, Riveting, Fitting-Up, and Plumbing	1810
1926.802	Coffer Dams	1811

A.3.2 California Standards

The following subchapters (safety orders) of Title 8, California Administrative Code, Chapter 4, are applicable. Note: In the event of conflict between applicable portions of Title 8 of the California Administrative Code and Federal OSHA regulations, the more restrictive of the two shall apply.

Subchapter	Applicable Sections and Reference
1	Unfired Pressure Vessel — Articles 1-4 and 7.
2	Boiler and Fired Pressure Vessel — Articles 1-7.
4	Construction — Articles 1-12, 14-30, 32-36, and Appendices.
5	Electrical
Group 1	Low-voltage Electrical Safety Orders — Articles 1-51, 55-63, 74, 75, 77, and 80-82.
Group 2	High-voltage Electrical Safety Orders — Articles 50-86.
6	Elevator — Articles 1-12 and 15-18.
7	General Industry — Articles 1-18.
Group 1	General Physical Conditions and Structures — Articles 1-6.
Group 2	Safe Practices and Personal Protection — Articles 7-11.
Group 4	General Mobile Equipment and Auxiliaries — Articles 23-27.
Group 6	Power Transmission Equipment, Prime Movers, Machine Parts — Articles 37, 41, 43, 44, 45, 46, and 47.
Group 9	Compressed Gas and Air Equipment — Articles 76-79.
Group 10	Gas Systems for Welding and Cutting — Articles 80-88.
Group 11	Electric Resistance Welding — Article 90.
Group 13	Cranes and Other Hoisting Equipment — Articles 91-101.
Group 15	Noise Control Safety Order — Article 105.
Group 16	Control of Hazardous Substances — Articles 107-112.
Group 18	Explosives and Fireworks — Articles 113-116, and 120.
Group 20	Flammable Liquids, Gases and Vapors — Articles 134-142, 145, and 146.
Group 25	Federal Regulations — Articles 150 and 151.
Group 27	Fire Protection — Articles 156-163.

15 Petroleum-Refining Transportation and Handling — Articles 1-23.

21 Telecommunications Safety — Article 1.

A.4 ASME BOILER AND PRESSURE VESSEL CODE

A.4.1 General

The applicable sections of the ASME Boiler and Pressure Vessel Code are as follows:

Section I, Rules for Construction of Power Boilers

Section II, Materials Specifications

Section V, Nondestructive Examination

Section VIII, Unfired Pressure Vessels

Section IX, Welding and Brazing Qualifications

A.4.2 Section Applicability

A.4.2.1 Section I — Power Boilers

This is the base code for Boilers and Coolers where steam vapor is either generated or otherwise evolved. The solar central power steam generating components shall be code stamped with the applicable Section I code stamp. In many cases Section I does not provide adequate guidance for methods of analysis to evaluate stresses, creep, or fatigue, local effects, and inelastic phenomena. Additional criteria as to calculational methods and construction details are to be utilized from the applicable sections of ANSI B31.1; Section VIII, Divisions 1 and 2, and ASME Code Case N-47 (1592), as described below.

Pressure parts of the boiler which lend themselves to piping flexibility analysis should be designed to the rules of ANSI B31.1. Valves shall meet the requirements of ANSI B16.5 and/or ANSI B16.34. All other pressure parts should be analyzed to the rules of Section VIII.

Where a creep environment exists, the deformation controlled stress limits shall be in conformance with the rules of Code Case N-47 (1592). Caution should be exercised in the use of Code Case N-47 piping rules if the stresses are computed using the ANSI B31.1 procedures because the stress intensification factors for piping analysis are different. For piping products not standardized in B31.1 piping analyses, the stress intensification factor $i = C_2K_2/2$, where C_2 and K_2 are stress indices for N-47 piping analysis.

A.4.2.2 Section VII – Pressure Vessels

This is the base code for pressure vessel design not covered by Section I. Pressure vessels shall be code stamped with the applicable Section VIII stamp. Where a creep-fatigue environment exists or where guidance is not otherwise provided, the additional criteria for strain and deformation stresses from the rules of Code Case N-47 (1592) may be utilized.

A.4.2.3 Code Case N-47 (1592) – Class I Components in Elevated Temperature Service

This code is applicable to Class I Nuclear components in high-temperature service. Since this Code Case provides rules for strain and deformation criteria above 800°F, it shall be used to supplement the rules of Section I and Section VIII as previously discussed.

A.4.2.4 ANSI B31.1 – Power Piping

The Power Piping Code is referenced from Section I for Boiler External Piping for materials, design, fabrication, installation, and testing. It also provides guidance for flexibility analysis of internal boiler piping. This Code references other ANSI Documents such as ANSI B16.5 (Steel Pipe Flanges and Flanged Fittings) and ANSI B16.34 (Steel Butt-Welding End Valves).

A.4.2.5 All code compliance stress analyses shall be documented in a stress report.

A.5 NATIONAL CONSENSUS STANDARDS

The two major sources of National Consensus Standards recognized by Congressional action (OSHA Safety and Health Standards, Title 29-CFR 1910) are the National Fire Protection Association (NFPA) and the American National Standards Institute (ANSI). The standards listed are provided as guideline references to be used for individual system applications and do not constitute all of the standards which may be applicable to specific pilot plant designs.

A.5.1 National Fire Protection Association (NFPA) National Fire Codes – 1975

Volume 1

NFPA (10-74)	Portable Fire Extinguishers
NFPA (13-74)	Sprinkler Systems, Installation

Volume 2

NFPA (15-73)	Water Spray Fixed Systems
NFPA (19-73)	Automotive Fire Apparatus
NFPA (194-74)	Fire Hose Connections

Volume 3

NFPA (30-73)	Flammable and Combustible Liquids Code
NFPA (321-73)	Classification of Flammable Liquids
NFPA (43A-74)	Liquid and Solid Oxidizing Materials

Volume 4

NFPA (50A-73)	Gaseous Hydrogen Systems
NFPA (50B-73)	Liquified Hydrogen Systems
NFPA (54-74)	Cutting and Welding Processes

Volume 5

NFPA (69-73)	Explosion Prevention Systems

Volume 6

NFPA (70-75)	National Electrical Code

Volume 7

NFPA (71-74)	Central Station Signaling Systems
NFPA (72A-74)	Local Protective Signaling Systems
NFPA (72B-74)	Auxiliary Signaling Systems
NFPA (72C-74)	Remote Station Signaling Systems

NFPA (72D-74)	Proprietary Signaling Systems
NFPA (72E-74)	Automatic Fire Detectors
NFPA (73-73)	Public Fire Service Communications
NFPA (75-72)	Electronic Computer/Data Processing Equipment
NFPA (76A-73)	Essential Electrical Systems
NFPA (78-68)	Lightning Protection Code
NFPA (80-74)	Fire Doors and Windows

Volume 9

NFPA (90A-74)	Air Conditioning and Ventilating Systems
NFPA (90B-73)	Warm Air Heating and Air Conditioning
NFPA (91-73)	Blower and Exhaust Systems
NFPA (101-73)	Life Safety Code
NFPA (214-71)	Water Cooling Towers
NFPA (231-74)	General Storage, Indoor

Volume 12

NFPA (6-74)	Industrial Fire Loss Prevention
NFPA (7-74)	Fire Emergencies Management
NFPA (13E-73)	Fire Department Operations in Properties Protected by Sprinkler, Standpipe Systems
NFPA (25-69)	Water Systems for Rural Fire Protection
NFPA (325M-69)	Properties of Flammable Liquids, Gases, Solids

Volume 13

NFPA (49-73)	Hazardous Chemicals Data

Volume 14

NFPA (76CM-70)	High-Frequency Electrical Equipment
NFPA (77-72)	Static Electricity

NFPA (80A-70)	Protection from Exposed Fires
NFPA (89M-71)	Clearances, Heat Producing Appliances
NFPA (92M-72)	Waterproofing and Draining of Floors
NFPA (203M-70)	Roof Coverings
NFPA (206M-70)	Building Areas and Heights
NFPA (231A-70)	General Storage, Outdoor

Volume 15

NFPA (901-73)	Uniform Coding for Fire Protection

A.5.2 American National Standards Institute (ANSI)

A10.8-1969	Safety Requirements for Scaffolding
A12.1-1973	Safety Requirement for Floor and Wall Openings, Railings and Toeboards
A14.1-1975	Safety Code for Portable Wood Ladders
A14.2-1972	Safety Code for Portable Metal Ladders
A14.3-1974	Safety Code for Fixed Ladders
A17.1-1971	Safety Code for Elevators
A58.1-1972	Minimum Design Loads in Buildings and Other Structures
A64.1-1968	Requirements for Fixed Industrial Stairs
A92.1-1971	Standard for Manually Propelled Mobile Ladder Stands and Scaffolds
A92.2-1969	Vehicle Mounted Elevating and Rotating Work Platforms
B15.1-1972	Safety Code for Mechanical Power Transmission Apparatus
B16.5-1977	Steel Pipe Flanges and Flanged Fittings
B16.34-1977	Steel Butt-Welding End Valves
B19.1-1972	Safety Code for Compressed Air Machinery
B30.2-1967	Safety Code for Overhead and Gantry Cranes

B30.5-1968	Safety Code for Crawler and Truck Cranes
B31.1-1977	Power Piping
B31.4-1974	Liquid Petroleum Transportation Piping
B56.1-1975	Safety Standard for Powered Industrial Trucks (Part I and II)
C2-1973	National Electrical Safety Code
Z53.1-1971	Safety Color Code for Marking Physical Hazards

A.6 HUMAN ENGINEERING DESIGN CRITERIA

MIL-STD-1472

A.7 BUILDING CODES

A.7.1 Building Codes of the County of San Bernardino.

A.7.2 Uniform Building Code — 1976 Edition, Vol. 1, by International Conference of Building Officials.

A.8 DESIGN, CONSTRUCTION, AND FABRICATION STANDARDS

A.8.1 Standards of the American Institute of Steel Construction and American Concrete Institute.

A.8.2 Standards of the Tubular Exchanger Manufacturers' Association (TEMA).

A.8.3 American Petroleum Institute (API) Standard 650, Welded Steel Tanks for Oil Storage.

A.9 ENVIRONMENTAL LEGISLATION

A.9.1 National Environmental Policy Act (NEPA)

A.9.2 California Environmental Quality Act (CEQA)

A.10 AVIATION REGULATIONS

A.10.1 Regulations of the Federal Aviation Administration

A.10.2 Regulations of the Civil Aeronautics Board

APPENDIX B

APPENDIX C

APPENDIX C

DESIGN ENVIRONMENTAL CONDITIONS

Environmental data including the following will be provided.

C.1 SITE ENVIRONMENTAL CONDITIONS

C.1.1 Solar Conditions:

(Insolation data for the design base year.)

C.1.2 Wind Conditions:

Annual 1-min average velocity maximum	________mph
50-year 1-min average velocity maximum	________mph
Prevailing direction, early morning	________mph
Prevailing direction, afternoon	________mph
Average velocity, daytime	________mph
Average velocity, nighttime	________mph

C.1.3 Precipitation:

Mean normal rainfall at the site	________in. /yea

Probable maximums during 50-year period are:

Annual rainfall	________in.
24-h rainfall	________in.
Annual snowfall	________in.
24-h snowfall	________in.
24-h hail storm	size________velocity________

C.1.4 Temperature

Average annual maximum	________°F
Average annual minimum	________°F
50-year probable maximum	________°F
50-year probable minimum	________°F

C.1.5 Humidity:

Average annual maximum ________%

Average annual minimum ________%

50-year probable maximum ________%

50-year probable minimum ________%

C.1.6 Seismic:

C.1.7 Flooding:

Occurrences at site 50-year probable ________

C.2 PLANT ENVIRONMENTAL DESIGN REQUIREMENTS

(These are the requirements which the A-E will use in his design calculations and/or his analysis.)

C.2.1 Solar Insolation

C.2.2 Wind

C.2.3 Precipitation

C.2.4 Atmospheric Temperature

C.2.5 Atmospheric Humidity

C.2.6 Seismic

C.2.7 Flooding

THE AEROSPACE CORPORATION

Post Office Box 92957, Los Angeles, California 90009, Telephone: (213) 648-5000

May 24, 1978

Mr. Richard Schweinberg
Project Director
Solar Ten Megawatt Project Office
Department of Energy
9550 Flair Drive, Ste. 210
El Monte, California 91731

Subject: Transmittal of Pilot Plant Environmental Conditions (OPDD Appendix C)

Dear Mr. Schweinberg:

Enclosed is the final report covering Aerospace Task 1.2 Environmental Conditions, entitled "Pilot Plant Environmental Conditions". STMPO-recommended changes have been incorporated.

The report has been developed for inclusion in the Pilot Plant Overall Plant Design Description (OPDD) document and is presented in that format.

Very truly yours,

Elliott L. Katz

Elliott L. Katz
Director
Solar Thermal Projects Office
Energy Systems Group

ELK/JVC/bj

cc: ✓A. Klein
C. Winarski
J. Otts
E. English
J. Zingeser
E. Cull
Etc?

APPENDIX C

DESIGN ENVIRONMENTAL CONDITIONS

Environmental data including the following will be provided.

C.1 SITE ENVIRONMENTAL CONDITIONS

C.1.1 Solar Conditions:

(Insolation data for the design base year.)

C.1.2 Wind Conditions:

Annual 1-min average velocity maximum	________mph
50-year 1-min average velocity maximum	________mph
Prevailing direction, early morning	________mph
Prevailing direction, afternoon	________mph
Average velocity, daytime	________mph
Average velocity, nighttime	________mph

C.1.3 Precipitation:

Mean normal rainfall at the site ________in. /yea

Probable maximums during 50-year period are:

Annual rainfall	________in.
24-h rainfall	________in.
Annual snowfall	________in.
24-h snowfall	________in.

24-h hail storm size________ velocity________

C.1.4 Temperature

Average annual maximum	________°F
Average annual minimum	________°F
50-year probable maximum	________°F
50-year probable minimum	________°F

C.1.5 Humidity:

Average annual maximum ________%

Average annual minimum ________%

50-year probable maximum ________%

50-year probable minimum ________%

C.1.6 Seismic:

C.1.7 Flooding:

Occurrences at site 50-year probable ________

C.2 PLANT ENVIRONMENTAL DESIGN REQUIREMENTS

(These are the requirements which the A-E will use in his design calculations and/or his analysis.)

C.2.1 Solar Insolation

C.2.2 Wind

C.2.3 Precipitation

C.2.4 Atmospheric Temperature

C.2.5 Atmospheric Humidity

C.2.6 Seismic

C.2.7 Flooding

W/chgs pp. 9 & 11 (9/19/80)

Aerospace Report No.
ATR-78(7695-05)-05 (Rev.)

PILOT PLANT ENVIRONMENTAL CONDITIONS

(OPDD APPENDIX C)

Revision No. 1
15 August 1978

Prepared by:

THE AEROSPACE CORPORATION
Energy Systems Group
El Segundo, California 90245

C. M. Randall, Chemistry and Physics Laboratory
M. E. Whitson, Chemistry and Physics Laboratory
J. V. Coggi, Solar Thermal Projects Office

FOREWORD

This report is written as a partial account of work performed for the Department of Energy, on the 10 MW Solar Thermal Pilot Plant Project, under Contract Number E(04-3)-1101, Project Agreement No. 2. The material herein has been developed for inclusion in the Pilot Plant Overall Plant Design Description document (OPDD), and is presented in that format.

APPENDIX C

PILOT PLANT DESIGN ENVIRONMENTAL CONDITIONS

C.0 INTRODUCTION

Environmental conditions must be specified in varying degrees of detail for various purposes in the design of the Solar Thermal Electric Pilot Plant. This appendix specifies in separate sections the environmental design criteria to be used for plant design day performance, operational environmental limits and survival environmental limits. Also included is a summary of primary data used in determination of these limits. In some cases, as noted, the selected design data apply to specific components of the plant.

The data summaries on which this appendix are based cover various time periods. They have been summarized by various organizations for other purposes and not specifically for the construction of this plant. While they are believed to be generally consistent, some minor inconsistencies may exist because of the variety of sources.

The Barstow/Daggett plant site is at 34.87 degrees north latitude and 116.83 degrees west longitude. The surface elevation is about 591m (1940 ft) above MSL.

C.1 DESIGN DAY ENVIRONMENTAL CONDITIONS

The Pilot Plant performance requirements noted in Section 1 are referred to two design days. These are the winter solstice day, December 21, and the summer solstice day, June 21.

Based on the environmental data at the Barstow Pilot Plant location, the following conditions are to be used for design day performance studies. The insolation values noted are typical for the "best" and "worst" days for a surround field. The temperature and wind values selected reflect a typical day.

C.1.1 Design Days Direct Solar Insolation

Best Day: See Figure 1 (Ref. 8)

Worst Day: See Figure 2 (Ref. 8)

Basis: Barstow data collected by SCE (Ref. 1 & Ref. 2). 24 June was adopted to represent 21 June since for the available 1976 insolation data this specific day was cloudy.

C.1.2 Temperature

C.1.2.1 Dry Bulb Temperature

Summer: See Figure 3 (Ref. 8)

Winter: See Figure 4 (Ref. 8)

Basis: Typical Barstow Data

C.1.3 Winds

C.1.3.1 Wind Speed at Ten Meter Altitude:* 29 mph (13 m/sec)

Basis: 97 percentile of annual wind velocity during time which plant is expected to be operational. (Daylight hours, clear skies) (Ref. 4). See Figure 5.

C.1.3.2 Wind Direction: 280°

Basis: Greater than 50% of wind observations occur within the direction from 258° to 304° Azimuth. (Ref. 4)

C.1.4 Ambient Atmospheric Pressure 13.72 psia (946 mbar)

Basis: Mean atmospheric pressure measured at plant site. (Ref. 11).

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*Wind Variation with Height (H) is given by $V = V_{10\ \text{meters}} \left(\frac{H}{10}\right)^{0.15}$

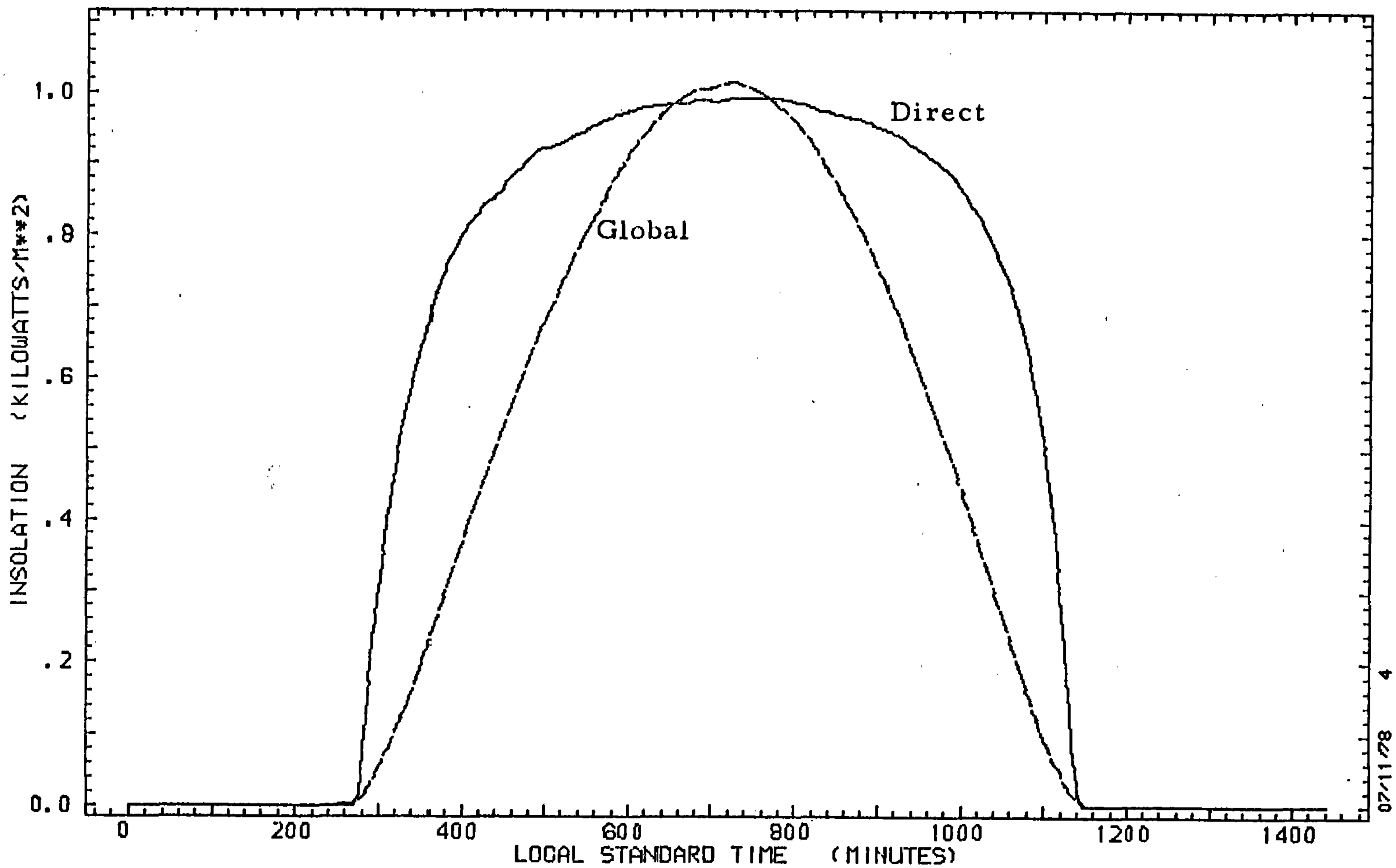


FIGURE 1. INSOLATION PROFILE FOR 21 JUNE (BEST DAY)

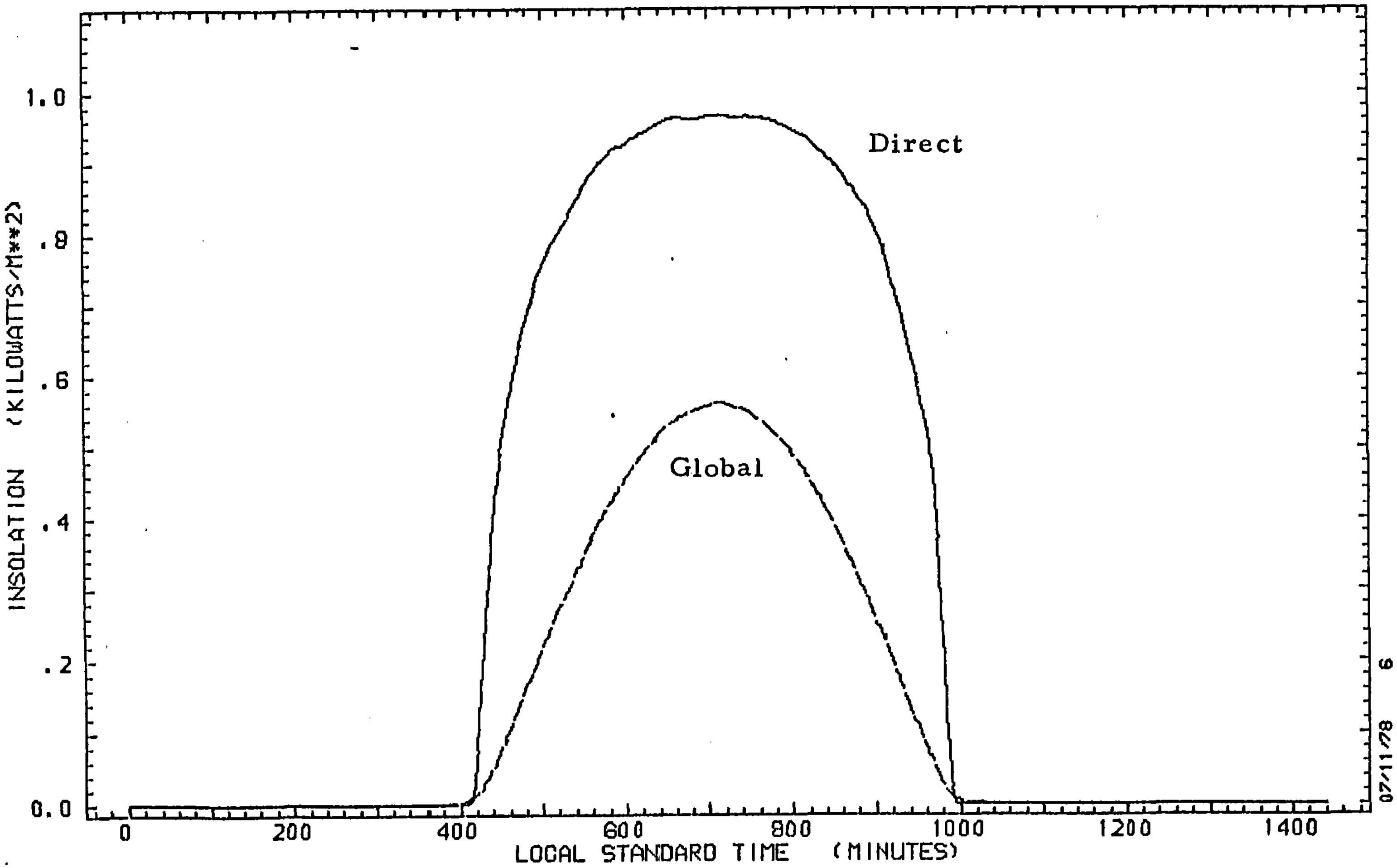


FIGURE 2. INSOLATION PROFILE FOR 21 DECEMBER (WORST DAY)

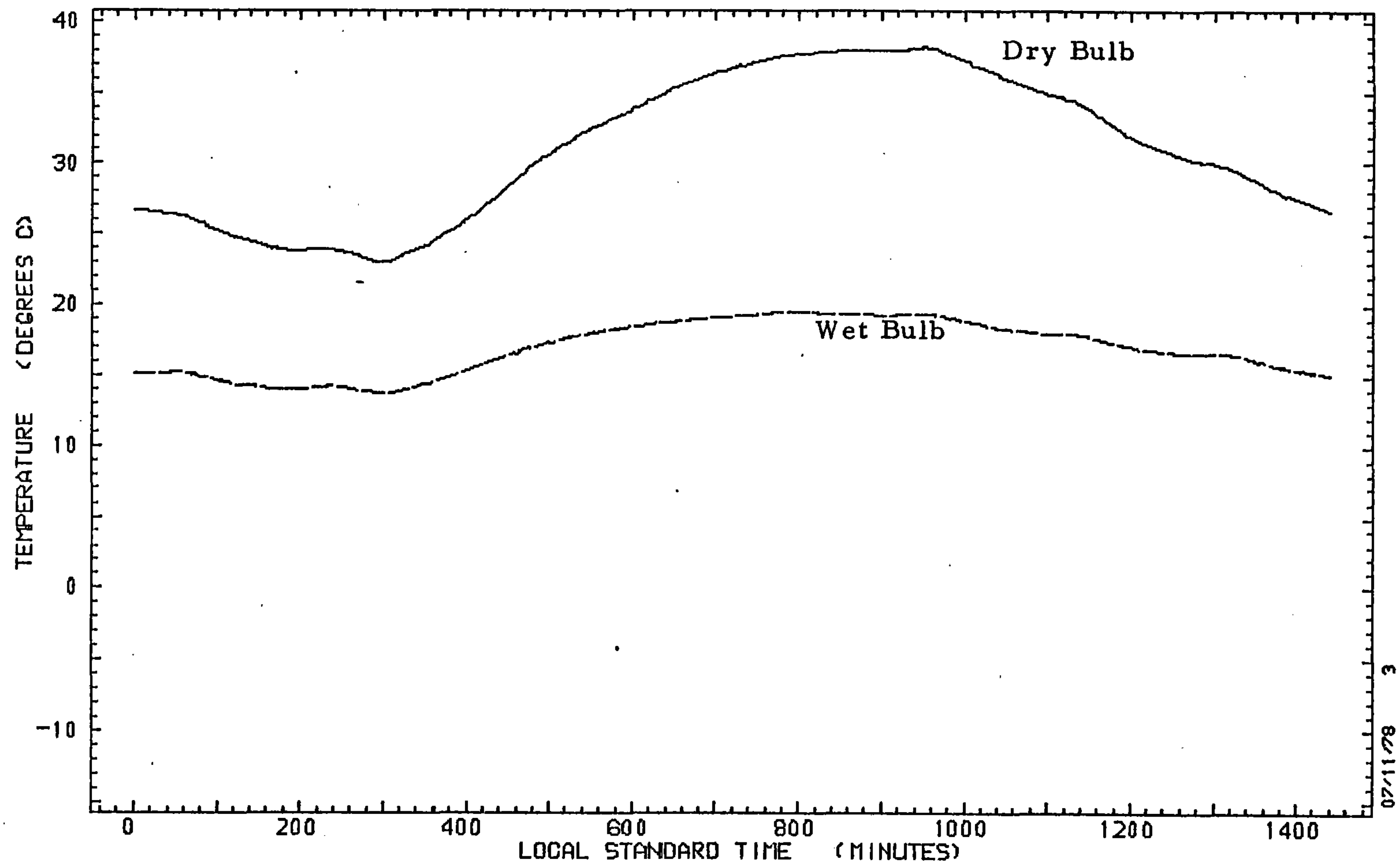


FIGURE 3. TEMPERATURE PROFILE FOR 21 JUNE (SUMMER DAY)

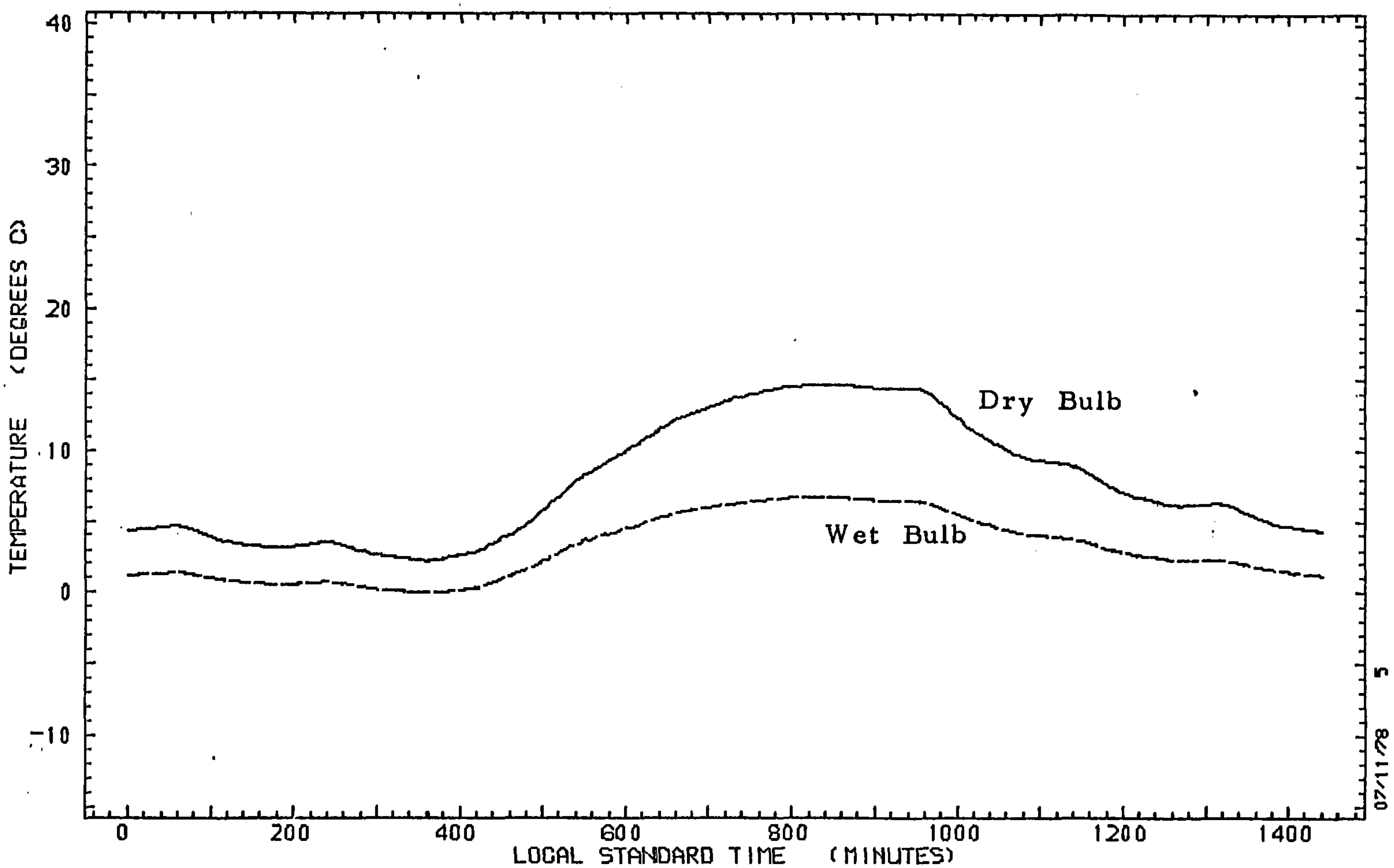


FIGURE 4. TEMPERATURE PROFILE FOR 21 DECEMBER (WINTER DAY)

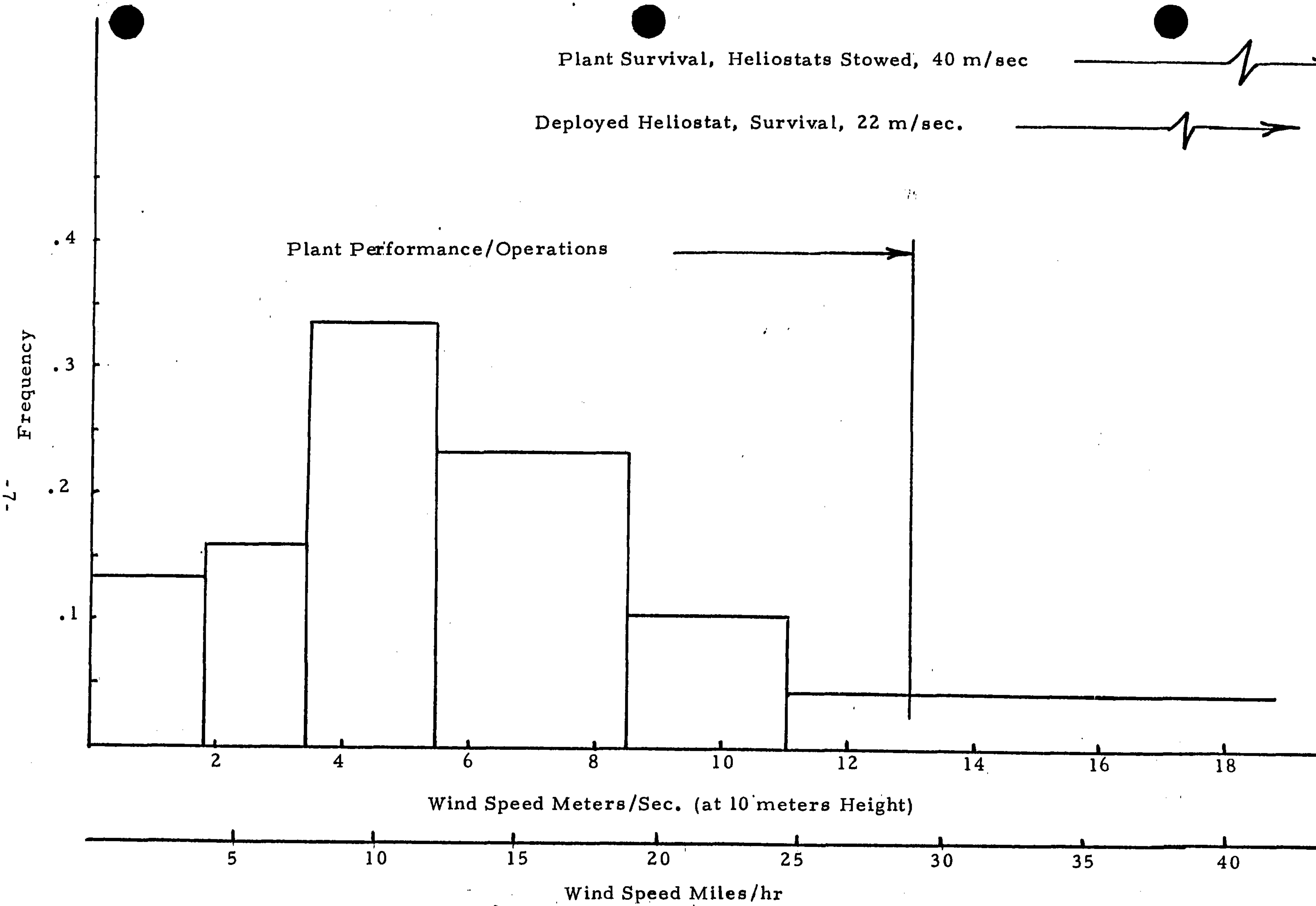


Figure 5. Wind Speed Frequency of Occurance for Daggett. The ordinate value is the fraction of hours for which observations were made which were clear and had wind speeds corresponding to the bin number definitions. The total number of annual observations is 96911 hours.

C.2 OPERATIONAL ENVIRONMENTAL CONDITIONS

The operational environmental conditions are those environmental data limits within which the plant is to remain fully operational. The plant performance, however, need not match the design performance throughout the total operational environmental data range. The operational environmental conditions are based on statistical selection of data.

C.2.1 Direct Insolation

The direct insolation minimum for which the plant is to remain operational is 690 watts/m^2.

Basis: The collector field shall provide predictable solar flux when the sun is 15° above the horizon.

C.2.2 Temperature

C.2.2.1 Dry Bulb Temperature

The dry bulb temperature range within which the plant is to remain operational is from 16°F(-9°C)to 113°F (45°C.)

Basis: The temperature operating limits were selected on the basis of statistical (97 percentile) temperatures at Daggett. (Ref. 11 and Tables 7.1 and 7.2).

C.2.2.2 Wet Bulb Temperature

The wet bulb temperature operating range is from 14°F (-10°C) to 77°F (25°C).

Basis: Daggett statistical data.

C.2.3 Winds Same requirement as C.1.3.1

C.2.4 Atmospheric Pressure

The plant shall be operational when the atmospheric pressure conditions range from 940 mBars (13.86 psia) to 956 mBars (13.6 psia).

Basis: Thirty year measurements at Barstow and greater than 99% probability within range (Ref. 11).

C.2.5 Precipitation

The average and maximum monthly precipitation is listed in Table 20. The Plant shall remain operational in cloudburst activity when the precipitation rates may reach 15 cm/hr for 2 minutes, and 6 cm/hr for 30 minutes (Ref. 10).

C.3 SURVIVAL ENVIRONMENTAL CONDITIONS

The plant shall be designed to survive without damage within the survival environmental conditions specified below. The plant may take measures to protect vulnerable equipment at points beyond the specific operational limits. The plant, however, shall return to operational status after the environments return to within the operational limits.

C.3.1 Direct Insolation

The maximum direct insolation will not exceed 1.15 kw/m^2.

C.3.2 Temperature

C.3.2.1 Dry Bulb Temperature

The plant shall be designed to survive maximum ambient dry bulb temperatures of 117°F (47°C) and minimum ambient temperatures of +9°F (-13°C). CORR. - to + 9/19/80

Basis: Statistical (99.9 percentile) temperature at Daggett.

C.3.2.2 Wet Bulb Temperature

The wet bulb temperature range is -14°C (5°F) to 28°C (82°F).

C.3.3 Winds (At 32 ft. above grade . . . see C.1.3.1 footnote)

C.3.3.1 Heliostats

The heliostat at any altitude shall withstand, without damage, a maximum wind of 50 mph (22 m/sec) from any direction. The heliostats shall be designed to survive, in the stowed position, winds of 90 mph (40 m/sec).

C.3.3.2 Remaining Equipment and Structures

The remaining equipment and structures, including the tower and receiver, shall survive without damage in winds both sustained and gusts of 90 mph (40 m/sec). See Figure 5.

Basis: Maximum wind speeds measured in Daggett for a 29 year period as noted in Table 18. (Ref. 11). Estimated mean recurrence interval of 90 mph (40 m/sec). winds at Daggett is once per 200 years (Ref. 26).

C.3.3.3 Tornadoes

Tornadoes need not be considered in wind-resistant design criteria.

Basis: Tornadoes are not a significant threat as calculated in risk model for Daggett, California (Ref. 26).

C.3.4 Seismic Structural Design Environment

All structures including but not limited to the receiver tower, heliostat assemblies, buildings, and equipment, shall be designed so as not to sustain damage when subjected to the following dynamic environment. The horizontal response spectrum of the base of the structure may occur in any horizontal direction and is given by the curve of Figure 6. A vertical response spectrum of the base of $\frac{2}{3}$ the spectral ordinates of Figure 6 shall be considered to occur concurrently with the horizontal spectrum applied in the most damaging (combined) direction. Suitable modal superposition, such as the square root of the sum of the squares of the responses of an appropriate number of modes shall be employed. Alternatively, a suitable collection of spectra-compatible time histories each at least 20 seconds in duration may be derived and employed.

Basis: The proposed site is within the jurisdiction of the Building and Safety Department of the County of San Bernardino. The local building code is currently the 1976 edition of the Uniform Building Code. The UBC includes a Section 2315 entitled "Earthquake Regulations" which is a seismic design criterion. This is a pseudo-static design criterion that yields a base shear of about 0.2 Weight of structure.

Various seismic risk maps have been developed for the State of California. These maps contain contours of equal ground acceleration for a given probability of not being exceeded in a specified period of time. The peak ground motion parameters for this location as taken from several sources are noted in Table 1.

Statistical calculations were made, and a single damping ratio of five percent was selected as being typical and reasonable for the structures of interest. The resultant design response spectrum (Figure 6) defines the response of a single-degree-of-freedom oscillator that has a probability of non-exceedance of 0.9 in 30 years.

C.3.5 Lightning

The plant design shall consider the effects of lightning strikes which result from 5-10 thunderstorms per year.

Basis: The proposed pilot plant site with a nominal 100 m tower may be expected to experience a direct lightning strike about every four years.

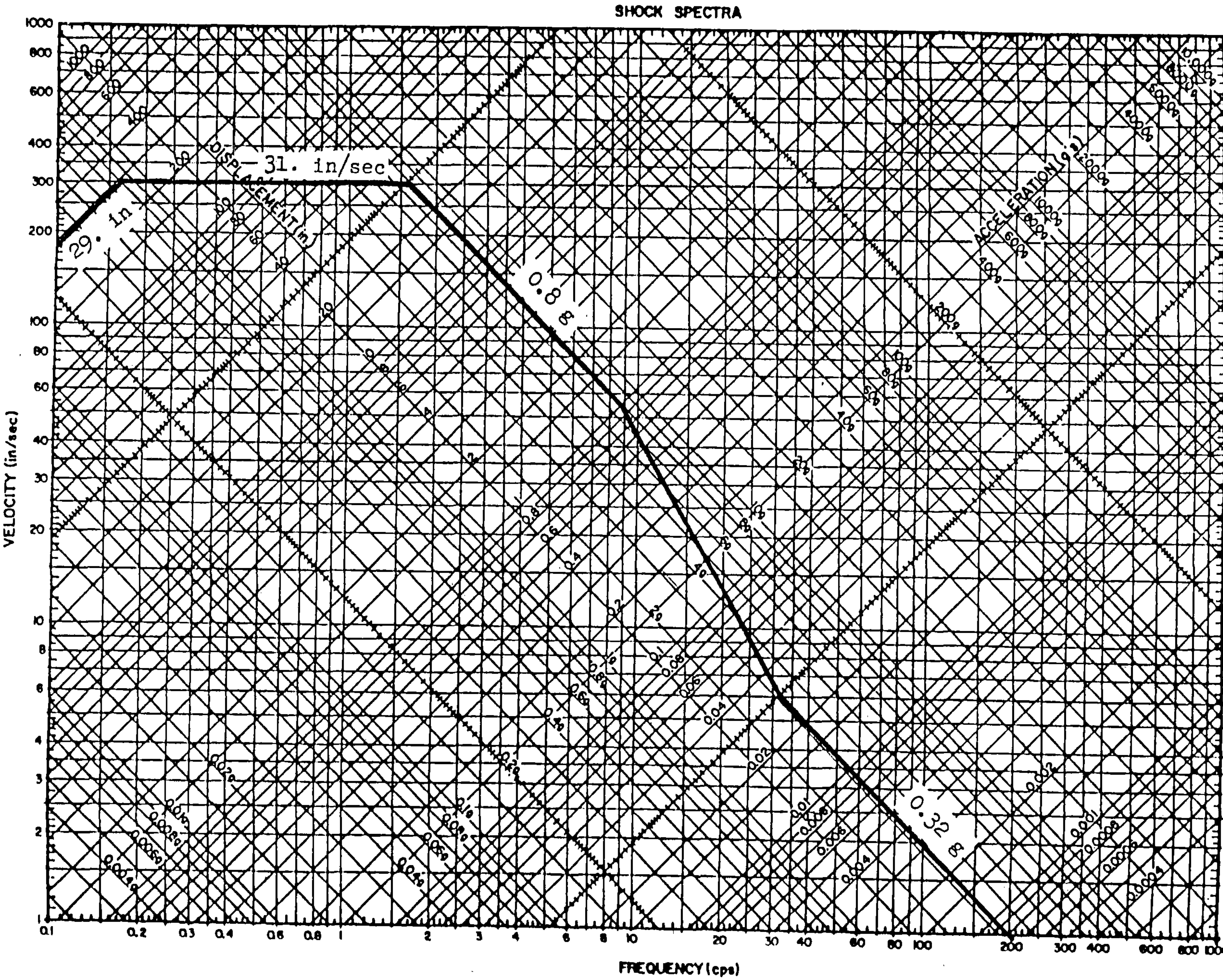


Figure 6. Design Response Spectrum for Horizontal Motion for Proposed Solar Thermal Electric Pilot Plant near Barstow, California. (Curve shifted upward one decade for convenience)

Table 1. Peak Ground Motion Parameters Estimated by Various Researchers for 116.83 Degrees West Longitude and 34.87 Degrees North Latitude

Reference	Statistical Basis	Peak Motion A(g)	Peak Motion V(in/sec)	Peak Motion D(in.)
15	P_n = .9 in 50 years	0.25	19.	8.8
16	P_n = .9 in 50 years	0.16		
17	P_n = .9 in 50 years	0.22 (1)		
18, 19	Maximum Probable	0.26 (2)		

(1) Adjustment was required to bring value quoted to a basis of P_n = .9 in 50 years. P_n = probability of non-occurrence.

(2) Richter estimate of MMI of VIII converted to acceleration by correlation given by Trifunac and Brady.

This expectation is based on the assumption of 5 to 10 thunderstorms per year at the plant site (Ref. 20 and 21). An empirical study indicates at a frequency of 32 thunderstorms per year the number of lightning strikes to structures of various heights is that provided in Table 21 (Ref. 22). The lightning strike rates have been multiplied by a factor of 0.25 to arrive at an estimated rate for the pilot plant site, based on an estimate of a thunderstorm rate of 8 per year. (8/32 = 0.25). References 24, 25, and 28 contain information applicable to large installations, like the Pilot Plant.

C.3.6 Flooding

The site is nearly flat. However, flooding is not expected to be a problem due to the porous nature of the soil and low rainfall (Ref. 10).

C.3.7 Snow/Ice

The power plant including the heliostats shall be designed to withstand snow loads of 5 lb/ft^2 and ice loads of 2 in. (50 mm).

Basis: Precipitation in the area is usually in the form of rainfall. Occasionally, however, an exceptionally strong cold frontal system will move through the area with precipitation in the form of snow. During the period 1956-1970, a total of fifteen snowfall occurrences have been noted at the Daggett airport, with eleven amounting to only a trace. The greatest monthly snowfall during the above period was 13.0 inches in December, 1968 (Ref. 10).

C.3.8 Hail

The power plant, including the heliostat operating at any orientation, shall survive continued impact of hail stones 3/4 in. (19 mm) at 65 ft/sec (20 m/sec). At the stowed position the heliostat shall survive hail impacts of 1 in. (25 mm) diameter at velocities of 75 ft/sec (23 m/sec).

C.3.9 Dust Devils

The plant shall survive dust devils with wind speeds up to 38 mph (17 m/sec).

C.4 SPECIAL ENVIRONMENTAL CONDITIONS

C.4.1 Clouds

The plant design shall take the transient effect of clouds into account.

Basis: Measurements are underway to define the cloud environment at the plant site. These measurements will define the cloud cover, cloud type, cloud velocity and direction. Until this data becomes available, a preliminary cloud description is defined for preliminary design purposes. (Ref. 27).

The following cloud is to be used as the basis for design. The design cloud is a water cloud with a base below 5,000 ft. which has sharply defined boundaries, as shown in Figure 7. The cloud is larger than the pilot plant heliostat field and, therefore, the assumption of a single cloud moving over the field is an adequate representation of actual expected conditions. The cloud velocity is 13 m/sec. referenced to ground speed, the highest wind velocity in which the plant is expected to remain operational. The single cloud may arrive from any direction.

The cloud frequency model is shown in Figure 8. This intermittent cloud model is to be used for basis of design in cyclic studies. The cloud characteristics are similar to the single cloud model except for its finite length. The model assumes a sky coverage of 50% and a solar elevation of 40° which yields a ground cloud coverage of 31%. The recommended cloud speed is the mean wind speed at the site referenced to ground.

C.4.2 Soils

The following preliminary soil condition description for the plant site is to be used for preliminary design until the geological surveys at the site are complete.

Soil Properties

The surface deposits of silty sand, which extends to depths of from 1 ft. to 5 ft. (0.3m to 1.5m), are only moderately firm and become weaker when wet. The sand below a depth of about 5 ft. (1.5m) is firm but contains thin layers of relatively soft silt. In general, the sand is firmer below 10 ft. (3 m) and layers of soft silt were not encountered.

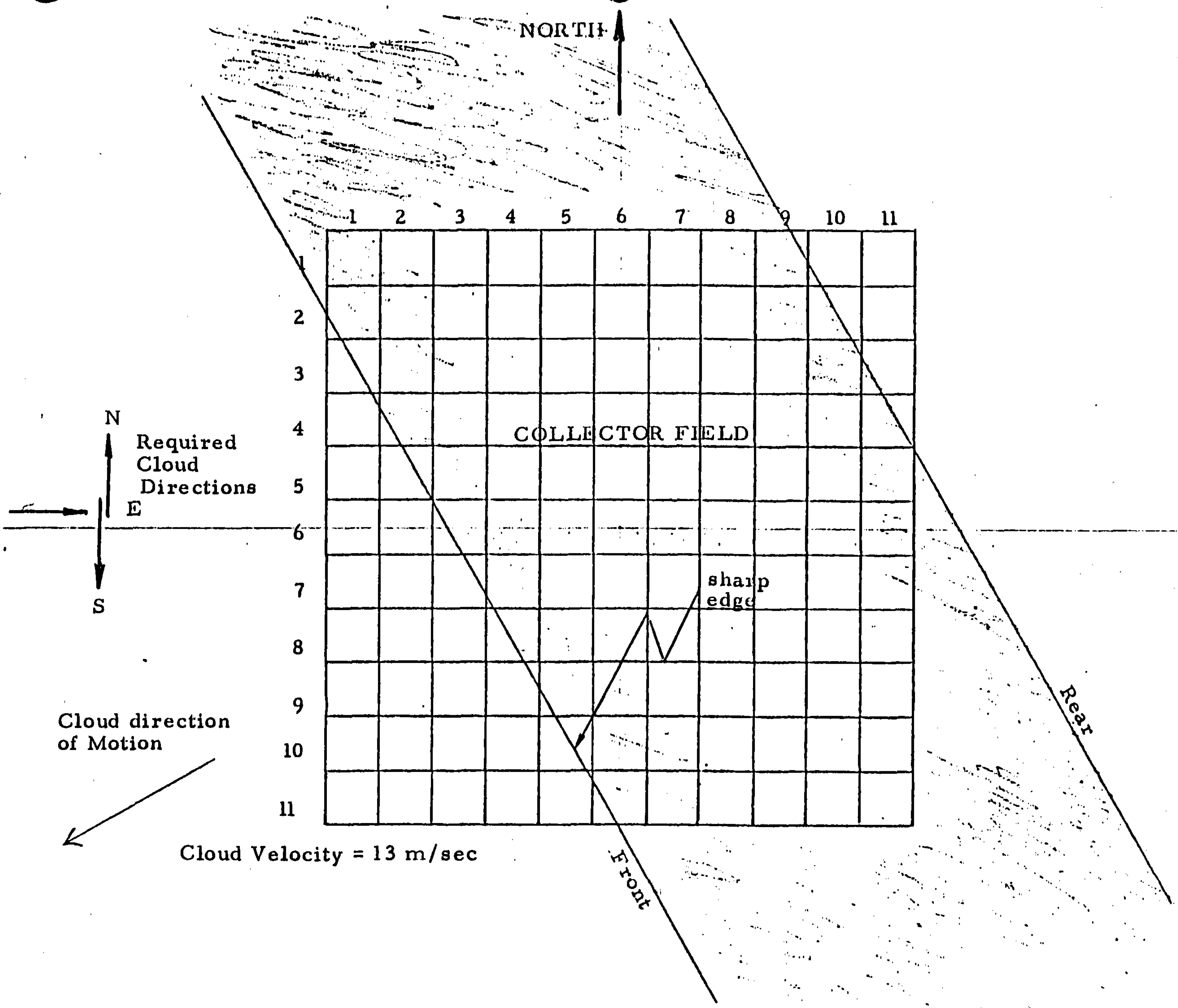


Figure 7. Schematic of Cloud Simulation.

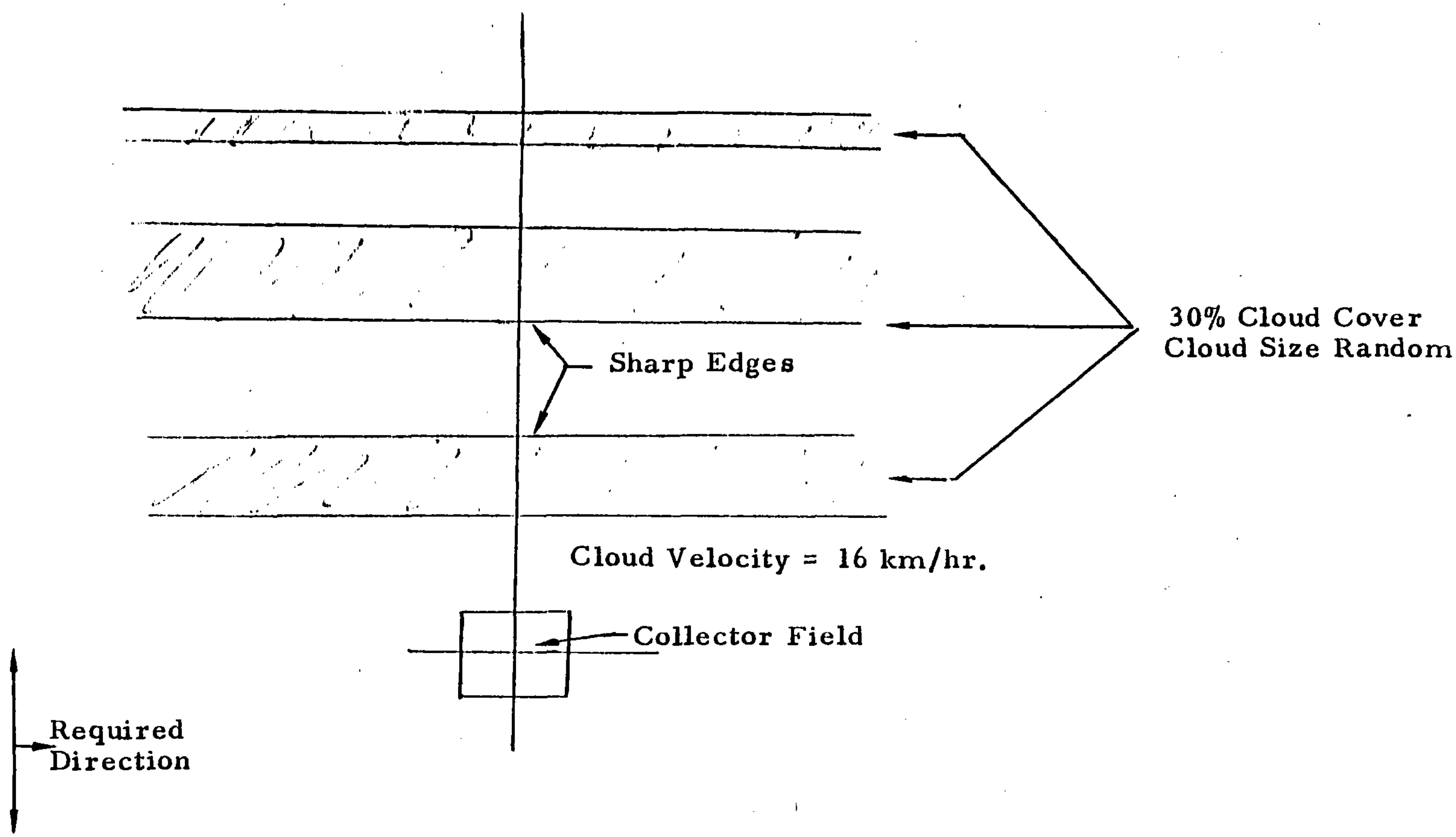


Figure 8. Cloud Frequency Model

G, Shear Modulus, and E, Secant Modulus

Shear Modulus = $G = \frac{\beta(h+z)}{2(1+\mu)} \cong \frac{\beta y}{2.6}$

Secant Modulus = $E = \beta(h+z) \cong y$

Where β = function of soil depth (see chart)

h = depth of burden

z = depth from burden

μ = constant = 0.3

y = depth from surface

Soil Depth (y)		Density		β		Secant Modulus at the free surface	
(m)	(ft)	(kg/m^3)	(Lb/ft^3)	(MPa/m)	(psi/ft)	(MPa)	(psi)
0-1.5	(0-5)	1600	(100)	1.7	(75)	0.7	(100)
1.5-3.0	(5-10)	1840	(115)	2.5	(110)	1.4	(200)
3.0-	(10-)	1920	(120)	3.4	(150)	2.1	(300).

At depth of 5 ft. (1.5m) G = 1500 psi (10 MPa)
E = 4000 psi (28 MPa)

At depth of 10 ft. (3.0m) G = 4600 psi (32 MPa),
E = 12,000 psi (83 MPa)

Geophysical data (from seismic refraction investigation) indicates a shear modulus at a strain rate of 10^{-4} m/m of between 15,000 to 20,000 psi (100 to 140 MPa) at a depth of 10 ft. (3m).

Bearing Capacity (allowable for standard spread or mat-type foundations).

Depth, m(ft)		Load kPa(psf)	
0.6	(2)	70	(1,500)
1.5	(5)	240	(5,000)
3.0	(10)	480	(10,000)

Penetration Data. The number of blows required to drive a materials sampler 12 in. (300mm) was recorded for a number of borings. To a depth of 25 ft. (7.5m) a weight of 1600 lb. (725 kg) (Kelly weight) falling a distance of 1 ft. (0.3m) was used to drive the 3 in. (76mm) diameter sampler.

Number of blows to drive an LC&A Sampler 12 in (300 m)

Depth (m)	(ft)	Average	Range	No. of Samples
0 - 1.5	(0-5)	2.6	0 - 9	74
1.5 - 3.0	(5-10)	4.2	1 - 10	42
3.0 - 4.5	(10-15)	5.9	2 - 11	31
4.5 - 6.0	(15-20)	8.0	4 - 15	19
6.0 - 7.5	(20-25)	9.0	5 - 20	17

Note: There does not appear to be a direct conversion between these data and a standard penetration test, so the results are qualitative in nature.

Water Table. Below 100 ft. (30 m)

C.5 ENVIRONMENTAL DATA SUMMARY

C.5.1 Data Sources

C.5.1.1 Southern California Edison Company-West Associates Data

The Southern California Edison Company/West Associates Data has been measuring direct and total insolation and dry bulb temperature in the city of Barstow about 10 miles from the pilot plant site. Data are recorded at 15 minute intervals and are available for the year 1976 on computer compatible magnetic tape. These 1976 data have been analyzed by West Associates and the results published. (Ref. 1, 2).

C.5.1.2 Federal Aviation Agency

At the Daggett/San Bernardino County Airport, approximately 2 miles from the plant site, the FAA maintains a weather station which records hourly surface observations. These are forwarded to the National Climatic Center in Asheville, North Carolina where they are stored.

All hourly data from November of 1948 through December of 1964 have been converted to computer compatible format. Every third hour from January, 1965 to the present has been converted to computer compatible format. A copy of the magnetic tape containing these computer transcribed data from November, 1948 through 1976 was obtained from the National Climatic Center. This tape is the basis for several of the analyses reported in this Appendix.

C.5.1.3 Aerospace Insolation/Meteorological Data Tape for 1976 Barstow

A 15 minute interval data tape for the entire year of 1976 is available. The insolation data are those observed by Southern California Edison Company. The hourly surface meteorological observations at the Daggett site, obtained from the National Climatic Center, containing temperature, wind, cloud cover and pressure information were included in the tape. Data values at 15 minute intervals were obtained by interpolation. The consistency of the data values was carefully evaluated and the resulting edited data placed on a magnetic tape in a modified SOLMET format. A separate report (Ref. 13) specifying in detail the contents, evaluation and format of this tape is available upon request.

C.5.2 Environmental Data

C.5.2.1 Insolation

Tables 2 and 3 provide values taken from the tape of direct normal and total hemispherical insolation and solar position at 15 minute intervals for the two design days. The insolation values listed in column 3 and 4 were measured by Southern California Edison (SCE) (Ref. 1 and 2). The values are of observed integrated energy during the 15 minute interval ending at the Local Standard Time (LST) indicated in columns 1 and 2. This time is for the end of the 15 minute period to which the values to the right apply.

The monthly mean daily direct-normal insolation is given in Table 4 (Ref. 8).

The observed number of days with direct insolation exceeding a given value is shown by months in Figure 9.1 to 9.12 (Ref. 2).

The number of days per month with insolation greater than a given insolation value D, for n or more consecutive 15 minute intervals is shown as a function of D for each month in Figures 10.1 to 10.12 (Ref. 9).

C.5.2.2 Temperature

The dry bulb, wet bulb and dew point temperatures for the design days as taken from the environmental data tape are shown in Tables 2 and 3.

C.5.2.2.1 Dry Bulb Temperature

The mean monthly minimum, average and maximum temperatures for the Daggett airport data are specified in Table 5 (Ref. 11).

The monthly mean and standard deviation of the dry bulb temperature is given at hourly intervals in Table 6 (Ref. 11).

The maximum and minimum dry bulb temperatures observed during a 29 year period at Daggett are shown in Tables 7.1, 7.2, and 8 (Ref. 11). Tables 7.1 and 7.2 list the maximum and minimum temperatures observed for each month of each year. Table 8 presents maximum, second highest, minimum, and next lowest temperatures observed during the 29 year period, and indicates the number of hours at maximum values.

C.5.2.2.2 Wet Bulb Temperature

The mean monthly minimum, average and maximum wet bulb temperatures at the Daggett Airport are specified in Table 9 (Ref. 11).

The monthly mean and standard deviation of the wet bulb temperature is given at hourly intervals in Table 10 (Ref. 11).

C.5.2.3 Winds

The frequency distribution of winds by direction and velocity for seasons and annually is shown in Tables 11 through 15 (Ref. 4).

The frequency of winds by velocity, irrespective of direction for each season and annually is shown in Table 16 (Ref. 4, 8).

The frequency distribution of winds during clear daylight hours by months is shown in Table 17 (Ref. 11).

A list of maximum wind speeds (by month), and the total number of hours that wind speeds exceed 30 m/sec (by month), observed over a 29 year period, is provided in Table 18 (Ref. 11).

C.5.2.4 Atmospheric Pressure

The monthly mean and standard deviation of the ambient atmospheric pressure is provided in Table 19 (Ref. 11).

C.5.2.5 Precipitation

The average precipitation, the maximum 24 precipitation rate and the minimum precipitation is provided by months in Table 20 (Ref. 10).

C.5.2.6 Lightning

The number of direct lightning strokes per year for various height structures is shown in Table 21.

TABLE 2. INSOLATION AND METEOROLOGICAL PARAMETERS AT 15 MINUTE INTERVALS FOR BARSTOW, CALIFORNIA

21 JUNE

TIME (INTERVAL END,LST)		INSOLATION (KJ/M**2)		TEMPERATURE (DEG. C)		WINDS		SOLAR POSITION (DEG.)	
HR	MIN	DIRECT	HEMIS.	DRY BULB	WET BULB	DIREC. (DEG.)	SPEED (M/S)	AZIMUTH	ELEV.
0	15	0.00	0.00	26.65	15.11	280.	7.00	0.00	-1.00
0	30	0.00	0.00	26.55	15.14	280.	6.90	0.00	-1.00
0	45	0.00	0.00	26.45	15.16	280.	6.80	0.00	-1.00
1	0	0.00	0.00	26.35	15.19	280.	6.70	0.00	-1.00
1	15	0.00	0.00	26.10	15.09	280.	6.65	0.00	-1.00
1	30	0.00	0.00	25.70	14.86	280.	6.64	0.00	-1.00
1	45	0.00	0.00	25.30	14.64	280.	6.63	0.00	-1.00
2	0	0.00	0.00	24.90	14.41	280.	6.62	0.00	-1.00
2	15	0.00	0.00	24.59	14.25	280.	6.57	0.00	-1.00
2	30	0.00	0.00	24.36	14.15	280.	6.48	0.00	-1.00
2	45	0.00	0.00	24.14	14.05	280.	6.40	0.00	-1.00
3	0	0.00	0.00	23.91	13.95	280.	6.31	0.00	-1.00
3	15	0.00	0.00	23.81	13.94	280.	6.23	0.00	-1.00
3	30	0.00	0.00	23.84	14.01	280.	6.15	0.00	-1.00
3	45	0.00	0.00	23.86	14.09	280.	6.08	0.00	-1.00
4	0	0.00	0.00	23.89	14.16	280.	6.00	0.00	-1.00
4	15	0.00	0.00	23.78	14.13	280.	5.95	0.00	-1.00
4	30	0.00	1.59	23.53	13.98	280.	5.94	0.00	-1.00
4	45	27.25	7.95	23.28	13.83	280.	5.93	0.00	-1.00
5	0	203.66	33.39	23.03	13.68	280.	5.92	-117.22	2.22
5	15	338.03	62.81	23.09	13.71	280.	5.94	-115.15	4.98
5	30	447.05	98.59	23.46	13.94	280.	6.00	-113.16	7.78
5	45	525.64	138.34	23.84	14.16	280.	6.05	-111.20	10.63
6	0	585.49	182.86	24.21	14.39	280.	6.11	-109.28	13.52
6	15	643.13	228.98	24.70	14.66	280.	6.17	-107.40	16.44
6	30	686.20	276.68	25.30	14.99	280.	6.24	-105.53	19.39
6	45	717.47	323.59	25.90	15.31	280.	6.30	-103.68	22.37
7	0	740.29	369.70	26.50	15.64	280.	6.37	-101.84	25.37
7	15	756.56	415.22	27.19	15.95	280.	6.44	-99.99	28.39
7	30	772.40	455.36	27.96	16.25	280.	6.52	-98.12	31.42
7	45	793.52	501.68	28.74	16.55	280.	6.60	-96.23	34.47

TABLE 2. INSOLATION AND METEOROLOGICAL PARAMETERS AT 15 MINUTE INTERVALS FOR BARSTOW, CALIFORNIA

21 JUNE

TIME (INTERVAL END, LST) HR	MIN	INSOLATION (KJ/M**2) DIRECT	HEMIS.	TEMPERATURE (DEG. C) DRY BULB	WET BULB	WINDS DIREC. (DEG.)	SPEED (M/S)	SOLAR POSITION (DEG.) AZIMUTH	ELEV.
8	0	807.89	543.82	29.51	16.85	280.	6.68	-94.29	37.54
8	15	824.79	585.15	30.19	17.11	280.	6.69	-92.28	40.61
8	30	829.86	619.34	30.76	17.34	280.	6.63	-90.20	43.68
8	45	835.78	653.54	31.34	17.56	280.	6.56	-88.00	46.76
9	0	845.07	691.73	31.91	17.79	280.	6.50	-85.67	49.83
9	15	852.22	722.70	32.40	17.98	280.	6.40	-83.15	52.89
9	30	860.83	748.94	32.80	18.13	280.	6.25	-80.39	55.94
9	45	867.89	784.72	33.20	18.28	280.	6.11	-77.31	58.95
10	0	874.65	810.95	33.60	18.43	280.	5.96	-73.81	61.93
10	15	877.19	834.80	34.03	18.55	280.	5.82	-69.74	64.85
10	30	882.25	854.68	34.48	18.65	280.	5.69	-64.90	67.69
10	45	883.94	871.38	34.93	18.75	280.	5.55	-58.97	70.41
11	0	884.79	884.89	35.38	18.85	280.	5.42	-51.53	72.94
11	15	885.64	896.02	35.74	18.94	280.	5.36	-42.00	75.19
11	30	890.70	903.97	36.01	19.01	280.	5.38	-29.73	77.00
11	45	888.17	904.77	36.29	19.09	280.	5.41	-14.67	78.17
12	0	890.70	910.33	36.56	19.16	280.	5.43	2.33	78.50
12	15	891.55	911.92	36.81	19.24	280.	5.45	19.01	77.93
12	30	891.55	907.15	37.04	19.31	280.	5.48	33.37	76.56
12	45	893.24	900.00	37.26	19.39	280.	5.50	44.82	74.62
13	0	892.40	886.48	37.49	19.46	280.	5.53	53.72	72.28
13	15	889.87	876.15	37.64	19.49	280.	5.59	60.70	69.69
13	30	885.64	857.06	37.71	19.46	280.	5.68	66.30	66.94
13	45	882.25	836.40	37.79	19.44	280.	5.77	70.91	64.07
14	0	876.34	810.95	37.86	19.41	280.	5.86	74.80	61.13
14	15	872.96	785.51	37.90	19.39	280.	5.96	78.18	58.14
14	30	868.73	757.68	37.90	19.36	280.	6.08	81.16	55.12
14	45	867.04	728.27	37.90	19.34	280.	6.20	83.85	52.07
15	0	859.44	693.29	37.90	19.31	280.	6.32	86.31	49.00
15	15	853.52	657.50	37.94	19.31	280.	6.45	88.61	45.93
15	30	845.92	620.94	38.01	19.34	280.	6.60	90.77	42.85
15	45	834.08	579.59	38.09	19.36	280.	6.74	92.83	39.78

TABLE 2. INSOLATION AND METEOROLOGICAL PARAMETERS AT 15 MINUTE INTERVALS FOR BARSTOW, CALIFORNIA

21 JUNE

TIME (INTERVAL END, LST)		INSOLATION (KJ/M**2)		TEMPERATURE (DEG. C)		WINDS		SOLAR POSITION (DEG.)	
HR	MIN	DIRECT	HEMIS.	DRY BULB	WET BULB	DIREC. (DEG.)	SPEED (M/S)	AZIMUTH	ELEV.
16	0	824.79	539.05	38.16	19.39	280.	6.89	94.81	35.71
16	15	812.95	495.32	38.01	19.30	280.	7.08	96.74	33.65
16	30	799.44	451.59	37.64	19.10	280.	7.31	98.63	30.60
16	45	78[illegible]	436.27	37.26	18.90	280.	7.54	100.49	27.57
17	0	756.34	357.78	36.89	18.70	280.	7.77	102.34	24.55
17	15	730.14	311.66	36.51	18.54	280.	7.92	104.18	21.56
17	30	695.49	262.37	36.14	18.41	280.	8.01	106.03	18.59
17	45	658.31	214.67	35.76	18.29	280.	8.09	107.90	15.65
18	0	604.76	165.96	35.39	18.16	280.	8.18	109.80	12.74
18	15	531.55	121.64	35.08	18.08	280.	8.20	111.73	9.86
18	30	434.37	79.51	34.83	18.03	280.	8.16	113.69	7.02
18	45	294.93	45.32	34.58	17.98	280.	8.11	115.71	4.23
19	0	92.11	16.70	34.33	17.93	280.	8.07	117.79	1.48
19	15	0.00	2.39	33.90	17.79	280.	8.05	0.00	-1.00
19	30	0.00	0.00	33.30	17.56	280.	8.05	0.00	-1.00
19	45	0.00	0.00	32.70	17.34	280.	8.05	0.00	-1.00
20	0	0.00	0.00	32.10	17.11	280.	8.05	0.00	-1.00
20	15	0.00	0.00	31.63	16.95	280.	8.02	0.00	-1.00
20	30	0.00	0.00	31.28	16.85	280.	7.97	0.00	-1.00
20	45	0.00	0.00	30.93	16.75	280.	7.91	0.00	-1.00
21	0	0.00	0.00	30.58	16.65	280.	7.86	0.00	-1.00
21	15	0.00	0.00	30.31	16.60	280.	7.79	0.00	-1.00
21	30	0.00	0.00	30.14	16.60	280.	7.70	0.00	-1.00
21	45	0.00	0.00	29.96	16.50	280.	7.61	0.00	-1.00
22	0	0.00	0.00	29.79	16.50	280.	7.52	0.00	-1.00
22	15	0.00	0.00	29.48	15.49	280.	7.46	0.00	-1.00
22	30	0.00	0.00	29.03	15.25	280.	7.42	0.00	-1.00
22	45	0.00	0.00	28.58	15.04	280.	7.38	0.00	-1.00
23	0	0.00	0.00	28.13	15.81	280.	7.34	0.00	-1.00
23	15	0.00	0.00	27.75	15.63	280.	7.29	0.00	-1.00
23	30	0.00	0.00	27.45	15.48	280.	7.22	0.00	-1.00
23	45	0.00	0.00	27.15	15.33	280.	7.15	0.00	-1.00

TABLE 3. INSOLATION AND METEOROLOGICAL PARAMETERS AT 15 MINUTE INTERVALS FOR BARSTOW, CALIFORNIA

21 DECEMBER

TIME (INTERVAL END, LST)		INSOLATION (KJ/M**2)		TEMPERATURE (DEG. C)		WINDS		SOLAR POSITION (DEG.)	
HR	MIN	DIRECT	HEMIS.	DRY BULB	WET BULB	DIREC. (DEG.)	SPEED (M/S)	AZIMUTH	ELEV.
0	15	0.00	0.00	4.35	1.23	280.	3.92	0.00	-1.00
0	30	0.00	0.00	4.45	1.28	280.	3.90	0.00	-1.00
0	45	0.00	0.00	4.55	1.33	280.	3.88	0.00	-1.00
1	0	0.00	0.00	4.65	1.38	280.	3.86	0.00	-1.00
1	15	0.00	0.00	4.55	1.33	280.	3.87	0.00	-1.00
1	30	0.00	0.00	4.25	1.18	280.	3.92	0.00	-1.00
1	45	0.00	0.00	3.95	1.03	280.	3.97	0.00	-1.00
2	0	0.00	0.00	3.65	.88	280.	4.02	0.00	-1.00
2	15	0.00	0.00	3.45	.76	280.	4.05	0.00	-1.00
2	30	0.00	0.00	3.35	.69	280.	4.08	0.00	-1.00
2	45	0.00	0.00	3.25	.61	280.	4.11	0.00	-1.00
3	0	0.00	0.00	3.15	.54	280.	4.14	0.00	-1.00
3	15	0.00	0.00	3.16	.54	280.	4.12	0.00	-1.00
3	30	0.00	0.00	3.29	.61	280.	4.07	0.00	-1.00
3	45	0.00	0.00	3.41	.69	280.	4.02	0.00	-1.00
4	0	0.00	0.00	3.54	.76	280.	3.97	0.00	-1.00
4	15	0.00	0.00	3.48	.73	280.	3.97	0.00	-1.00
4	30	0.00	0.00	3.23	.58	280.	4.02	0.00	-1.00
4	45	0.00	0.00	2.98	.43	280.	4.07	0.00	-1.00
5	0	0.00	0.00	2.73	.28	280.	4.12	0.00	-1.00
5	15	0.00	0.00	2.55	.18	280.	4.13	0.00	-1.00
5	30	0.00	0.00	2.45	.13	280.	4.10	0.00	-1.00
5	45	0.00	0.00	2.35	.08	280.	4.07	0.00	-1.00
6	0	0.00	0.00	2.25	.03	280.	4.04	0.00	-1.00
6	15	0.00	0.00	2.29	.04	280.	4.01	0.00	-1.00
6	30	0.00	0.00	2.46	.11	280.	3.98	0.00	-1.00
6	45	0.00	1.59	2.64	.19	280.	3.95	0.00	-1.00
7	0	0.00	5.56	2.81	.26	280.	3.92	0.00	-1.00
7	15	154.23	21.67	3.13	.46	280.	3.91	-59.45	1.90
7	30	332.82	52.47	3.58	.79	280.	3.91	-57.21	4.52
7	45	494.37	87.45	4.03	1.11	280.	3.90	-54.89	7.07

TABLE 3. INSOLATION AND METEOROLOGICAL PARAMETERS AT 15 MINUTE INTERVALS FOR BARSTOW, CALIFORNIA

21 DECEMBER

TIME (INTERVAL END.LST) HR	MIN	INSOLATION (KJ/M**2) DIRECT	HEMIS.	TEMPERATURE (DEG. C) DRY BULB	WET BULB	WINDS DIREC. (DEG.)	SPEED (M/S)	SOLAR POSITION (DEG.) AZIMUTH	ELEV.
8	0	579.72	127.21	4.48	1.44	280.	3.90	-52.48	9.55
8	15	642.25	165.38	5.10	1.84	280.	3.93	-49.97	11.95
8	30	688.73	203.54	5.90	2.31	280.	3.98	-47.35	14.25
8	45	719.15	240.30	6.70	2.79	280.	4.04	-44.62	16.47
9	0	748.64	272.72	7.50	3.26	280.	4.09	-41.76	18.53
9	15	778.31	307.68	8.16	3.63	280.	4.12	-38.78	20.56
9	30	801.97	342.67	8.69	3.88	280.	4.11	-35.67	22.43
9	45	819.72	371.29	9.21	4.13	280.	4.11	-32.43	24.15
10	0	831.56	398.32	9.74	4.38	280.	4.10	-29.06	25.72
10	15	838.31	421.38	10.28	4.64	280.	4.12	-25.55	27.13
10	30	845.46	442.85	10.83	4.91	280.	4.15	-21.92	28.37
10	45	857.74	461.93	11.38	5.19	280.	4.18	-18.18	29.43
11	0	856.20	477.83	11.93	5.46	280.	4.21	-14.34	30.29
11	15	856.20	488.16	12.35	5.68	280.	4.25	-10.42	30.95
11	30	864.51	496.12	12.69	5.83	280.	4.30	-6.43	31.40
11	45	869.94	502.47	13.01	5.98	280.	4.34	-2.41	31.64
12	0	870.43	504.86	13.34	6.13	280.	4.39	1.64	31.66
12	15	867.89	501.68	13.61	6.25	280.	4.39	5.67	31.46
12	30	858.73	495.91	13.84	6.35	280.	4.36	9.66	31.05
12	45	867.04	486.57	14.06	6.45	280.	4.32	13.60	30.43
13	0	854.51	473.85	14.29	6.55	280.	4.29	17.46	29.61
13	15	852.59	457.16	14.44	6.61	280.	4.30	21.22	28.59
13	30	848.46	436.48	14.51	6.64	280.	4.36	24.87	27.38
13	45	841.69	412.63	14.59	6.66	280.	4.42	28.40	26.00
14	0	825.63	384.80	14.66	6.69	280.	4.48	31.80	24.46
14	15	812.96	355.39	14.66	6.68	280.	4.52	35.06	22.77
14	30	790.99	321.99	14.59	6.53	280.	4.55	38.20	20.93
14	45	769.86	287.01	14.51	6.58	280.	4.57	41.20	18.96
15	0	747.05	251.24	14.44	6.53	280.	4.60	44.08	16.88
15	15	705.64	212.28	14.39	6.49	280.	4.57	46.84	14.69
15	30	649.02	170.15	14.36	6.46	280.	4.49	49.48	12.40
15	45	599.31	135.39	14.34	6.44	280.	4.42	52.01	10.01

TABLE 3. INSOLATION AND METEOROLOGICAL PARAMETERS AT 15 MINUTE INTERVALS FOR BARSTOW, CALIFORNIA

21 DECEMBER

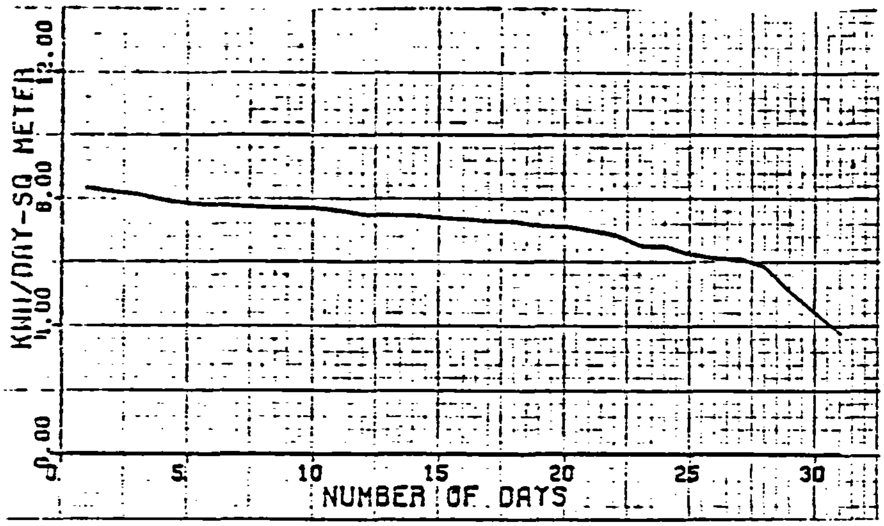
TIME (INTERVAL END, LST) HR	MIN	INSOLATION (KJ/M**2) DIRECT	HEMIS.	TEMPERATURE (DEG. C) DRY BULB	WET BULB	WINDS DIREC. (DEG.)	SPEED (M/S)	SOLAR POSITION (DEG.) AZIMUTH	ELEV.
16	0	518.89	91.43	14.31	6.41	280.	4.34	54.44	7.55
16	15	419.15	55.66	13.93	6.23	280.	4.23	56.77	5.01
16	30	143.66	20.57	13.18	5.88	280.	4.10	59.03	2.41
16	45	0.00	5.56	12.43	5.53	280.	3.97	0.00	-1.00
17	0	0.00	1.59	11.68	5.18	280.	3.84	0.00	-1.00
17	15	0.00	0.00	11.06	4.89	280.	3.74	0.00	-1.00
17	30	0.00	0.00	10.59	4.66	280.	3.68	0.00	-1.00
17	45	0.00	0.00	10.11	4.44	280.	3.61	0.00	-1.00
18	0	0.00	0.00	9.64	4.21	280.	3.55	0.00	-1.00
18	15	0.00	0.00	9.35	4.06	280.	3.48	0.00	-1.00
18	30	0.00	0.00	9.25	3.99	280.	3.40	0.00	-1.00
18	45	0.00	0.00	9.15	3.91	280.	3.31	0.00	-1.00
19	0	0.00	0.00	9.05	3.84	280.	3.23	0.00	-1.00
19	15	0.00	0.00	8.75	3.68	280.	3.21	0.00	-1.00
19	30	0.00	0.00	8.25	3.43	280.	3.26	0.00	-1.00
19	45	0.00	0.00	7.75	3.18	280.	3.31	0.00	-1.00
20	0	0.00	0.00	7.25	2.93	280.	3.36	0.00	-1.00
20	15	0.00	0.00	6.89	2.74	280.	3.38	0.00	-1.00
20	30	0.00	0.00	6.66	2.61	280.	3.38	0.00	-1.00
20	45	0.00	0.00	6.44	2.49	280.	3.38	0.00	-1.00
21	0	0.00	0.00	6.21	2.36	280.	3.38	0.00	-1.00
21	15	0.00	0.00	6.13	2.30	280.	3.38	0.00	-1.00
21	30	0.00	0.00	6.18	2.30	280.	3.37	0.00	-1.00
21	45	0.00	0.00	6.23	2.30	280.	3.37	0.00	-1.00
22	0	0.00	0.00	6.28	2.30	280.	3.36	0.00	-1.00
22	15	0.00	0.00	6.11	2.21	280.	3.40	0.00	-1.00
22	30	0.00	0.00	5.74	2.04	280.	3.49	0.00	-1.00
22	45	0.00	0.00	5.36	1.86	280.	3.58	0.00	-1.00
23	0	0.00	0.00	4.99	1.69	280.	3.67	0.00	-1.00
23	15	0.00	0.00	4.74	1.55	280.	3.74	0.00	-1.00
23	30	0.00	0.00	4.61	1.45	280.	3.79	0.00	-1.00
23	45	0.00	0.00	4.49	1.35	280.	3.85	0.00	-1.00

Table 4. Monthly Mean Daily Direct Insolation ($MJoules/m^2$)

	1975	1976
January		25.56
February		22.14
March		26.40
April		28.80
May		32.22
June		38.02
July		29.63
August	32.98	36.47
September	27.68	20.81
October	25.67	26.90
November	24.30	25.88
December	22.79	23.04

Figure 9. Monthly Solar Duration Curves (Number of Days Having a Daily Insolation Level Equal to or Greater Than a Specified Value).

9.1 JANUARY



9.2 FEBRUARY

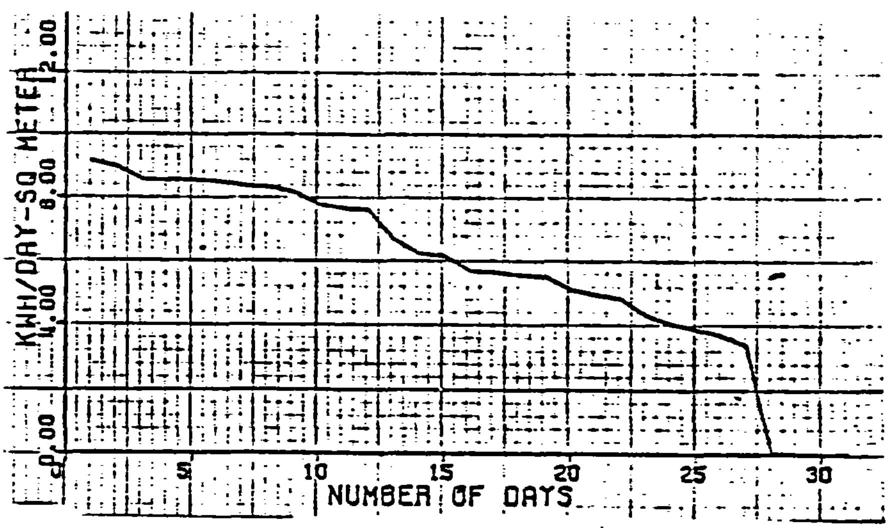
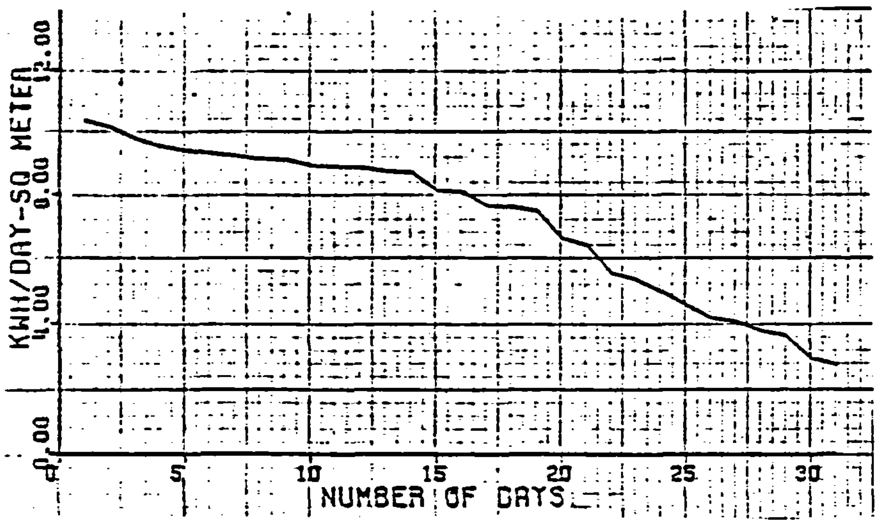


Figure 9. (Continued)

9.3 MARCH



9.4 APRIL

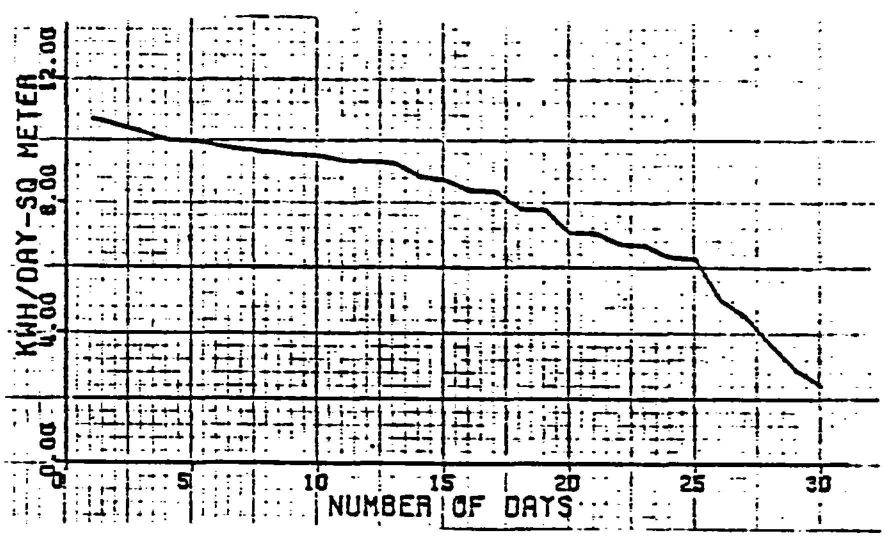
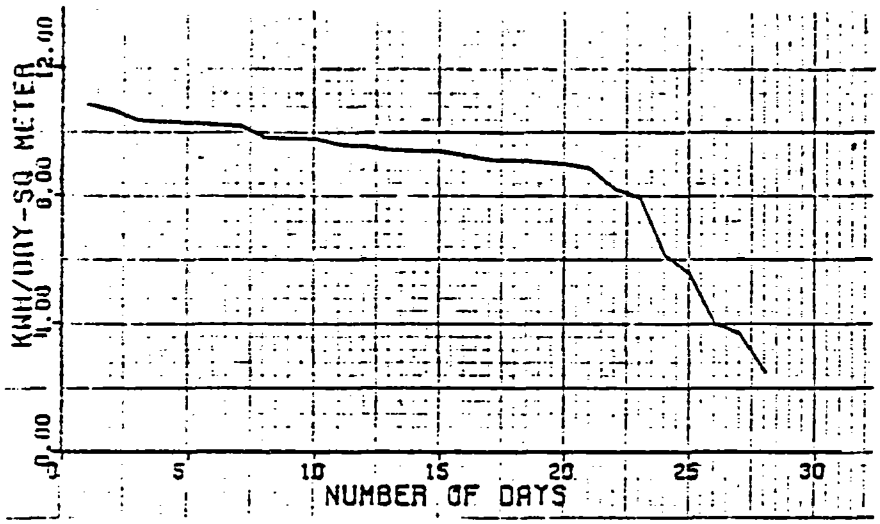


Figure 9. (Continued)

9.5 MAY



9.6 JUNE

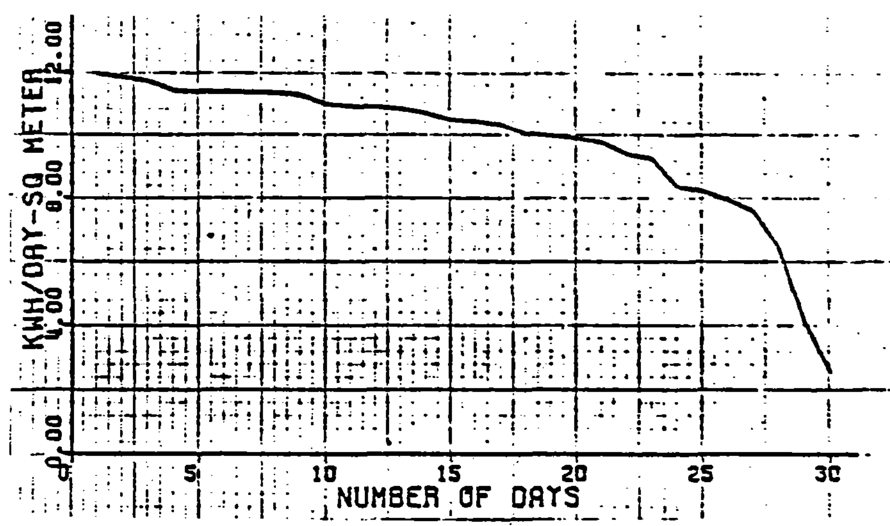
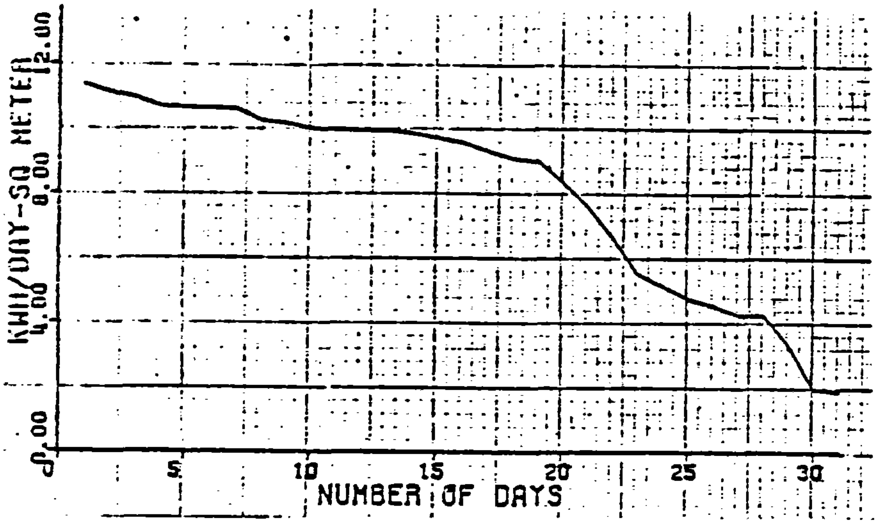


Figure 9. (Continued)

9.7 JULY



9.8 AUGUST

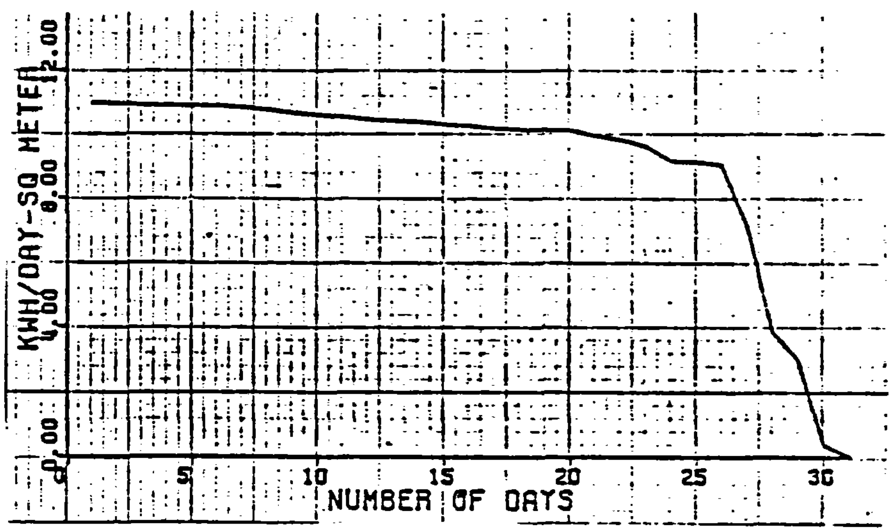
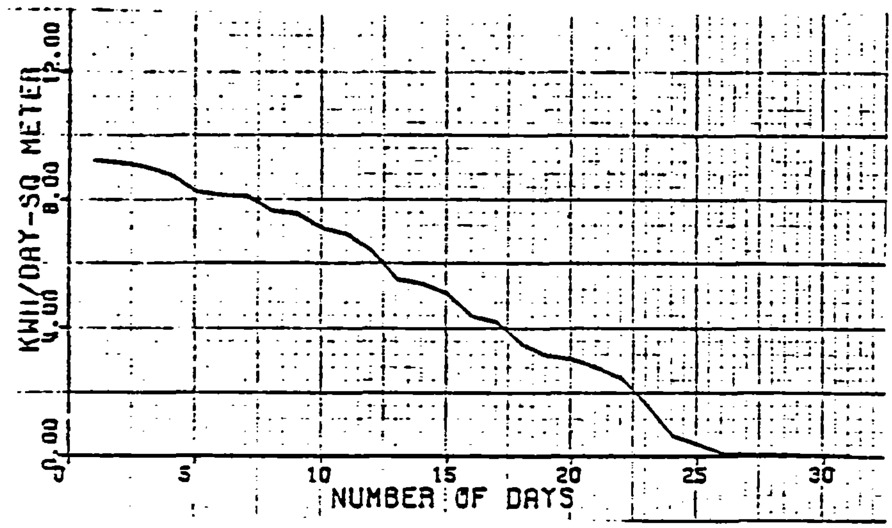


Figure 9. (Continued)

9.9 SEPTEMBER



9.10 OCTOBER

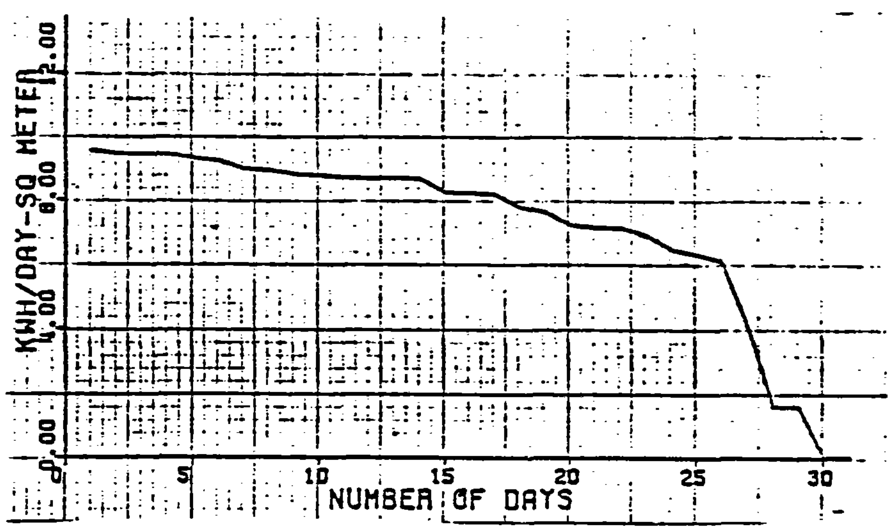
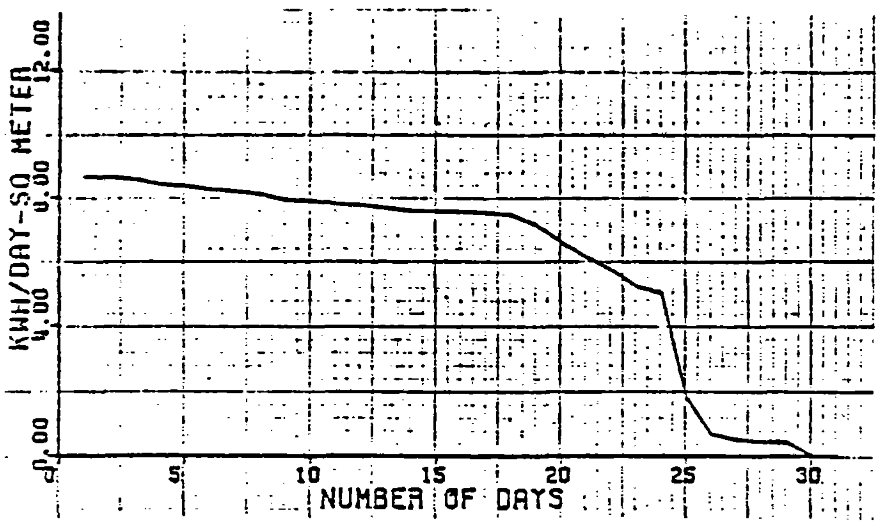


Figure 9. (Continued)

9.11 NOVEMBER



9.12 DECEMBER

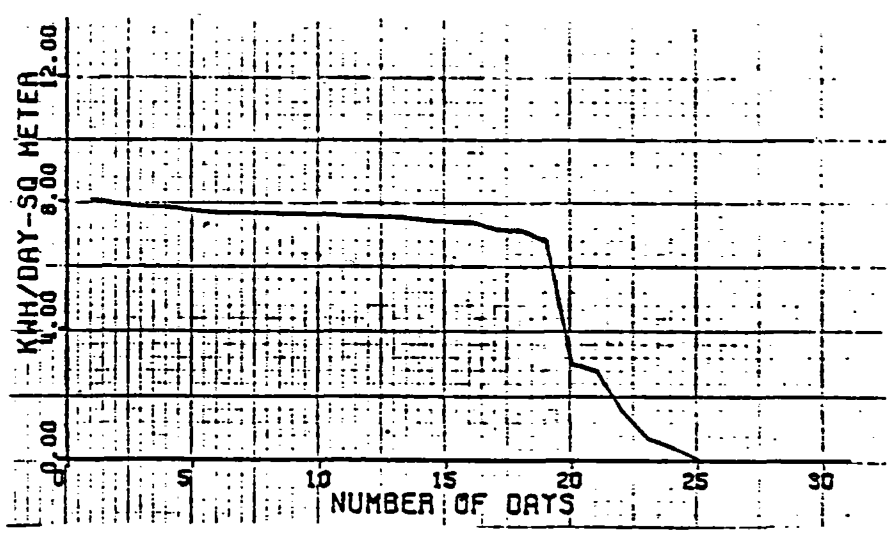
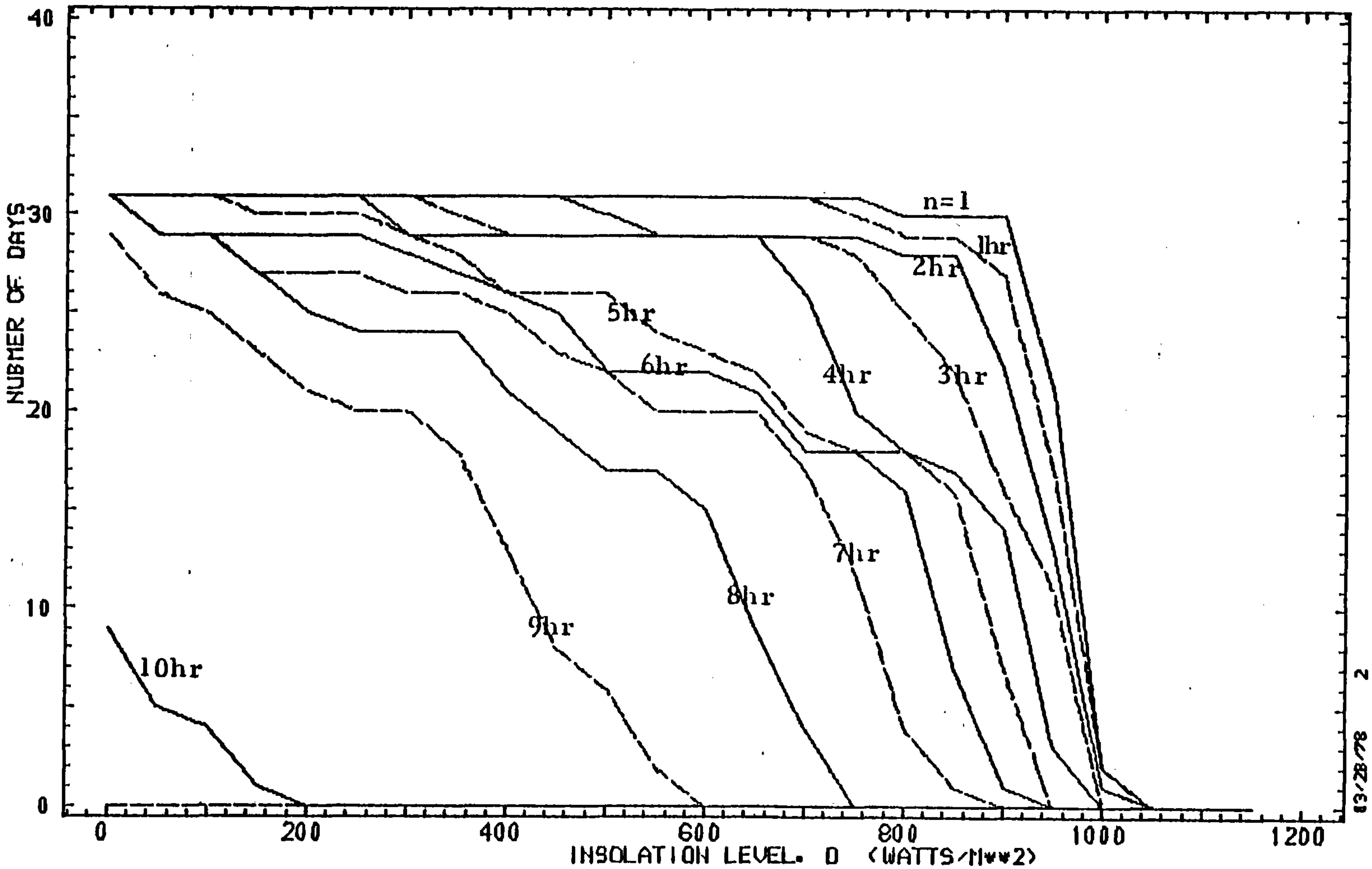
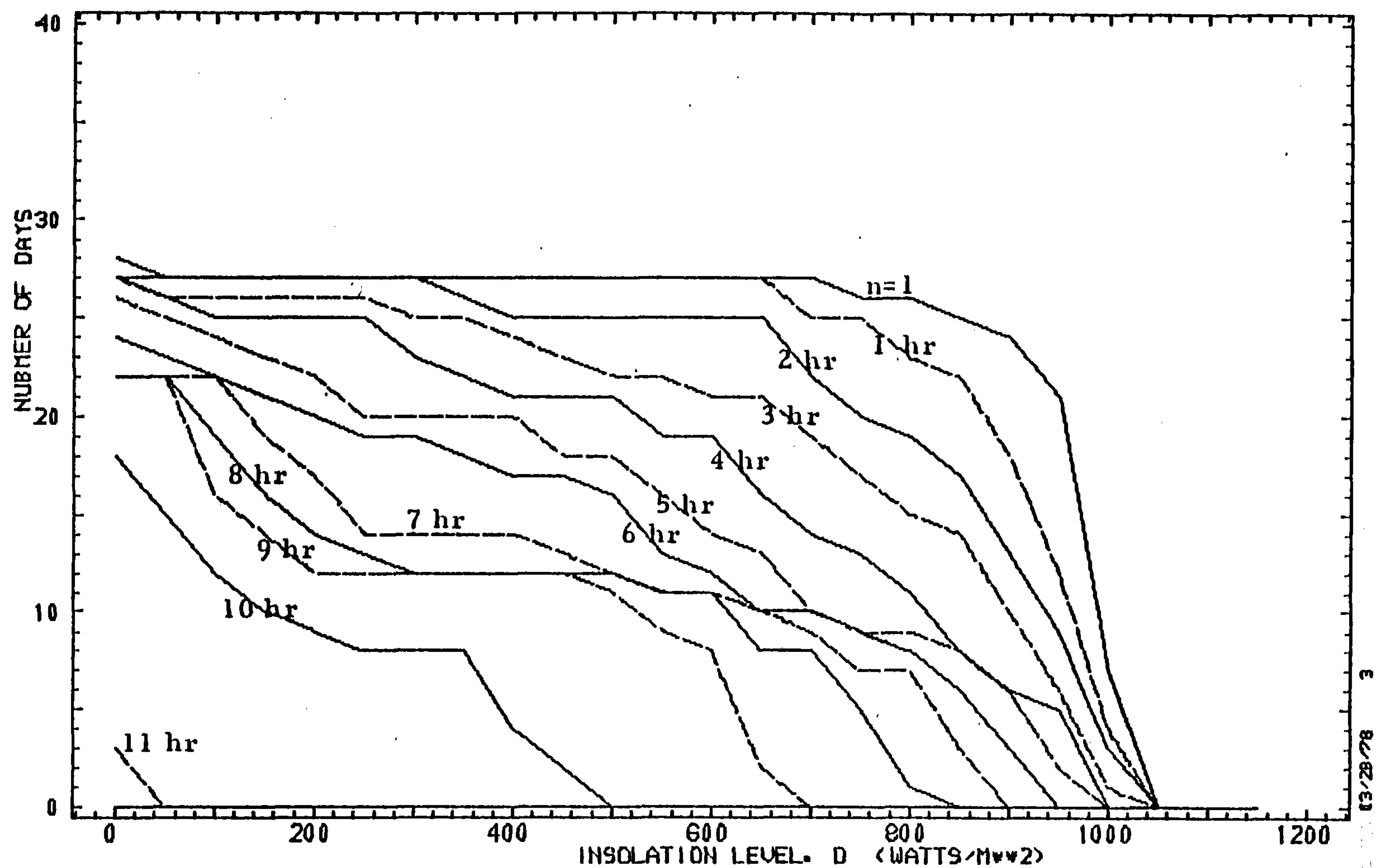


Figure10.1



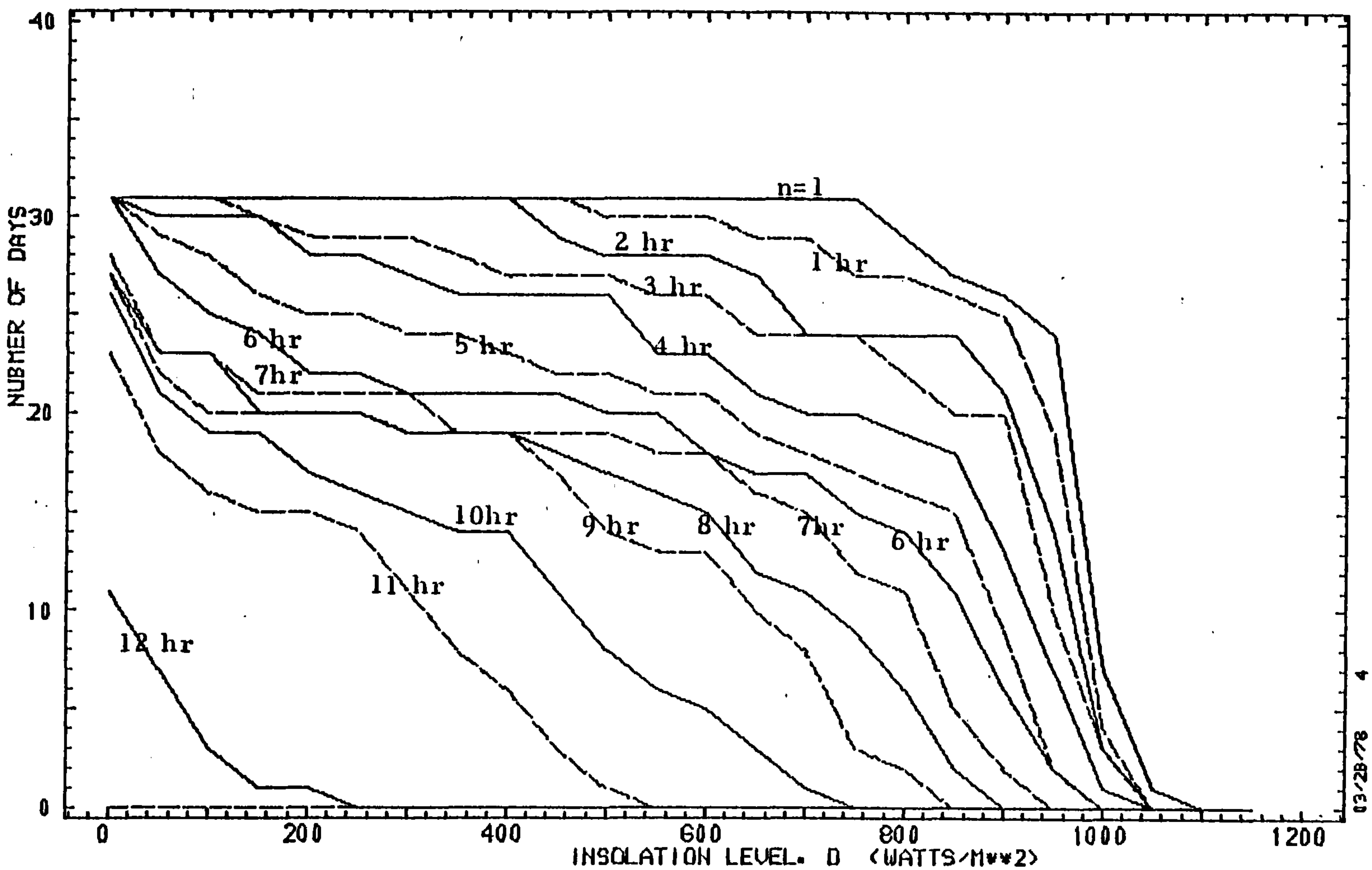
JANUARY DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure 10. 2



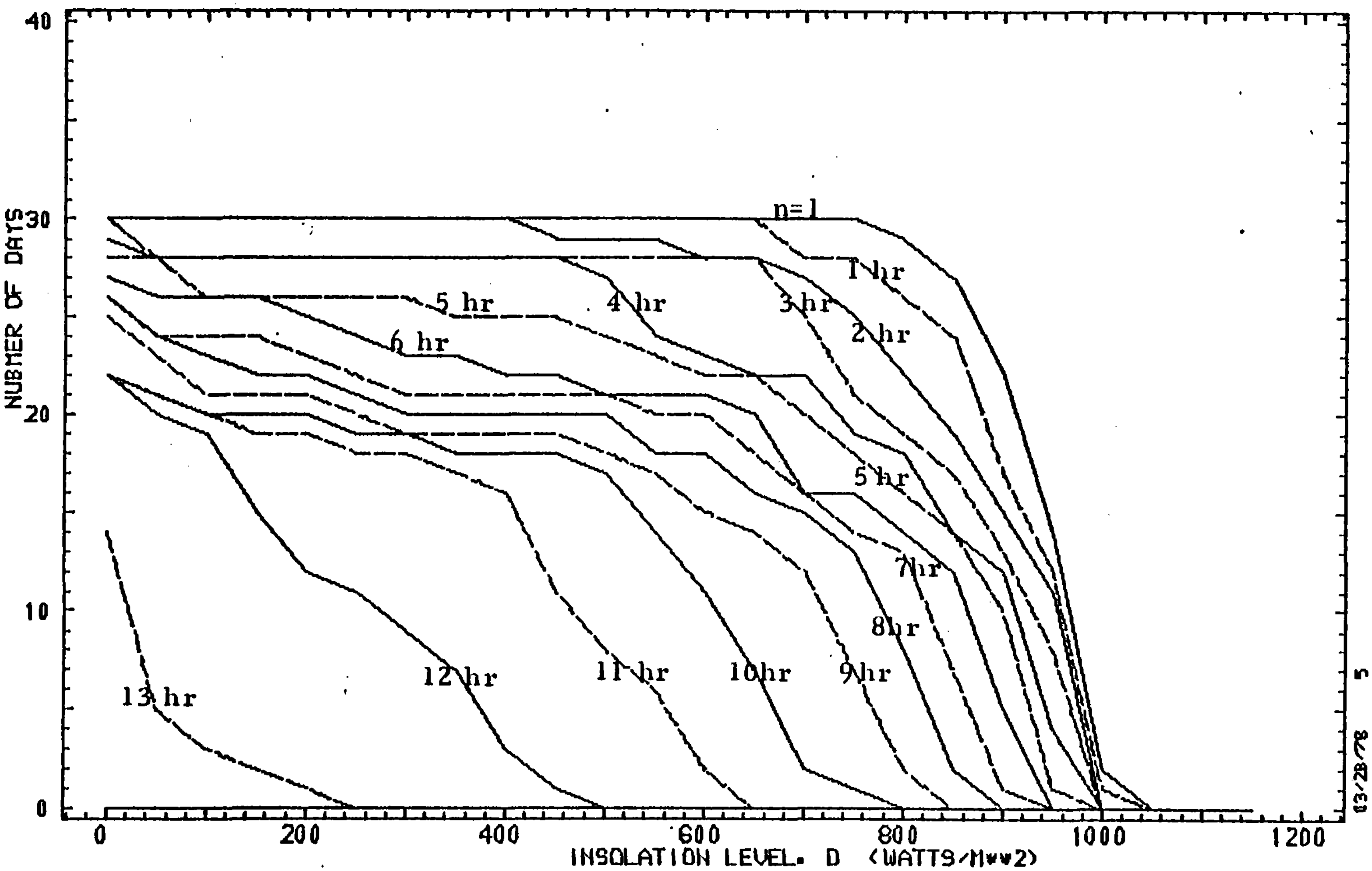
FEBRUARY DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure 10.3



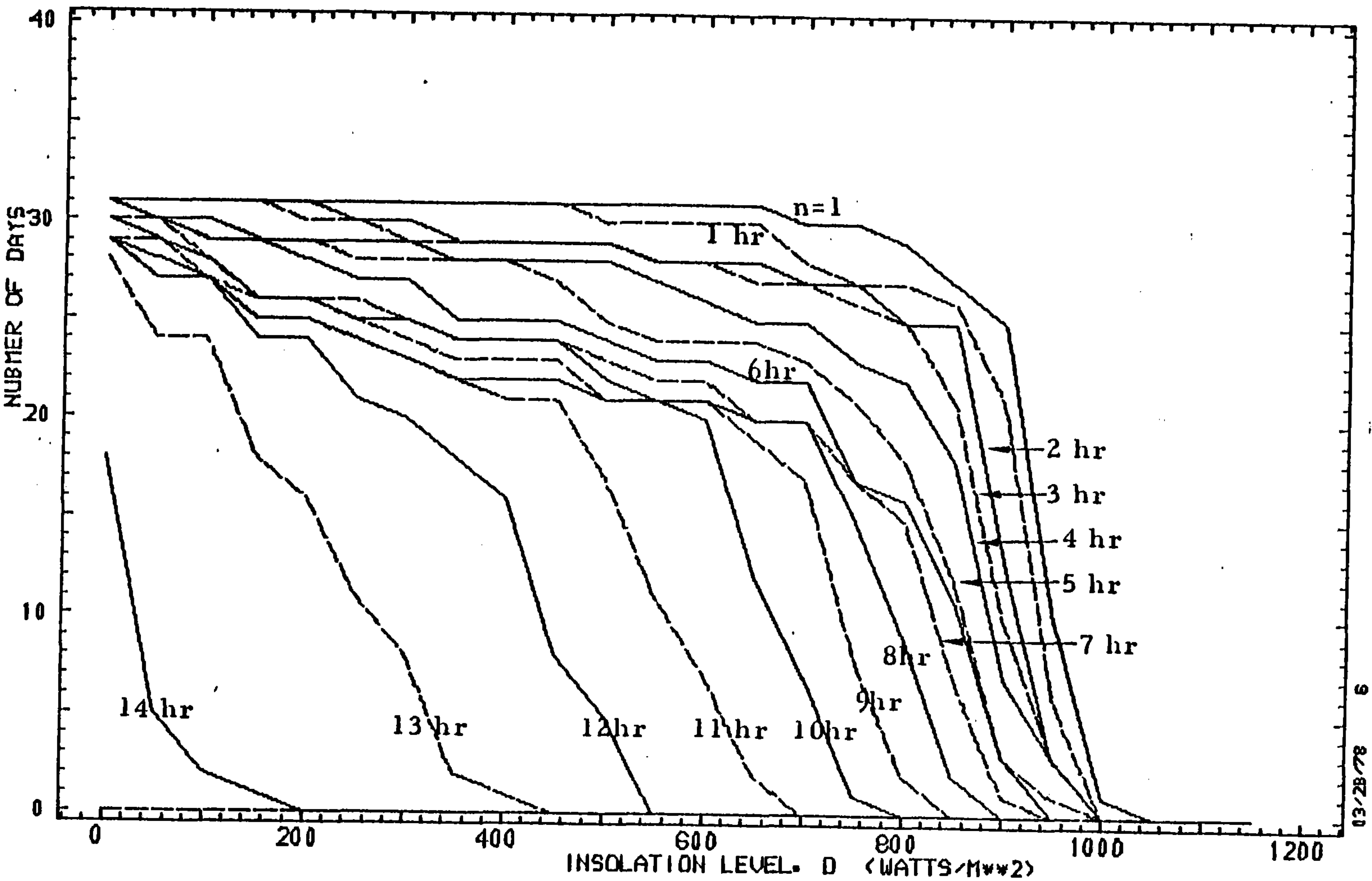
MARCH DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure 10.4



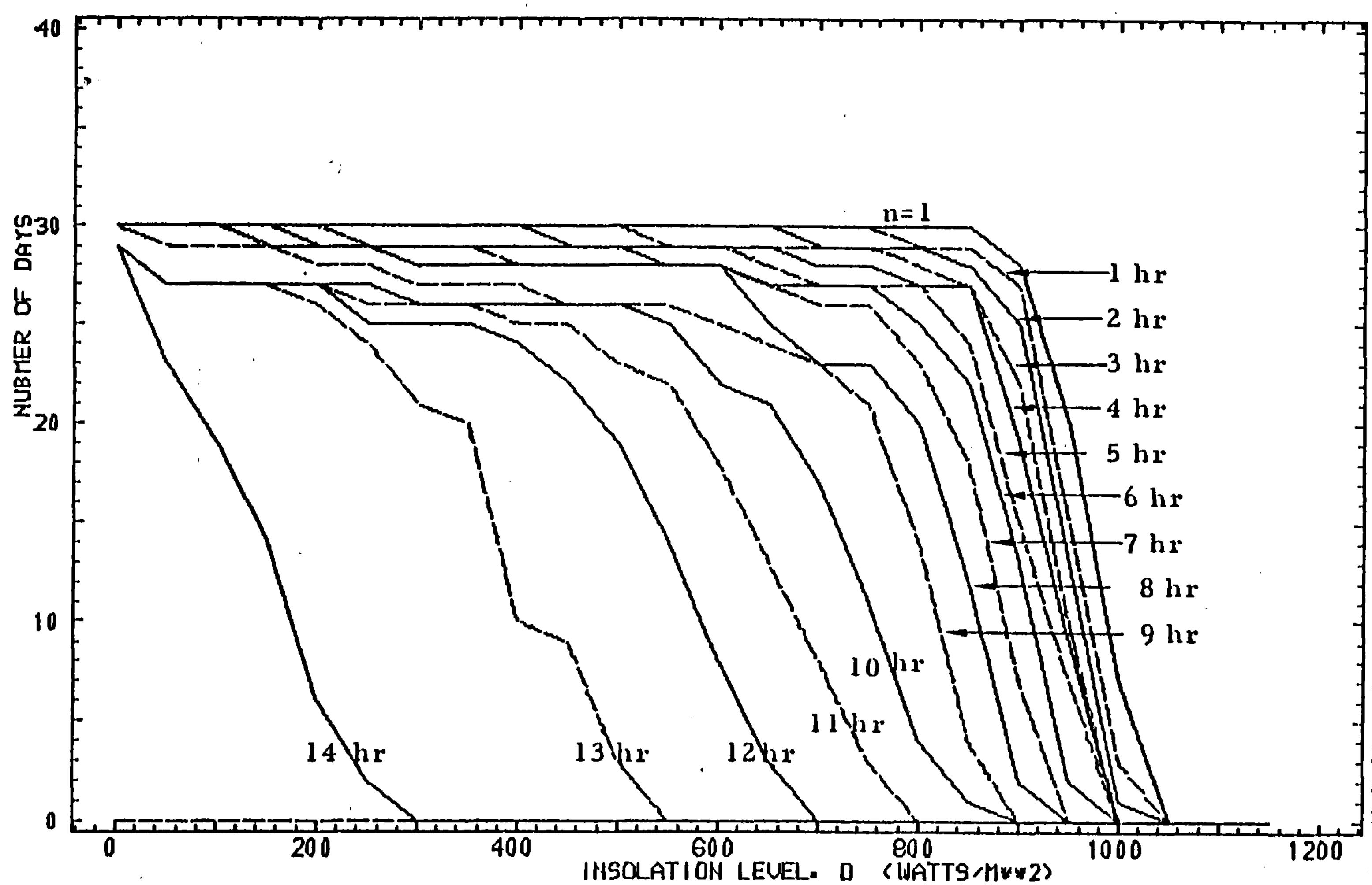
APRIL DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure 10.5



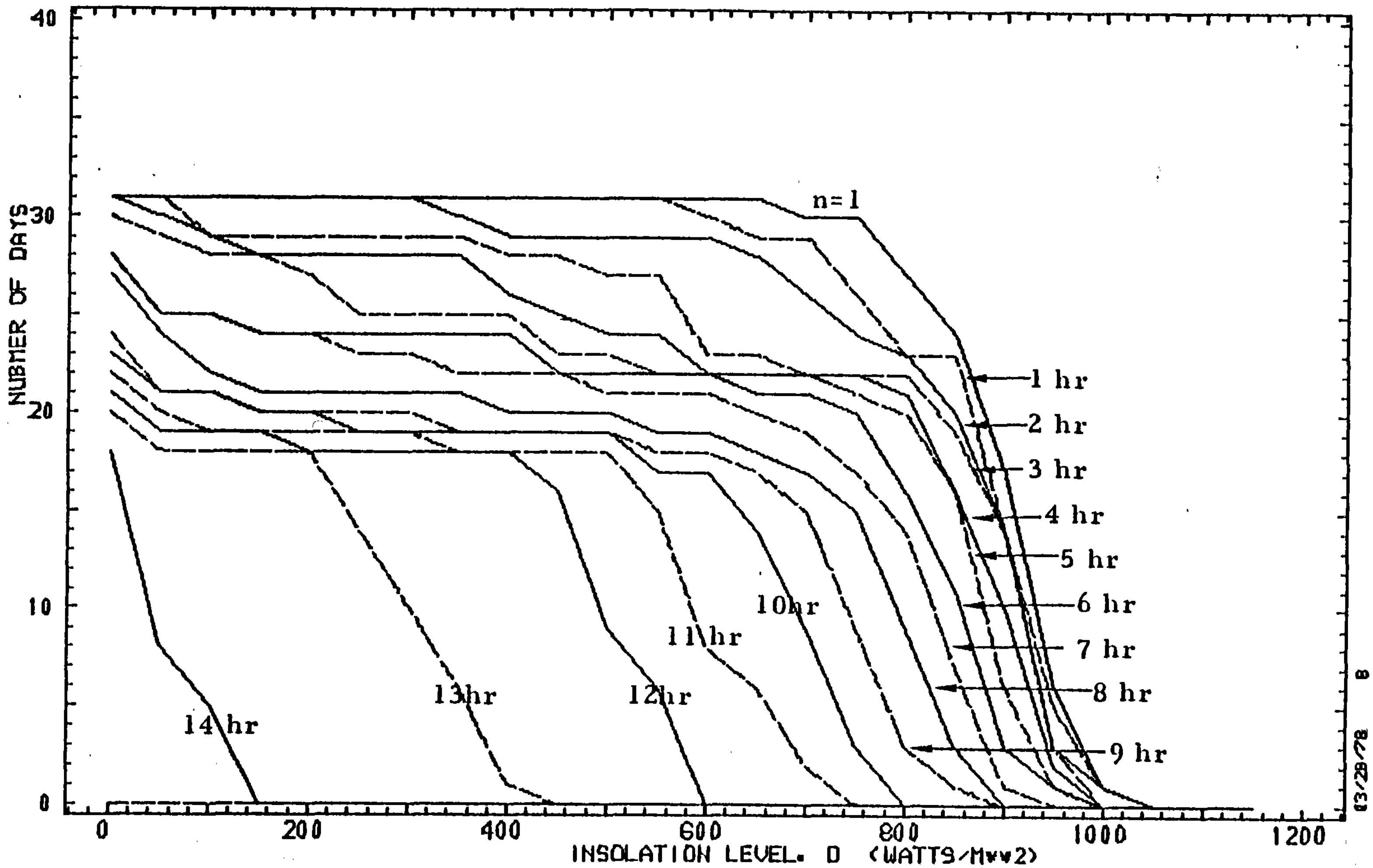
MAY DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure 10.6



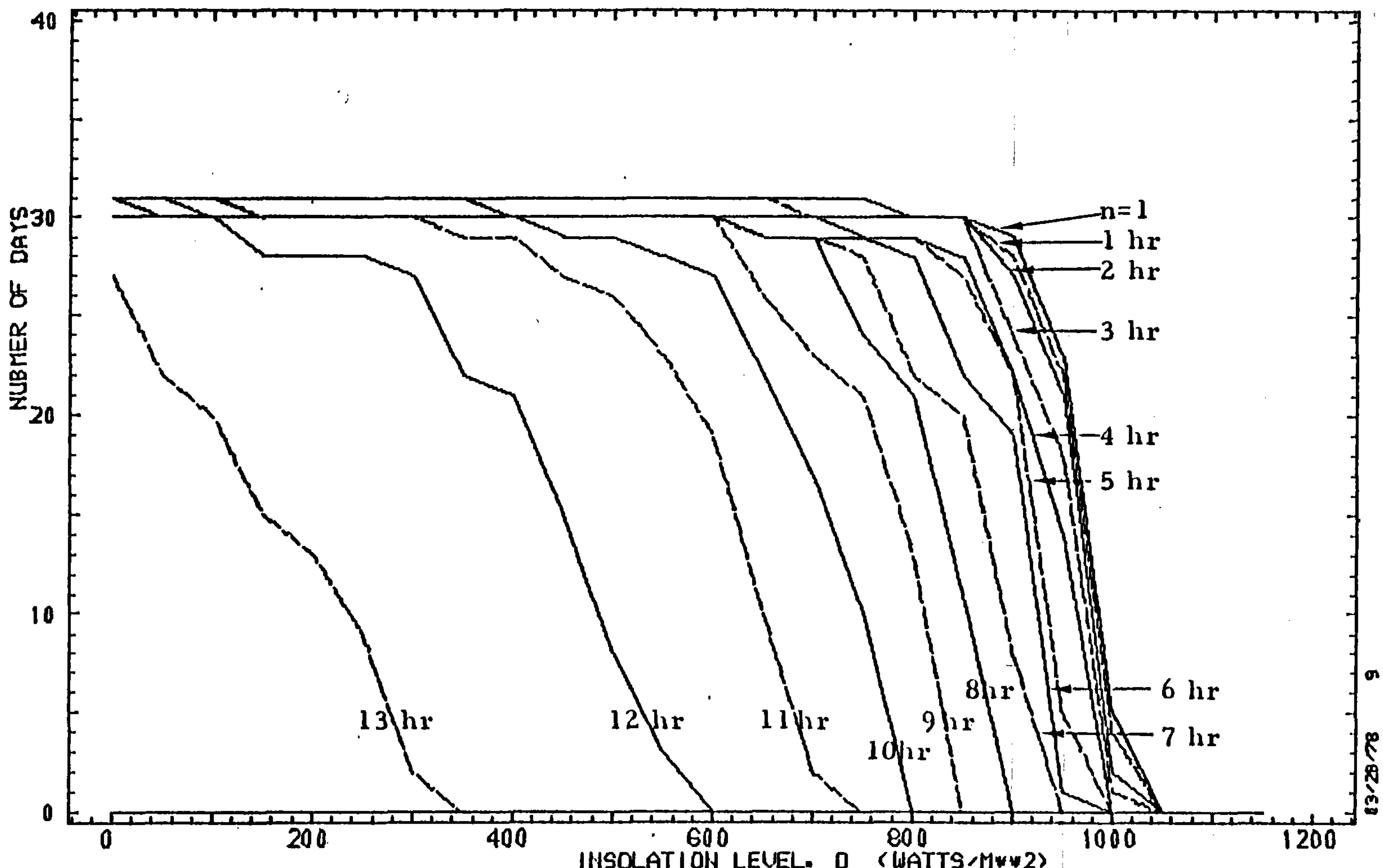
JUNE DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure10.7



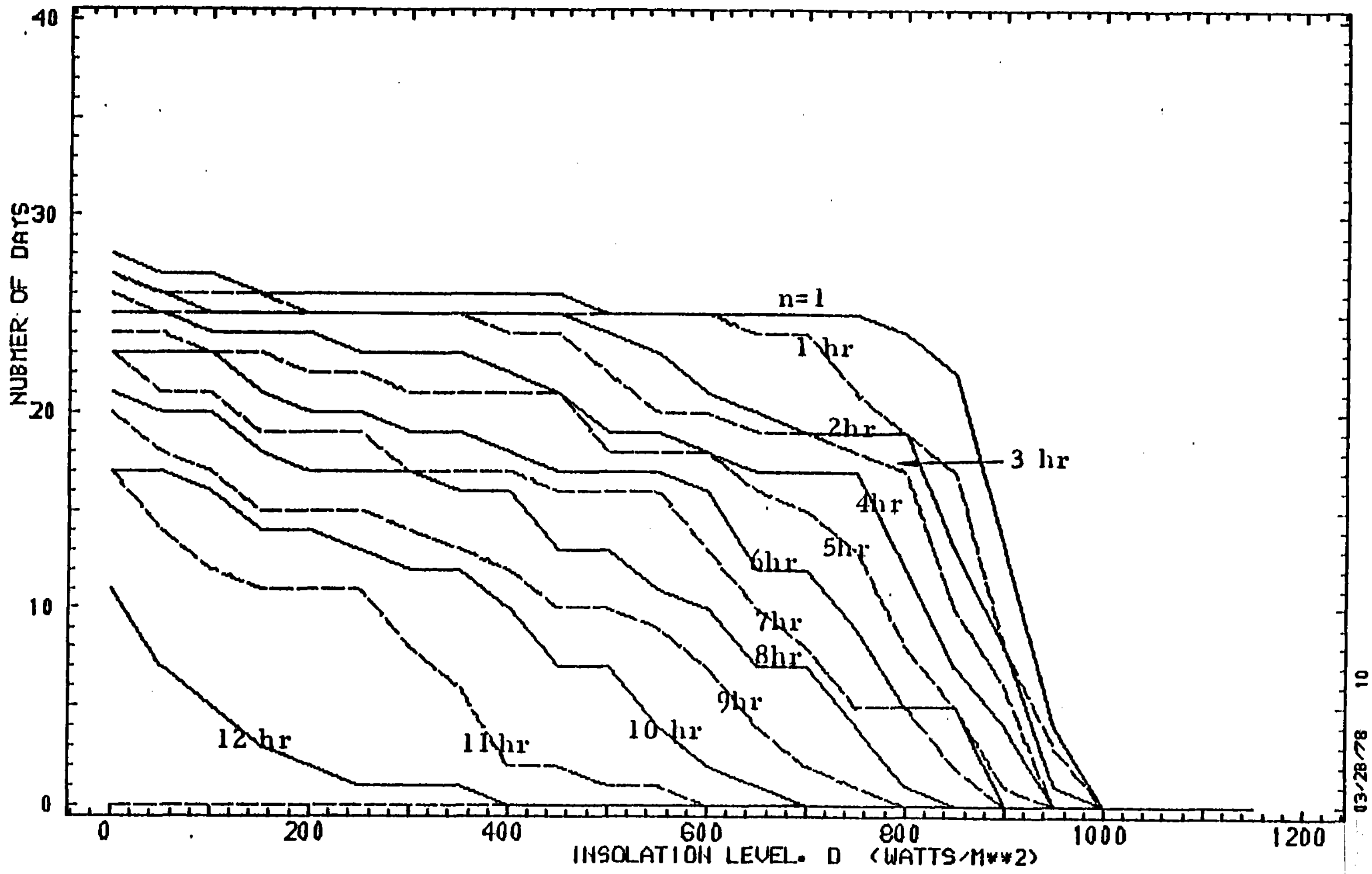
JULY DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure 10. 8



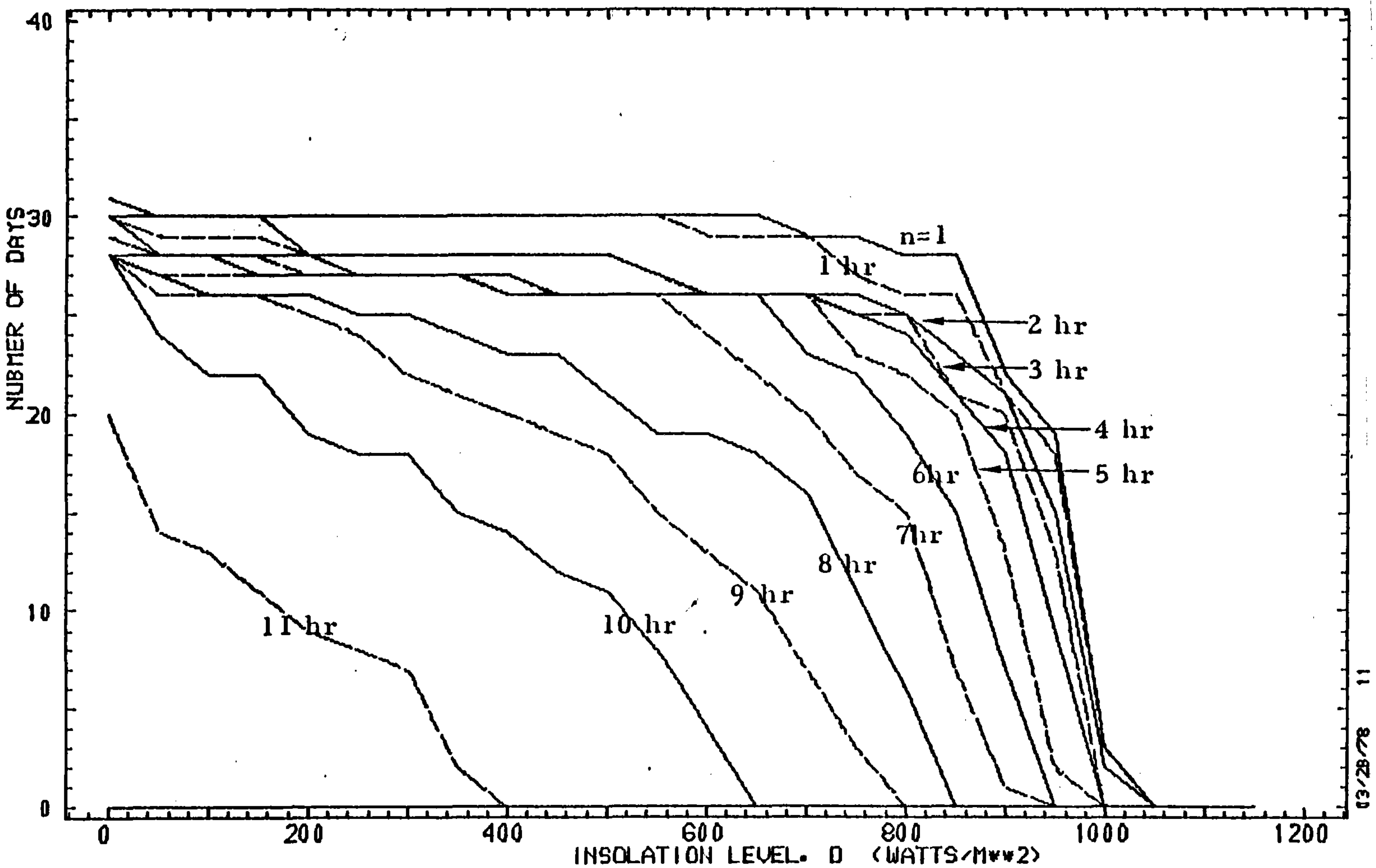
AUGUST DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure 10. 9



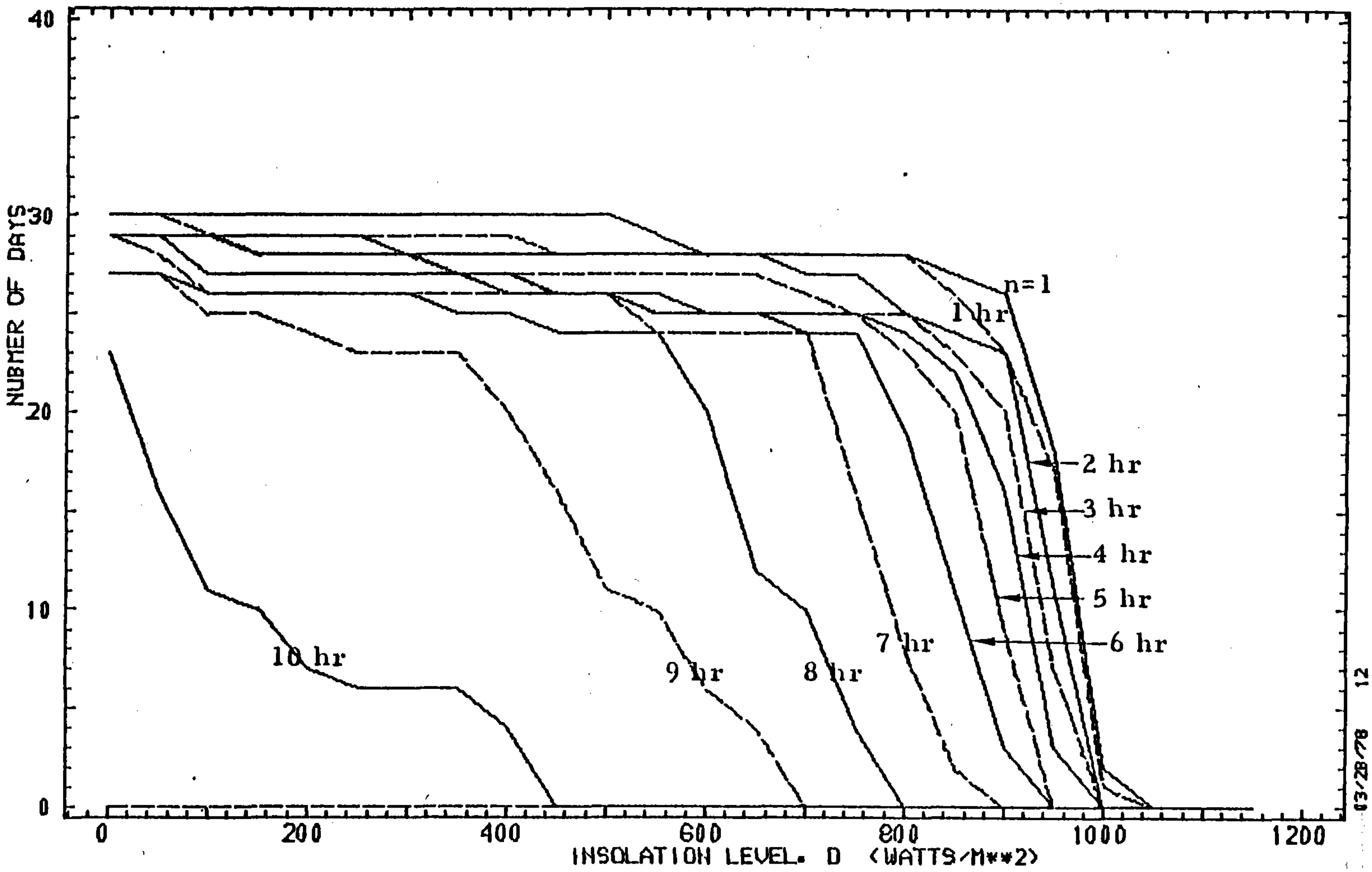
SEPTEMBER DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure 10.10



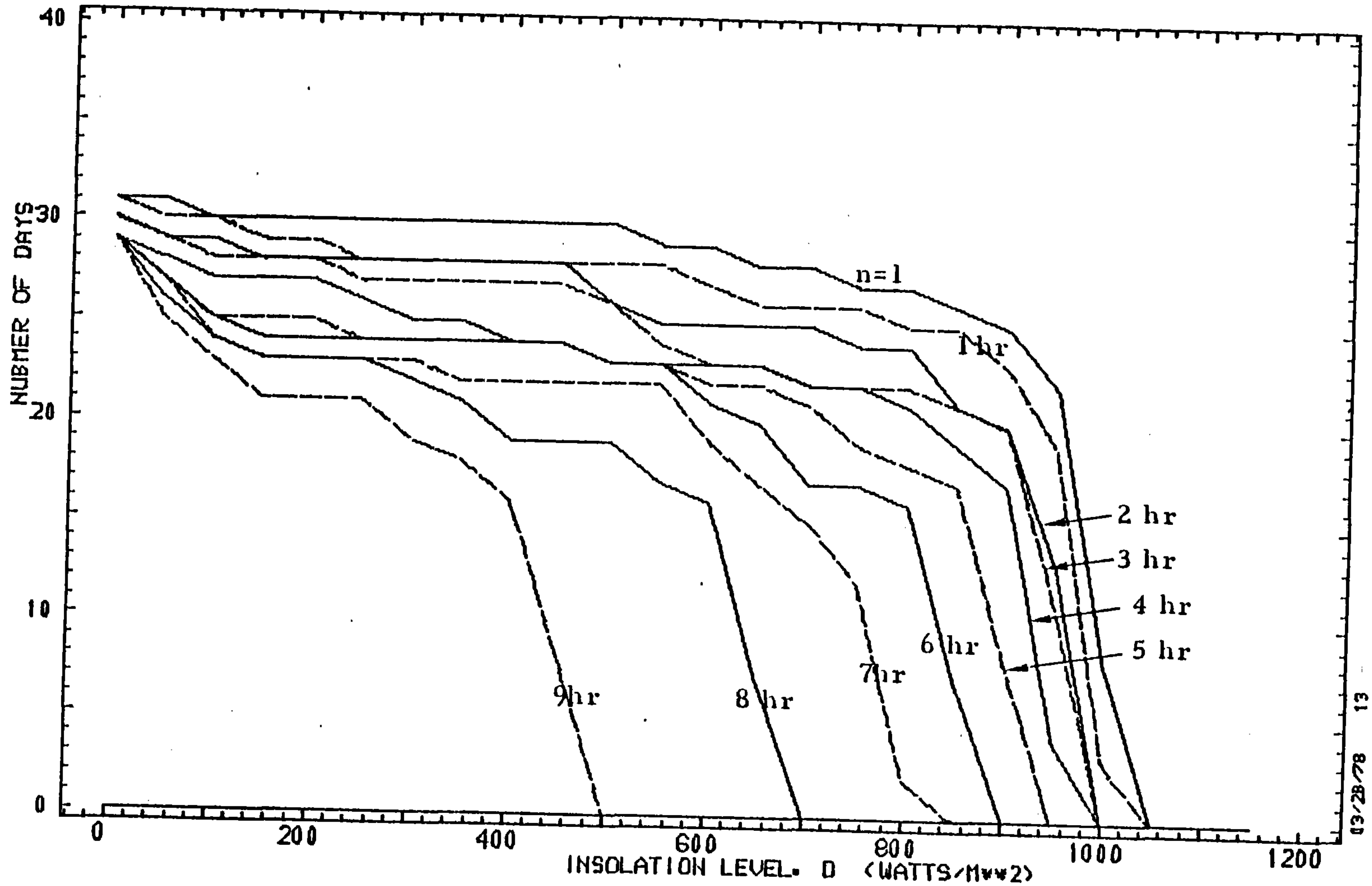
OCTOBER DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure10.11



NOVEMBER DAYS DIR. INSL. GT. D FOR N OR MORE INT.

Figure10.12



DECEMBER DAYS DIR. INSL. GT. D FOR N OR MORE INT.

TABLE 5. MEAN MONTHLY MINIMUM, AVERAGE, AND MAXIMUM DRY BULB TEMPERATURES FOR DAGGETT,1948-1976 (REF. 11)

TEMPERATURE (DEGREES C)

MONTH	MEAN MINIMUM	MEAN MAXIMUM	AVERAGE
1	-4.6	21.9	7.9
2	-1.6	24.5	11.0
3	.7	28.5	13.7
4	3.9	32.5	18.1
5	8.3	36.9	22.3
6	12.2	41.5	27.4
7	17.6	42.4	31.1
8	16.7	41.5	29.8
9	12.7	39.4	26.4
10	5.4	34.1	20.0
11	-.6	26.9	12.8
12	-3.7	21.8	8.5

TABLE 6. (REF. 11)
MONTHLY MEAN AND STANDARD DEVIATION OF THE DRY BULB TEMPERATURE (C)

HOUR	MONTH 1	2	3	4	5	6	7	8	9	10	11	12
0	4.3	7.2	9.6	14.2	17.5	22.8	26.7	25.4	22.1	16.0	8.7	5.1
1	4.7	7.5	9.9	13.3	17.7	22.3	26.3	25.3	21.8	15.5	9.2	5.0
2	3.5	6.2	8.4	12.7	15.9	20.8	24.7	23.6	20.5	14.7	7.8	4.2
3	3.1	5.8	7.9	12.1	15.2	19.9	23.8	22.9	19.9	14.1	7.4	3.9
4	3.6	6.2	8.4	11.5	15.6	19.8	23.9	23.0	19.7	14.0	8.0	4.0
5	2.6	5.0	6.9	10.9	14.4	19.1	22.9	21.7	18.7	13.2	6.7	3.3
6	2.2	4.6	6.9	11.8	16.1	20.9	24.4	22.7	19.2	13.2	6.4	2.9
7	2.9	5.9	9.1	13.5	18.8	23.4	26.8	25.2	21.3	14.8	8.1	3.4
8	4.7	8.4	11.9	17.3	21.4	26.5	29.9	28.3	25.1	18.7	11.0	6.0
9	7.9	11.3	14.6	19.9	23.6	28.7	32.2	30.9	28.0	21.8	14.0	9.2
10	10.0	13.3	16.3	20.5	25.4	30.2	33.8	32.7	29.4	23.1	16.0	10.8
11	12.2	15.5	18.2	23.4	27.0	32.1	35.6	34.4	31.9	25.9	18.3	13.7
12	13.5	16.8	19.4	24.5	28.2	33.3	36.7	35.6	33.1	27.0	19.5	15.1
13	14.4	17.4	20.1	24.2	29.2	34.2	37.6	36.6	33.3	27.1	20.0	15.2
14	14.7	18.0	20.6	25.7	29.3	34.8	37.9	36.9	34.2	28.0	20.4	16.2
15	14.4	17.8	20.4	25.5	29.3	34.9	37.9	36.7	33.6	27.1	19.5	15.8
16	14.3	17.4	20.2	24.1	29.3	34.7	38.2	36.8	33.0	26.5	19.1	14.4
17	11.3	15.4	18.3	23.2	27.1	33.0	36.7	35.0	31.6	24.5	15.9	11.6
18	9.4	13.1	16.2	21.4	25.5	31.3	35.2	33.7	29.7	22.5	14.2	9.9
19	9.0	12.5	15.4	19.4	24.4	30.0	34.2	32.7	28.4	21.1	13.4	8.9
20	7.0	10.4	13.4	18.2	21.9	27.6	31.8	30.6	26.6	19.6	11.6	7.4
21	6.1	9.4	12.2	17.0	20.7	26.3	30.4	29.0	25.1	18.3	10.6	6.6
22	6.3	9.4	12.2	15.9	20.5	25.6	29.7	28.4	24.3	17.5	10.6	6.3
23	4.8	7.9	10.5	15.0	18.6	24.0	27.9	26.4	22.8	16.5	9.1	5.3
STD DEV	4.4	4.0	4.2	4.5	4.5	4.3	2.8	3.0	3.7	4.2	4.2	3.9

STD DEV IS APPROXIMATELY CONSTANT FOR ALL HOURS

TABLE 7.1 YEARLY LIST OF MONTHLY MAXIMUM AND MINIMUM TEMPERATURES (REF. 11)

MAXIMUM VALUES OF DRY BULB TEMPERATURE (C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
	***	***	***	***	***	***	***	***	***	***	28	21	1948
	16	24	25	37	38	41	44	42	41	34	29	24	1949
	26	26	30	35	39	42	43	42	43	36	29	24	1950
	23	27	29	32	41	42	42	41	40	36	25	22	1951
	19	22	27	32	38	38	41	41	40	36	26	22	1952
	24	24	30	33	32	41	42	41	41	34	27	22	1953
	24	28	28	36	38	43	42	42	37	36	25	19	1954
	19	25	28	30	35	43	41	41	42	34	30	24	1955
	23	25	32	32	36	43	41	41	39	33	27	23	1956
	17	27	28	32	36	42	41	41	41	30	22	23	1957
	24	25	24	34	38	42	44	41	41	35	27	28	1958
	24	23	28	35	36	42	43	41	39	35	27	23	1959
	21	23	31	34	39	41	43	42	40	34	29	20	1960
	22	25	29	36	34	44	44	41	37	34	26	19	1961
	25	24	29	34	34	40	40	41	39	34	29	23	1962
	22	28	28	31	36	39	41	39	39	36	27	21	1963
	19	22	28	33	35	39	41	41	36	37	24	24	1964
	24	25	25	33	33	37	40	41	36	34	28	18	1965
	17	19	32	33	36	40	42	42	38	31	27	22	1966
	22	24	28	26	39	42	43	41	36	33	29	19	1967
	20	26	29	32	39	42	42	39	39	31	25	18	1968
	23	18	32	32	39	39	42	43	41	34	27	24	1969
	23	23	29	31	37	43	43	43	41	34	25	19	1970
	27	27	31	31	34	41	43	43	42	36	24	17	1971
	19	29	32	32	37	46	43	43	36	31	23	23	1972
	18	20	22	32	37	43	44	41	38	33	29	22	1973
	23	25	29	31	41	43	43	40	41	36	25	21	1974
	26	26	25	27	38	41	44	43	39	34	28	25	1975
	24	25	29	33	38	43	44	44	42	33	29	21	1976
MEAN	21.9	24.5	28.5	32.5	36.9	41.5	42.4	41.5	39.4	34.1	26.9	21.8	

TABLE 7.2 YEARLY LIST OF MONTHLY MAXIMUM AND MINIMUM TEMPERATURES (REF. 11)

MINIMUM VALUES OF DRY BULB TEMPERATURE (C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
	***	***	***	***	***	***	***	***	***	***	-2	-7	1948
	-8	-8	2	4	8	12	17	13	10	0	2	-8	1949
	-10	-4	-2	3	5	8	19	16	9	6	-2	1	1950
	-3	-2	-2	3	7	11	18	13	13	5	-1	-6	1951
	-5	0	0	4	11	11	16	13	10	10	-2	-3	1952
	0	-6	-2	0	6	9	17	13	12	3	-1	-7	1953
	-3	0	-2	6	6	8	18	13	12	3	-1	-6	1954
	-3	-6	-2	1	6	10	14	17	11	7	-1	-2	1955
	-1	-4	0	2	6	13	14	16	13	2	-4	-8	1956
	-4	-2	1	2	8	12	17	13	13	6	-5	-2	1957
	-1	2	-1	2	8	12	17	21	9	4	-3	-2	1958
	-4	-1	2	8	7	15	16	13	11	8	0	-1	1959
	-6	0	2	5	7	16	19	14	14	7	-1	-4	1960
	-4	0	1	5	9	11	16	17	12	4	-1	-5	1961
	-7	-6	-1	7	7	12	18	17	14	8	1	-5	1962
	-12	4	1	2	7	10	17	14	13	8	0	-3	1963
	-5	-3	0	4	6	11	16	14	11	1	-2	-4	1964
	-4	-3	0	0	8	10	17	18	11	8	0	-3	1965
	-4	-2	-2	3	11	14	17	18	13	6	0	-4	1966
	-5	-1	2	2	6	9	20	22	16	5	2	-2	1967
	-2	2	4	4	10	13	21	15	12	8	-1	-8	1968
	-3	-2	2	6	11	15	18	20	16	7	0	-1	1969
	-7	1	2	3	10	13	21	22	11	1	2	0	1970
	-8	-3	0	6	10	11	19	20	11	-1	1	-2	1971
	-4	-3	4	5	9	14	18	18	13	8	2	-6	1972
	-4	1	4	4	9	16	20	15	12	8	2	1	1973
	-7	0	3	8	11	17	19	21	19	8	1	-2	1974
	-2	-1	1	5	9	14	18	13	18	4	-2	-6	1975
	-4	1	2	6	13	14	16	17	16	8	-2	-1	1976
MEAN	-4.6	-1.6	.7	3.9	8.3	12.2	17.6	16.7	12.7	5.4	-.5	-3.7	

TABLE 8. MAXIMUM AND MINIMUM DRY BULB TEMPERATURES OBSERVED DURING A 29 YEAR PERIOD AT DAGGETT)

MONTH	MAXIMUM (C)	HOURS AT MAXIMUM VALUES	SECOND MAXIMUM (C)	HOURS AT SECOND MAX VALUES	MINIMUM (C)	HOURS AT MINIMUM VALUES	SECOND MINIMUM (C)	HOURS AT SECOND MIN VALUES
1	27	2	26	3	-12	2	-11	1
2	29	1	28	2	- 8	1	- 6	7
3	32	5	31	15	- 2	11	- 1	22
4	37	1	36	10	0	4	1	5
5	41	4	40	2	5	2	6	24
6	46	1	44	4	8	5	9	12
7	44	15	43	57	14	3	16	19
8	44	1	43	8	13	11	14	22
9	43	2	42	14	9	4	10	3
10	37	1	36	27	- 1	1	0	3
11	30	2	29	17	- 5	1	- 4	5
12	28	1	26	6	- 8	5	- 7	7

TABLE 9. MEAN MONTHLY MINIMUM, AVERAGE, AND MAXIMUM WET BULB TEMPERATURES FOR DAGGETT, 1948-1976 (REF. 11)

TEMPERATURE (DEGREES C)

MONTH	MEAN MINIMUM	MEAN MAXIMUM	AVERAGE
1	-6.5	12.0	3.2
2	-5.5	12.5	4.9
3	-2.3	13.6	6.4
4	.8	15.3	9.1
5	3.4	18.1	11.7
6	5.9	20.7	14.3
7	9.1	22.9	17.0
8	8.9	23.0	16.7
9	5.9	21.5	14.6
10	.8	17.8	10.8
11	-2.8	14.4	6.3
12	-5.5	12.1	3.5

TABLE 10. (REF. 11)
MONTHLY MEAN AND STANDARD DEVIATION OF THE WET BULB TEMPERATURE (C)

	MONTH											
HOUR	1	2	3	4	5	6	7	8	9	10	11	12
0	1.2	3.1	4.5	7.6	9.8	12.5	15.1	14.8	12.8	9.1	4.2	1.6
1	1.4	3.2	4.9	7.1	10.0	12.5	15.2	15.1	13.0	8.8	4.6	1.6
2	.8	2.5	3.8	7.0	9.1	11.6	14.3	14.0	12.2	8.5	3.7	1.1
3	.5	2.3	3.6	6.7	8.8	11.3	13.9	13.8	11.9	8.2	3.5	.9
4	.8	2.5	4.0	6.2	9.1	11.5	14.2	14.2	12.2	8.0	4.0	1.0
5	.2	1.8	3.1	6.1	8.5	11.0	13.6	13.3	11.4	7.7	3.1	.5
6	.0	1.5	3.0	6.7	9.4	12.1	14.5	13.9	11.7	7.7	2.9	.3
7	.3	2.4	4.5	7.5	10.8	13.4	15.8	15.4	13.1	8.6	4.0	.6
8	1.5	3.9	5.8	9.4	11.9	14.6	17.0	16.5	14.6	10.7	5.5	2.2
9	3.5	5.4	7.2	10.5	12.8	15.4	17.9	17.6	15.8	12.2	7.1	4.1
10	4.5	6.4	8.0	10.3	13.3	15.9	18.5	18.2	16.4	12.6	8.3	5.0
11	5.6	7.3	8.6	11.5	13.7	16.4	18.9	18.7	17.0	13.7	9.1	6.4
12	6.2	7.8	9.0	11.9	13.9	16.5	19.2	19.0	17.3	14.0	9.6	6.9
13	6.5	8.1	9.3	11.3	14.1	16.7	19.5	19.4	17.4	13.8	9.9	7.0
14	6.7	8.1	9.4	12.0	14.1	16.7	19.4	19.2	17.5	14.2	9.9	7.4
15	6.5	8.1	9.2	11.8	13.9	16.7	19.3	19.0	17.1	13.7	9.5	7.1
16	6.4	8.0	9.1	11.1	13.9	16.5	19.4	19.1	16.9	13.3	9.4	6.6
17	5.0	7.1	8.3	10.9	13.0	15.9	18.6	18.2	16.2	12.6	7.8	5.2
18	4.1	6.0	7.4	10.3	12.5	15.3	18.1	17.6	15.4	11.7	6.9	4.3
19	3.8	5.8	7.2	9.3	12.3	14.9	17.9	17.5	15.2	11.0	6.7	3.8
20	2.8	4.8	6.2	9.1	11.4	14.2	17.0	16.6	14.4	10.5	5.6	2.9
21	2.3	4.3	5.7	8.7	11.0	13.8	16.6	16.0	13.8	9.9	5.2	2.5
22	2.3	4.3	5.9	8.1	11.1	13.7	16.6	16.2	13.8	9.5	5.3	2.4
23	1.6	3.4	4.9	7.9	10.2	13.0	15.7	15.0	13.0	9.2	4.4	1.7
STD DEV	3.6	3.4	2.8	2.7	2.6	2.2	2.4	2.6	2.7	3.0	3.3	3.3

STD DEV IS APPROXIMATELY CONSTANT FOR ALL HOURS

TABLE 11. RELATIVE WIND FREQUENCY DISTRIBUTION (DEC,JAN,FEB)

SPEED (METERS/SEC)

DIRECTION	0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1+	TOTAL
N	0.005512	0.005465	0.003639	0.001945	0.000324	0.000000	0.016904
NNE	0.004126	0.003334	0.003659	0.003195	0.001065	0.000000	0.015380
NE	0.009012	0.008568	0.009494	0.003427	0.000556	0.000000	0.031056
ENE	0.009750	0.009031	0.008336	0.001714	0.000046	0.000000	0.028876
E	0.021284	0.021164	0.021164	0.003473	0.000509	0.000000	0.067596
ESE	0.013366	0.012875	0.008753	0.001158	0.000463	0.000046	0.036661
SE	0.014937	0.014820	0.005233	0.000278	0.000000	0.000000	0.035268
SSE	0.004927	0.004677	0.001621	0.000046	0.000000	0.000000	0.011272
S	0.005479	0.005326	0.001389	0.000139	0.000000	0.000000	0.012333
SSW	0.002303	0.001899	0.001343	0.000509	0.000278	0.000093	0.006425
SW	0.008453	0.008012	0.005233	0.003705	0.004539	0.002223	0.032164
WSW	0.014478	0.014079	0.018663	0.014264	0.017784	0.008799	0.088066
W	0.043107	0.045478	0.080072	0.039504	0.017135	0.011207	0.236503
WNW	0.048694	0.052239	0.107396	0.052008	0.012550	0.003288	0.276175
NW	0.023567	0.023341	0.030010	0.010374	0.001250	0.000139	0.088681
NNW	0.006033	0.005372	0.003936	0.001158	0.000139	0.000000	0.016639
TOT	0.235029	0.235678	0.309961	0.136896	0.056639	0.025795	

TABLE 12. RELATIVE WIND FREQUENCY DISTRIBUTION (MAR,AP,MAY)

SPEED (METERS/SEC)

DIRECTION	0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1+	TOTAL
N	0.003574	0.004893	0.005300	0.002175	0.000362	0.000091	0.016394
NNE	0.003203	0.004258	0.005210	0.003081	0.000453	0.000227	0.016432
NE	0.005644	0.008562	0.010238	0.002220	0.000181	0.000000	0.026845
ENE	0.004250	0.005436	0.008834	0.003081	0.000045	0.000000	0.021646
E	0.005878	0.008472	0.013681	0.006161	0.000815	0.000045	0.035052
ESE	0.003162	0.004802	0.006206	0.002763	0.000725	0.000000	0.017659
SE	0.003528	0.004938	0.003941	0.000906	0.000362	0.000045	0.013721
SSE	0.001821	0.002628	0.001087	0.000680	0.000317	0.000045	0.006578
S	0.001360	0.002084	0.001133	0.000498	0.000272	0.000045	0.005392
SSW	0.000805	0.001133	0.001178	0.000951	0.001133	0.000181	0.005380
SW	0.002210	0.003171	0.003987	0.008970	0.015403	0.008426	0.042166
WSW	0.009657	0.005527	0.016852	0.042176	0.063468	0.028087	0.159768
W	0.008862	0.013092	0.071668	0.074613	0.058576	0.031485	0.258296
WNW	0.011484	0.018076	0.094364	0.094863	0.032618	0.011779	0.263183
NW	0.008103	0.011914	0.040455	0.026774	0.003624	0.000951	0.091821
NNW	0.003449	0.004802	0.007565	0.003398	0.000453	0.000000	0.019667
TOT	0.070988	0.103787	0.291700	0.273308	0.178807	0.081408	

TABLE 13. RELATIVE WIND FREQUENCY DISTRIBUTION (JUNE, JULY, AUG)

SPEED (METERS/SEC)

DIRECTION	0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1+	TOTAL
N	0.005435	0.007435	0.007526	0.001451	0.000181	0.000000	0.022028
NNE	0.002768	0.004670	0.004080	0.000453	0.000000	0.000045	0.012016
NE	0.005963	0.009430	0.009294	0.001360	0.000363	0.000000	0.026409
ENE	0.003581	0.005667	0.007888	0.002085	0.000635	0.000000	0.019857
E	0.004685	0.007344	0.010427	0.005848	0.001451	0.000181	0.029937
ESE	0.002000	0.003173	0.005531	0.004443	0.001587	0.000272	0.017006
SE	0.002576	0.002856	0.003763	0.001632	0.000589	0.000045	0.011462
SSE	0.000775	0.000907	0.001269	0.000771	0.000272	0.000045	0.004039
S	0.000891	0.001179	0.001405	0.000816	0.000635	0.000181	0.005107
SSW	0.000697	0.001179	0.001179	0.001995	0.001043	0.000136	0.006228
SW	0.002336	0.003355	0.006710	0.014235	0.013510	0.002131	0.042277
WSW	0.003149	0.005259	0.026068	0.056079	0.053541	0.010382	0.154477
W	0.007364	0.015142	0.091214	0.079790	0.040031	0.007208	0.240749
WNW	0.008093	0.016547	0.113353	0.102820	0.019585	0.003355	0.263783
NW	0.009025	0.016003	0.054991	0.033321	0.002856	0.000136	0.116333
NNW	0.004220	0.006710	0.012558	0.004488	0.000272	0.000045	0.028293
TOT	0.063560	0.106855	0.357285	0.311587	0.136549	0.024164	

TABLE 14. RELATIVE WIND FREQUENCY DISTRIBUTION (SEPT,OCT,NOV)

SPEED (METERS/SEC)

DIRECTION	0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1+	TOTAL
N	0.005615	0.006230	0.004077	0.001512	0.000458	0.000092	0.017933
NNE	0.003978	0.004306	0.004077	0.002245	0.000733	0.000092	0.015430
NE	0.010411	0.012505	0.011543	0.002565	0.000321	0.000000	0.037345
ENE	0.005691	0.007237	0.010581	0.003390	0.000046	0.000046	0.026991
E	0.012859	0.015941	0.018689	0.006734	0.000595	0.000092	0.054909
ESE	0.007139	0.008686	0.009024	0.002748	0.000595	0.000000	0.028393
SE	0.007624	0.009253	0.004718	0.000733	0.000321	0.000000	0.022649
SSE	0.003546	0.003344	0.000779	0.000275	0.000137	0.000000	0.008081
S	0.004333	0.004260	0.001054	0.000229	0.000183	0.000000	0.010059
SSW	0.002415	0.002153	0.002107	0.000779	0.000595	0.000046	0.008095
SW	0.004694	0.005680	0.007329	0.006505	0.005772	0.001832	0.031611
WSW	0.009099	0.011726	0.022308	0.022262	0.016857	0.006413	0.088665
W	0.025585	0.033484	0.106133	0.056159	0.015483	0.005817	0.242662
WNW	0.029926	0.040447	0.126380	0.072649	0.013146	0.003069	0.285617
NW	0.019242	0.023957	0.041088	0.016490	0.001924	0.000092	0.102793
NNW	0.004958	0.005726	0.005680	0.001970	0.000183	0.000000	0.018517
TOT	0.157116	0.195135	0.375567	0.197242	0.057350	0.017590	

TABLE 15. RELATIVE WIND FREQUENCY DISTRIBUTION (ANNUAL)

SPEED (METERS/SEC)

DIRECTION	0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1+	TOTAL
N	0.005505	0.006008	0.005151	0.001770	0.000331	0.000046	0.018811
NNE	0.003806	0.004146	0.004260	0.002239	0.000560	0.000091	0.015101
NE	0.008275	0.009765	0.010142	0.002387	0.000354	0.000000	0.030923
ENE	0.005954	0.006830	0.008909	0.002570	0.000194	0.000011	0.024468
E	0.010944	0.013180	0.015956	0.005562	0.000845	0.000080	0.046567
ESE	0.006153	0.007401	0.007367	0.002787	0.000845	0.000080	0.024633
SE	0.006841	0.007926	0.004409	0.000891	0.000320	0.000023	0.020409
SSE	0.002686	0.002878	0.001188	0.000445	0.000183	0.000023	0.007403
S	0.002905	0.003198	0.001245	0.000423	0.000274	0.000057	0.008102
SSW	0.001570	0.001588	0.001451	0.001062	0.000765	0.000114	0.006550
SW	0.004378	0.005037	0.005813	0.008383	0.009845	0.003666	0.037123
WSW	0.007443	0.009114	0.020981	0.033830	0.038078	0.013466	0.122912
W	0.020489	0.026680	0.087258	0.062657	0.032939	0.013968	0.243992
WNW	0.023735	0.031694	0.110352	0.080760	0.019530	0.005391	0.271462
NW	0.015332	0.018765	0.041699	0.021815	0.002421	0.000331	0.100363
NNW	0.005032	0.005654	0.007458	0.002764	0.000263	0.000011	0.021181
TOT	0.131047	0.159863	0.333638	0.230344	0.107748	0.037359	

Table 16. Fractional Distribution of Observed Winds for Various Speeds by Season and Annually (Ref. 8).

Wind Speed Interval (m/s)	December January February	March April May	June July August	September October November	Annual
0-1.8	.235	.071	.064	.157	.131
1.8-3.4	.236	.104	.107	.195	.160
3.4-5.4	.309	.292	.356	.376	.334
5.4-8.5	.137	.273	.312	.197	.230
8.5-11.1	.057	.179	.137	.057	.108
>11.1	.026	.081	.024	.018	.037

TABLE 17.1 MONTHLY FREQUENCY DISTRIBUTION OF WINDS DURING CLEAR DAYLIGHT HOURS. MONTH 1. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
7	.0576	.0933	.1555	.0611	.0138	.0104	.0023	0.0000	.3940	868
8	.0685	.1048	.1250	.0544	.0121	.0081	.0020	0.0000	.3750	496
9	.0867	.0585	.1351	.0565	.0181	.0141	.0020	0.0000	.3710	496
10	.0795	.0841	.1244	.0507	.0127	.0092	.0058	0.0000	.3664	868
11	.1008	.0847	.0948	.0323	.0222	.0060	.0081	0.0000	.3488	496
12	.0988	.0625	.1048	.0363	.0121	.0141	.0040	0.0000	.3327	496
13	.0956	.0622	.1083	.0403	.0138	.0092	.0023	.0012	.3329	868
14	.0827	.0726	.1169	.0343	.0101	.0202	.0040	.0020	.3427	496
15	.0766	.0766	.1210	.0282	.0141	.0202	.0020	0.0000	.3387	496
16	.0668	.1025	.0991	.0300	.0104	.0127	.0023	0.0000	.3237	868
17	.1129	.1210	.0766	.0141	.0161	.0081	.0020	0.0000	.3508	496
18	.1719	.1875	.0781	.0156	.0156	.0156	0.0000	0.0000	.4844	64
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.2. MONTHLY FREQUENCY DISTRIBUTION OF WINDS DURING CLEAR DAYLIGHT HOURS. MONTH 2. (REF. 11).

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
7	.0594	.0872	.1568	.0721	.0114	.0114	.0013	0.0000	.3995	791
8	.0575	.0929	.1416	.0951	.0243	.0177	.0022	0.0000	.4314	452
9	.0686	.0774	.1416	.0819	.0420	.0155	.0044	0.0000	.4314	452
10	.0607	.0746	.1201	.0822	.0303	.0177	0.0000	0.0000	.3856	791
11	.0929	.0708	.1106	.0885	.0354	.0177	0.0000	0.0000	.4159	452
12	.1018	.0686	.0907	.0774	.0420	.0111	.0022	0.0000	.3938	452
13	.0518	.0759	.1125	.0645	.0265	.0139	.0013	0.0000	.3464	791
14	.0487	.0885	.1261	.0531	.0288	.0177	0.0000	0.0000	.3628	452
15	.0442	.0774	.1305	.0619	.0199	.0199	0.0000	0.0000	.3540	452
16	.0417	.0733	.1201	.0632	.0291	.0139	.0025	0.0000	.3439	791
17	.0575	.0996	.1106	.0619	.0243	.0155	.0022	0.0000	.3717	452
18	.1084	.1460	.0929	.0553	.0221	.0088	.0022	0.0000	.4358	452
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.3. MONTHLY FREQUENCY DISTRIBUTION OF WINDS DURING CLEAR DAYLIGHT HOURS. MONTH 3. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
6	.0489	.0516	.1766	.1386	.0353	.0217	.0027	0.0000	.4755	368
7	.0380	.0553	.1843	.1118	.0369	.0127	.0035	0.0000	.4424	868
8	.0484	.0302	.1855	.1190	.0544	.0343	.0060	0.0000	.4778	496
9	.0444	.0685	.1310	.1089	.0665	.0383	.0060	0.0000	.4637	496
10	.0484	.0657	.1234	.1096	.0450	.0265	0.0000	0.0000	.4187	867
11	.0544	.0867	.1149	.1008	.0343	.0282	.0020	.0020	.4234	496
12	.0464	.0887	.1210	.0887	.0282	.0262	.0060	0.0000	.4052	496
13	.0392	.0680	.1164	.0864	.0323	.0196	.0046	0.0000	.3664	868
14	.0363	.0524	.1371	.0786	.0242	.0242	.0040	.0101	.3669	496
15	.0444	.0544	.1230	.0625	.0302	.0181	.0141	.0040	.3508	496
16	.0357	.0668	.1083	.0599	.0334	.0230	.0092	.0012	.3376	868
17	.0423	.0746	.1008	.0323	.0423	.0242	.0181	0.0000	.3347	496
18	.0565	.0988	.0827	.0444	.0464	.0403	.0060	.0020	.3770	496
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.4. MONTHLY FREQUENCY DISTRIBUTION OF WINDS DURING CLEAR DAYLIGHT HOURS. MONTH 4. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	0.0000	.0250	.2125	.1750	.0250	.0375	.0063	0.0000	.4813	160
6	.0208	.0313	.2292	.1688	.0292	.0313	.0021	0.0000	.5125	480
7	.0250	.0321	.2107	.1619	.0655	.0321	.0048	.0012	.5333	840
8	.0286	.0408	.1633	.1735	.0612	.0306	.0122	0.0000	.5102	490
9	.0479	.0458	.1375	.1625	.0521	.0354	.0063	0.0000	.4875	480
10	.0440	.0690	.1429	.1417	.0583	.0274	.0048	0.0000	.4881	840
11	.0429	.0776	.1592	.0857	.0490	.0245	.0102	0.0000	.4490	490
12	.0583	.0750	.1625	.0667	.0521	.0271	.0042	0.0000	.4458	480
13	.0583	.0607	.1679	.0821	.0417	.0333	.0060	0.0000	.4500	840
14	.0551	.0878	.1245	.0653	.0367	.0408	.0082	0.0000	.4184	490
15	.0396	.0604	.1354	.0729	.0438	.0417	.0125	0.0000	.4063	480
16	.0321	.0786	.1095	.0869	.0548	.0357	.0143	0.0000	.4119	840
17	.0408	.0755	.1000	.0633	.0735	.0449	.0102	0.0000	.4082	490
18	.0646	.0979	.0854	.0500	.0688	.0708	.0083	0.0000	.4458	480
19	.0788	.0936	.0776	.1047	.1121	.0530	.0037	0.0000	.5234	812
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.5. MONTHLY FREQUENCY DISTRIBUTION OF WINDS DURING CLEAR DAYLIGHT HOURS, MONTH 5. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	.0121	.0242	.2520	.2157	.0383	.0282	.0020	0.0000	.5726	496
6	.0060	.0343	.2702	.1935	.0565	.0403	0.0000	0.0000	.6008	496
7	.0184	.0300	.2224	.2166	.0703	.0403	.0023	0.0000	.6002	868
8	.0242	.0282	.1815	.2117	.0887	.0524	.0040	0.0000	.5907	496
9	.0302	.0423	.1935	.2117	.0786	.0403	.0020	0.0000	.5988	496
10	.0426	.0726	.1820	.1878	.0657	.0253	.0023	0.0000	.5783	868
11	.0645	.0867	.1754	.1633	.0565	.0282	.0081	0.0000	.5827	496
12	.0605	.0948	.1452	.1210	.0524	.0464	.0101	0.0000	.5302	496
13	.0380	.0853	.1636	.1221	.0703	.0311	.0092	0.0000	.5196	868
14	.0383	.0685	.1371	.1149	.0766	.0464	.0121	.0020	.4960	496
15	.0262	.0706	.1250	.1028	.0927	.0464	.0181	0.0000	.4819	496
16	.0184	.0795	.1106	.1002	.1071	.0645	.0092	0.0000	.4896	868
17	.0242	.0565	.0887	.0927	.1169	.0867	.0161	0.0000	.4819	496
18	.0242	.0504	.1048	.0706	.1452	.1028	.0121	0.0000	.5101	496
19	.0415	.0887	.0484	.1152	.1809	.0680	.0035	0.0000	.5461	868
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 11.6. MONTHLY FREQUENCY DISTRIBUTION OF WINDS
DURING CLEAR DAYLIGHT HOURS. MONTH 6. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	.0042	.0354	.3750	.2667	.0771	.0208	0.0000	0.0000	.7792	480
6	.0146	.0333	.3104	.3271	.0688	.0271	.0021	0.0000	.7833	480
7	.0095	.0226	.2595	.3357	.0893	.0357	.0012	0.0000	.7536	840
8	.0208	.0250	.2375	.3375	.1250	.0375	0.0000	.0021	.7854	480
9	.0333	.0500	.2208	.3271	.1188	.0333	0.0000	0.0000	.7833	480
10	.0476	.0964	.2250	.2571	.0964	.0238	.0012	0.0000	.7476	840
11	.0854	.1333	.2417	.2167	.0750	.0271	0.0000	0.0000	.7792	480
12	.0833	.1417	.2354	.1583	.0938	.0333	.0063	0.0000	.7521	480
13	.0631	.1298	.2048	.1548	.0881	.0417	.0036	0.0000	.6857	840
14	.0646	.1146	.2021	.1542	.1063	.0438	.0063	0.0000	.6917	480
15	.0647	.1044	.1712	.1294	.1336	.0626	.0084	0.0000	.6743	479
16	.0393	.0762	.1512	.1429	.1619	.0726	.0048	.0012	.6500	840
17	.0417	.0667	.1188	.1250	.2083	.1250	.0063	0.0000	.6917	480
18	.0438	.0646	.0813	.1271	.2521	.1271	.0042	0.0000	.7000	480
19	.0393	.0571	.0560	.1702	.2714	.0952	.0048	0.0000	.6940	840
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.7. MONTHLY FREQUENCY DISTRIBUTION OF WINDS
DURING CLEAR DAYLIGHT HOURS. MONTH 7. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	.0081	.0524	.4032	.1774	.0161	0.0000	0.0000	.0020	.6593	496
6	.0121	.0585	.3790	.1956	.0121	.0040	0.0000	0.0000	.6613	496
7	.0161	.0541	.3445	.2074	.0207	.0012	0.0000	0.0000	.6440	868
8	.0363	.0544	.2762	.2500	.0423	.0101	0.0000	0.0000	.6694	496
9	.0645	.0625	.2359	.2560	.0464	.0020	0.0003	0.0000	.6673	496
10	.0576	.1048	.2431	.1959	.0288	.0046	0.0000	.0012	.6359	868
11	.0827	.1250	.2621	.1331	.0383	.0040	0.0000	0.0000	.6452	496
12	.0827	.1270	.2036	.1492	.0403	.0060	0.0000	0.0000	.6089	496
13	.0611	.1198	.1601	.1256	.0403	.0058	0.0000	0.0000	.5127	868
14	.0585	.0806	.1774	.1069	.0585	.0101	0.0000	0.0000	.4919	496
15	.0302	.0907	.1351	.1250	.0706	.0262	0.0000	0.0000	.4778	496
16	.0265	.0461	.1094	.1417	.0991	.0230	.0012	0.0000	.4470	868
17	.0323	.0282	.0968	.1411	.1331	.0484	.0020	0.0000	.4819	496
18	.0181	.0282	.0605	.1492	.1956	.0605	0.0000	0.0000	.5121	496
19	.0138	.0208	.0461	.1822	.2272	.0311	0.0000	0.0000	.5213	867
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE. TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.8. MONTHLY FREQUENCY DISTRIBUTION OF WINDS
DURING CLEAR DAYLIGHT HOURS. MONTH 8. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	.0230	.0428	.3684	.2039	.0132	0.0000	0.0000	0.0000	.6513	304
6	.0242	.0565	.4194	.1935	.0081	0.0000	0.0000	0.0000	.7016	496
7	.0173	.0472	.3767	.2200	.0104	.0023	0.0000	0.0000	.6740	868
8	.0363	.0645	.3125	.2601	.0242	.0060	0.0000	0.0000	.7036	496
9	.0565	.0746	.2944	.2460	.0302	.0020	0.0000	0.0000	.7036	496
10	.0645	.1429	.2558	.1993	.0184	.0035	0.0000	0.0000	.6843	868
11	.1371	.1714	.2137	.1048	.0282	.0020	0.0000	0.0000	.6573	496
12	.1028	.1653	.1895	.1008	.0343	0.0000	0.0000	0.0000	.5927	496
13	.0795	.1256	.1855	.1141	.0265	.0069	0.0000	0.0000	.5380	868
14	.0747	.0970	.1636	.0990	.0384	.0162	0.0000	0.0000	.4889	495
15	.0645	.0927	.1593	.0786	.0706	.0181	0.0000	0.0000	.4839	496
16	.0426	.0726	.1267	.1302	.0818	.0230	.0012	0.0000	.4781	868
17	.0605	.0645	.0806	.1290	.1411	.0383	0.0000	0.0000	.5141	496
18	.0484	.0444	.0907	.1250	.1855	.0464	0.0000	0.0000	.5403	496
19	.0288	.0438	.0772	.2488	.1567	.0207	0.0000	0.0000	.5760	868
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.9. MONTHLY FREQUENCY DISTRIBUTION OF WINDS DURING CLEAR DAYLIGHT HOURS. MONTH 9. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
6	.0375	.0896	.4042	.2208	.0188	.0021	0.0000	0.0000	.7729	480
7	.0476	.0833	.3833	.2060	.0179	.0048	0.0000	0.0000	.7429	840
8	.0438	.0771	.3438	.2688	.0375	.0083	0.0000	0.0000	.7792	480
9	.0854	.1104	.3396	.1875	.0438	.0146	0.0000	0.0000	.7813	480
10	.1060	.1524	.2679	.1679	.0417	.0083	0.0000	0.0000	.7440	840
11	.1083	.1792	.2896	.1438	.0438	.0063	.0021	0.0000	.7729	480
12	.1104	.2000	.2438	.1146	.0417	.0146	0.0000	0.0000	.7250	480
13	.1012	.1595	.2214	.1179	.0440	.0119	.0012	0.0000	.6571	840
14	.1000	.1667	.2208	.1188	.0583	.0083	.0021	0.0000	.6750	480
15	.1000	.1292	.2146	.1333	.0667	.0188	.0021	0.0000	.6646	480
16	.0762	.1155	.1786	.1286	.0774	.0214	.0012	0.0000	.5988	840
17	.0939	.1378	.1524	.1420	.1086	.0334	0.0000	0.0000	.6681	479
18	.1188	.1417	.1646	.1583	.1146	.0167	0.0000	0.0000	.7146	480
19	.0893	.1250	.1488	.1905	.0536	.0179	0.0000	0.0000	.6250	168
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.10. MONTHLY FREQUENCY DISTRIBUTION OF WINDS DURING CLEAR DAYLIGHT HOURS. MONTH 10. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
6	.0544	.0806	.2964	.1895	.0121	.0040	.0020	0.0000	.6391	496
7	.0508	.0947	.2968	.1605	.0219	.0046	0.0000	0.0000	.6293	866
8	.0766	.0524	.2480	.2359	.0222	.0141	.0040	0.0000	.6532	496
9	.0685	.0907	.2802	.1875	.0181	.0202	.0020	0.0000	.6673	496
10	.0855	.1409	.2390	.1305	.0231	.0127	.0012	.0012	.6339	866
11	.1190	.1653	.2137	.1028	.0242	.0141	.0020	.0020	.6431	496
12	.1290	.1734	.1935	.0948	.0202	.0040	.0060	.0020	.6230	496
13	.0983	.1642	.2116	.0659	.0277	.0150	.0046	0.0000	.5873	865
14	.1230	.1371	.2177	.0726	.0323	.0121	.0101	0.0000	.6048	496
15	.1190	.1532	.1794	.0827	.0343	.0202	.0060	.0020	.5968	496
16	.0901	.1536	.1917	.0774	.0346	.0150	.0023	0.0000	.5647	866
17	.1452	.1694	.1411	.0544	.0383	.0081	.0040	0.0000	.5605	496
18	.1360	.1544	.1581	.0882	.0515	.0110	.0037	.0037	.6066	272
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.11 MONTHLY FREQUENCY DISTRIBUTION OF WINDS DURING CLEAR DAYLIGHT HOURS. MONTH 11. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
6	0.0000	.0588	.2941	.0882	.0294	0.0000	0.0000	0.0000	.4706	34
7	.0517	.0954	.2552	.0966	.0092	.0046	.0034	0.0000	.5161	870
8	.0725	.0745	.2176	.1608	.0176	.0098	.0039	0.0000	.5569	510
9	.0588	.0725	.2118	.1373	.0216	.0176	0.0000	0.0000	.5196	510
10	.1046	.0966	.1552	.1046	.0241	.0161	0.0000	0.0000	.5011	870
11	.1235	.1000	.1608	.0804	.0255	.0157	0.0000	0.0000	.5059	510
12	.1118	.1118	.1490	.0667	.0314	.0118	0.0000	0.0000	.4824	510
13	.0897	.1207	.1391	.0609	.0184	.0103	0.0000	.0011	.4402	870
14	.1196	.1098	.1353	.0784	.0216	.0137	.0020	0.0000	.4804	510
15	.0922	.1235	.1529	.0686	.0216	.0176	.0039	0.0000	.4804	510
16	.0943	.1333	.1437	.0322	.0218	.0126	0.0000	.0011	.4391	870
17	.1608	.1549	.1392	.0294	.0157	.0078	.0020	0.0000	.5098	510
18	0.0000	0.0000	C.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

TABLE 17.12. MONTHLY FREQUENCY DISTRIBUTION OF WINDS
DURING CLEAR DAYLIGHT HOURS. MONTH 12. (REF. 11)

SPEED (M/SEC)

HOUR	0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
7	.0590	.0968	.1791	.0768	.0078	.0056	0.0000	0.0000	.4249	899
8	.0911	.0683	.1708	.0683	.0114	.0038	.0038	0.0000	.4175	527
9	.0854	.0607	.1537	.0930	.0133	.0114	0.0000	0.0000	.4175	527
10	.0756	.0834	.1635	.0667	.0111	.0067	.0011	0.0000	.4082	899
11	.1176	.0911	.1271	.0417	.0076	.0095	0.0000	0.0000	.3947	527
12	.1082	.1063	.1252	.0304	.0171	.0076	0.0000	0.0000	.3947	527
13	.0901	.1012	.1235	.0389	.0145	.0111	.0011	.0011	.3815	899
14	.1139	.0854	.1309	.0380	.0057	.0114	.0019	0.0000	.3871	527
15	.0968	.1233	.1328	.0228	.0114	.0095	.0019	0.0000	.3985	527
16	.0768	.1546	.0957	.0267	.0156	.0111	0.0000	0.0000	.3804	899
17	.1575	.1499	.0892	.0228	.0152	.0057	0.0000	0.0000	.4402	527
18	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0

NOTE: THE TABLE ABOVE IS NORMALIZED BY ROWS ONLY , E.G., THE NUMBER OF TIMES A GIVEN HOUR HAD WINDS IN A SPECIFIC RANGE , THE SUN WAS UP, AND THE SKY WAS CLEAR,WAS DIVIDED BY TOTHRS,THE NUMBER OF CLEAR DAYLIGHT HOURS FOR WHICH OBSERVATIONS ARE AVAILABLE.TOTHRS IS NOT A CONSTANT BECAUSE FOR SOME PERIODS,OBSERVATIONS WERE MADE ONLY EVERY THREE HOURS. CLRHRS IS THE FRACTION OF DAYLIGHT HOURS WHICH HAD ZERO TOTAL SKY COVER.

Table 17.13

FRACTIONAL DISTRIBUTION OF OBSERVED WINDS
FOR VARIOUS SPEEDS BY MONTH AND ANNUALLY

CLEAR DAYLIGHT HOURS ONLY

MONTH	WIND SPEED INTERVAL (M/SEC) 0.0-1.8	1.8-3.4	3.4-5.4	5.4-8.5	8.5-11.1	11.1-15.7	15.7-20.8	20.8+	CLRHRS	TOTHRS
JANUARY	.0830	.0852	.1159	.0408	.0138	.0117	.0033	.0003	.3540	7008
FEBRUARY	.0636	.0844	.1224	.0712	.0273	.0149	.0015	0.0000	.3853	6780
MARCH	.0439	.0661	.1308	.0877	.0388	.0250	.0060	.0013	.3996	7807
APRIL	.0450	.0655	.1444	.1093	.0582	.0374	.0075	.0001	.4673	8692
MAY	.0314	.0629	.1571	.1491	.0889	.0490	.0070	.0001	.5456	9300
JUNE	.0429	.0767	.2007	.2147	.1331	.0538	.0032	.0002	.7253	8999
JULY	.0390	.0700	.2032	.1694	.0737	.0153	.0002	.0002	.5710	9299
AUGUST	.0559	.0878	.2145	.1666	.0590	.0124	.0001	0.0000	.5962	9107
SEPTEMBER	.0861	.1327	.2609	.1615	.0531	.0129	.0006	0.0000	.7078	7847
OCTOBER	.0950	.1335	.2251	.1176	.0269	.0119	.0034	.0006	.6140	7703
NOVEMBER	.0950	.1088	.1705	.0813	.0203	.0121	.0013	.0003	.4897	7084
DECEMBER	.0929	.1034	.1366	.0487	.0119	.0085	.0008	.0001	.4030	7285
ANNUAL	.0645	.0897	.1735	.1182	.0504	.0221	.0029	.0000	.5216	96911

TABLE 18

MONTHLY WIND SPEED MAXIMUM VALUES AND NUMBER OF HOURS HAVING WIND SPEEDS EQUAL TO OR GREATER THAN 30 M/SEC

MONTH	NUMBER GE 30M/SEC	MAXIMUM WIND (M/SEC)
1	0	27
2	0	25
3	4	34
4	0	23
5	1	30
6	0	26
7	0	22
8	0	20
9	0	23
10	0	22
11	3	40
12	0	28

TABLE 19. (REF. 11)

MONTHLY MEAN AND STANDARD DEVIATION
OF THE AMBIENT ATMOSPHERIC PRESSURE
(MBAR)

MEAN	STD DEV	MONTH
950.74	5.46	1
949.42	5.15	2
946.77	4.81	3
945.23	3.96	4
943.81	3.47	5
942.47	2.84	6
943.83	2.52	7
944.27	2.48	8
944.09	2.97	9
946.65	3.94	10
949.95	4.87	11
951.08	5.58	12

Table 20. Precipitation Summary Barstow-Daggett Airport (1956-1970)
10 MWe Pilot Plant Site

Precipitation (cm)	Month J	F	M	A	M	J	J	A	S	O	N	D
Average	0.79	0.81	0.71	0.79	0.18	0.13	0.79	1.52	1.30	0.56	0.94	0.89
Maximum 24-hr	1.85	1.78	2.24	1.65	0.94	0.81	2.44	5.23	2.82	1.68	2.74	2.57
Maximum Monthly	2.49	3.81	2.57	4.65	1.24	0.81	2.44	8.18	5.87	2.57	4.42	5.13
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Average Annual 9.40 cm

Table 21. Number of Direct Lightning Strokes per Year for Various Height Structures (Ref. 22)

Height (m)	(ft)	Strikes/Year Observed for 32 Thunderstorms/Year	Strikes Estimated for 8 Thunderstorms/Year
30	100	0.15	.04
60	200	0.45	.11
90	300	0.90	.23
120	400	1.40	.35
150	500	1.75	.44
180	600	2.10	.53
210	700	2.30	.58

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SEP 19 1980

Mr. Bob Riedesel
McDonnell Douglas Astronautics Co.
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Huntington Beach, CA 92647

SUBJECT: Errata for OPDD Appendix C, Aerospace ATR-78 (7695-05)-05, 15 August 1978

ATTACHMENT: Figure 6, Design Response Spectrum for Barstow, California

Dear Bob:

In the course of the multiple reproductions taking place in the production of the above referenced report the labels on the curve shown in Figure 6 (P.11) were changed to incorrect values. A corrected curve prepared by M. L. Eskijian of Aerospace is attached. This problem was brought to our attention by Dr. Ramesh Shah, a consultant to Southern California Edison.

A second error in this report occurs in Section C.3.2.1 on page 9. The minimum ambient temperature should be +9°F rather than -9°F. The -13°C is the correct value.

Please incorporate these changes into your final revision and submittal of the Environmental Specification.

Sincerely,

H. D. Eden

H. D. Eden
Technical Monitor

cc: M. Slaminski
R. Schweinberg
C. Randall - Aerospace

9-80-366

APPENDIX D

APPENDIX D

TEST PLAN

A test plan in the typical test request document format below will be provided.

TEST REQUEST DOCUMENT FORMAT

Approval: ____________
Test Requester

____
STMPO

Test Title ______________________________

Test Number (If appropriate) ______________________

Test Requester ______________________________

1. INTRODUCTION

State the questions to be answered or problems to be resolved by the test program. Include contractual background and reference other test requests, where applicable.

2. ABSTRACT

Briefly summarize the test program.

3. OBJECTIVES

State what is to be investigated, determined, verified, or obtained by conducting the test program. Answer the question what? and why? in this section. If there is more than one objective, list them in order of importance.

4. SCHEDULE

State the schedule requirements.

5. TEST METHODS

Describe briefly, in general terms, how the test requirements are to be met or demonstrated. Subsections may be added as applicable to discuss subjects such as environment and operation. If the test program consists of a series of different tests, each of these tests should be covered.

6. TEST RESULTS

Discuss the theory covering the analysis, the expected results, and the fundamental assumptions from which these were derived. This should be developed through iterative consultation with the STMPO specialist in charge of analyzing the data.

Set guidelines to limit continuance of the test by either giving failure criteria or by indicating means of determining attainment of the test objectives. Specify, if possible, when the test should be concluded.

7. DESCRIPTION OF TESTS

7.1 Description of Test Article

Briefly describe the test article, using sketches or appropriate drawings and specifications. Reference existing documents, as applicable. Identify modifications that may be made to the test article to accommodate test program requirements. Detailed drawings showing interfaces with the test facility must be provided for installation in the test facility. Provide installation, operation, maintenance, and repair manuals, if appropriate.

7.2 Test Article Handling

Describe special handling, maintenance, or storage requirements for the test article. Any special receipt inspection requirements should be stated. Pre-installation cleaning should be described, if required. Describe all special tooling, jigs, and fixtures required for assembly and disassembly operations.

7.3 Description of Test Facility Requirements

Required facility interfaces with the test article and required facility capabilities relative to the required test parameters (such as flow, temperature, pressure, thermal transients, sodium purity, etc.) should be discussed. Describe special precautions or details to be observed when installing the test article in the test facility. Note any special leak detection and fire extinguishing methods required.

7.4 Test Sequence and Logic

Define physical requirements and operating ranges, including transients, if any, of the test article. If the test program consists of a series of different tests, list the tests in the order in which they are to be accomplished. The logic used to arrive at that sequence should be explained. Set guidelines for aborting the test.

7.5 Detailed Test Description

Give a brief introduction indicating the number of separate basic tests and referencing a supporting tabulation of required parameters. The basic tests should then be given separate subheadings and discussed individually in detail. Describe action required when potential problems arise to when limits are exceeded. List "hold points" if required. Alternative approaches to the test should be included in this section.

7.6 Measurements Required

This section should identify the parameters to be measured, the accuracy required, instrumentation response characteristics, and the range of variables being measured. A tabulated listing of specific requirements should be included. If formal error analysis should be conducted to determine accuracy requirements of the instrumentation, it should be requested at this time. Consultation with STMPO during the preparation of this section is recommended.

7.7 Disposition of Test Equipment

Describe the required disposition for the test article or equipment at the end of the test program or, in the event of failure, during the test program. This should include examination, cleaning, storage, packaging, and shipping requirements.

8. DATA

8.1 Data Handling

When the data are to be analyzed by the requester, the types of data to be obtained and the requirements for displaying, recording, and processing should be defined. When the data are to be analyzed by STMPO, these services will be provided by STMPO.

8.2 Data Reduction and Analysis

Describe the methods to be used in reducing, correcting, and analyzing data required to evaluate the test results. Describe the error analysis effort to be made. Capabilities exist within STMPO for real-time and/or post-test computer data reduction or analysis of test data.

8.3 Data Identification and Storage

Recorder charts and raw data sheets will be labeled and stored in a permanent file for seven years. Magnetic tapes will be stored for seven years. At the end of that period, they will be discarded. Note if any deviations to this policy are required.

8.4 Interim Reporting

Indicate the desired form of status and data reporting during the testing phase and the intervals between reports when interim reports on the reduction and analysis of test data are required.

8.5 Final Report

Describe any special requirements to be included in the final report.

9. SYSTEM SAFETY

Describe the potential safety hazards associated with the testing of the test article. Provide emergency procedures for the test article. The requester need not include the "usual" potential hazards associated with any elevated temperature sodium system, but should concentrate on those hazards associated with the test article. The test requester is responsible for assuring that his design is safe for use over the range of test parameters requested.

The test requester is also responsible for preparing engineering calculations, studies, fabrication procedures, inspection records, and code reports to verify that the test article is safe for use over the range of test parameters requested. Prior to the start of the test, these calculations must be available to STMPO for use in the safety review by the STMPO Safety Review Committee. STMPO is ultimately responsible for the safe conduct of testing and will not knowingly operate tests or test facilities in an unsafe manner.

The test article should include means for lead detection, firefighting, emergency shutdown, and installation of protective devices as required by the General Safety Orders of California. STMPO will assist the test requester in meeting these requirements.

10. QUALITY ASSURANCE AND APPLICABLE STANDARDS

10.1 Quality Assurance

State QA documents either in existence or to be prepared which are applicable to the test program.

11. ORGANIZATION INTERFACE

Define the participation and responsibilities of the test requester organizations involved in the test program. Identify responsible test requester personnel.

12. REFERENCES

List documents referenced in the test request giving title, document number, and revision date or letter.

APPENDIX E

APPENDIX E

SAFETY REQUIREMENTS

The following safety requirements shall be applied in the design and construction of the 10-MWe Solar Pilot Plant. These requirements are provided as a convenience to the user and do not represent a complete listing. The omission of safety requirement is not to be construed as nonapplicability.

E. 1 GENERAL SAFETY REQUIREMENTS

The general safety hazards located throughout the pilot plant include the potentials for electrical shock/electrocution, fall from elevated work platforms/areas, and handling of chemicals or cleaning liquids. Safety requirements to avoid these safety hazards are:

E.1.1 Electrical/Electronic Systems

E.1.1.1 General Systems

1) Ensure that a primary and secondary (backup) power system or systems are provided to all critical systems and controls to allow safe securing of plant operations.

2) Ensure that primary and redundant systems circuits are not supplied from the same power bus or circuit breaker.

3) Avoid termination of power and control/signal leads on adjacent pins of connectors.

4) All electrical/electronic equipment shall have an external grounding terminal for connection to a facility ground network.

5) All portable electrical equipment shall be designed so that an internal short will not result in a hazardous voltage condition.

6) All control shafts, knobs, handles, or levers shall be grounded, insulated, or made of nonconductive material to preclude personnel shock or burn.

7) All racks, chassis, and compartments which contain exposed terminals and similar components shall be clearly marked or

placarded to indicate the highest operating voltage potential present. Provide barriers or guards on all contacts, terminals, and similar devices having voltages between 70 to 500 V (ac and dc) with respect to ground to prevent personnel from accidental contact with such voltages.

8) Guide pins or slides shall be located on all panel drawer and chassis subassemblies for alignment during installation and to prevent contact with exposed terminals during installation and removal.

9) Insulated guides shall be provided wherever an adjustment tool could contact any adjacent circuit component having a hazardous voltage potential.

10) Provide for means to isolate all power from the specific equipment to facilitate maintenance or removal and to ensure personnel safety. Ascertain that the removal of power does not adversely affect the remaining system components.

11) All electrical connectors and cable installations shall be designed with sufficient flexibility, length, and accessibility to permit disconnection and reconnection without damage to wiring or connectors.

12) All connectors, circuit boards, terminal boards, switches, relays, and similar components in equipment which may contribute to a hazardous condition shall be potted, sealed, or similarly protected against liquid leakage or condensation.

13) Polyurethane conformal coatings containing solvents which dissolve polystyrene shall not be used on circuit boards containing polystyrene components.

14) Do not use dissimilar metals in intimate contact unless specifically designed for that purpose. If unavoidable, ensure that such junctions are suitably protected against electrolytic corrosion.

15) Locate circuit breakers in an easily accessible area and provide them with a visual means to indicate their condition (open or closed).

16) It is recommended for critical systems that all gages, electrical meters, and similar readout devices should be color-banded to indicate system operating, marginal, and hazardous range limits.

17) Critical system gages, electrical meters, and similar readout devices shall indicate normal system operating range within the center 50% of the total range of the readout device.

18) All critical equipment requiring adjustment during normal operation shall have external adjustment provisions. (Not to include periodic calibrations or adjustments.)

19) All critical systems shall revert to a safe configuration when an input power loss occurs.

E.1.1.2 Cabling and Wiring

1) All electrical cables and wiring shall be clamped and supported to remain clear of sharp edges and moving parts.

2) Solid wires (single strand) shall not be used in locations where they may be subjected to flexing.

3) Cabling or wiring subject to flexing shall be capable of flexing without damage to the wire or insulation at the maximum temperature extremes anticipated for the service environment.

4) Electrical cables and wires shall be marked to clearly indicate the correct mating connection or termination point to prevent phase reversal or cross connection. Identification or marking of the insulation by hot stamping will not be used.

5) Electrical power cables with connectors supplied for use with critical support equipment shall be heavy duty type with positive locking devices to prevent inadvertent disconnection.

6) All power cables shall have an independent noncurrent-carrying grounding conductor.

7) Reduce coupling at low frequencies by separating power wires from signal wires and input lines from output lines (do not route same cable bundle). Use shielding to minimize RF coupling.

8) All external electrical and electronic wiring routed at exposed ground level or below grade shall incorporate suitable rodent protection.

E.1.1.3 Connectors

1) All mating plugs and receptacles shall be marked or coded to clearly indicate mating connection.

2) Adjacent connectors in critical systems shall be keyed, sized, or shaped so that they are physically impossible to mismate or cross-connect.

3) Connectors with unkeyed symmetrical pin arrangements shall not be used.

4) Only female connectors shall be used as access to sources of power.

5) Receptacles whose mating plugs have locking features requiring a twisting motion (bayonnet or threaded types) shall be positively keyed or pinned to their mounting surface so that it is physically impossible for the receptacle to turn during plug attachment.

6) Reduce coupling at low frequencies by separating power wires from signal wires and input lines from output lines (do not route through the same connector). Use shielding to minimize RF coupling.

7) All power receptacles and connectors located in or used with equipment containing flammable vapor or liquids shall be incapable of causing ignition.

E.1.1.4 Batteries

1) All wet cell batteries shall have positive venting capability for each cell.

2) All hermetically sealed batteries shall have blowout plugs for pressure relief.

3) All battery vents, blowout plugs, and relief outlets shall be designed so that battery electrolyte cannot be ejected from the battery.

4) All battery vents, blowout plugs, and relief outlets shall be routed so that they do not discharge into an area containing equipment or materials that would cause ignition of the discharged material or cause injury to operating personnel.

5) Batteries shall have decals or markers which indicate the type of electrolyte and special safety precautions.

E.1.1.5 Control Functions and Components

1) All switches in critical systems shall be clearly marked or labeled to indicate the system function for each switch position.

2) All circuit breakers or switches used to control equipment or circuitry intended for emergency purposes in critical systems shall have positive protection against inadvertent operation.

3) Self-latching pushbutton illuminated switches, which may be operated without indicating the functional switch position during a power-off phase, shall not be used in critical systems.

4) Primary and redundant system circuits shall not be supplied from the same branch power bus or circuit breaker if the redundant system is used to safe the system.

5) Redundant control circuit components shall be independent of those components used in the primary control circuit if they are used for system safing control.

6) Primary and redundant control circuit wiring shall not be routed through the same cable of connector if the redundant control is required for system safing.

7) Negative power control (switching in the power return leads of a component) shall not be used unless the positive lead is switched simultaneously.

8) If a system uses self-test circuits, it shall indicate the actual system response, rather than indicate only the initiation of a command or test signal.

9) System indicators used to monitor critical system status shall indicate the actual system response rather than indicate only the initiation of a command or application of power.

10) Loss of control circuit power shall not result in power loss to devices which indicate response or configuration status of controlled components (i. e., an indication of heliostat control system failure shall be provided so that safing action can be initiated).

11) Ensure that the temperature of front panels and operating controls does not exceed 110° F in environment protected areas (in structures). This does not apply to nonprotected controls located outside of structures.

E.1.1.6 Overload Protection

1) Circuit breakers shall provide a visual indication when tripped.

2) Circuit breakers shall trip and protect the circuit even if the switch lever is physically held in the "ON" position.

3) Overload protection devices shall be installed in each ungrounded conductor in 3-phase power systems and shall be designed so that all three devices trip simultaneously.

4) Overload protection devices shall be sized (or set) so that the combination of current and time at which the device operates will not cause the operation of upstream protective devices.

E.1.1.7 Grounding and Lightning Protection

1) The design must determine and demonstrate the extent of grounding and lightning protection necessary for each of the pilot plant systems or structures to provide adequate protection for operating personnel.

2) Grounding conductors shall be of corrosion-resistant materials of adequate size for mechanical and electrical integrity and protected from mechanical injury.

3) Braze or weld connectors shall be of the mechanical type and arranged for convenient selectionalized testing of conductor continuity and ground resistance.

4) In areas containing underground piping or other metallic equipment, design grounding systems and equipment to minimize electrolytic corrosion caused by dissimilar metals.

5) Provide ground connections at parking, servicing, and maintenance areas where ground support equipment will operate and where transfer of flammable or combustible liquids will occur. Where feasible these connections should be tied to the main facility grounding system.

6) Lightning protection devices shall be provided for critical systems control, data, and power circuits. The design should incorporate transient suppressors in the control/data circuits and surge arrestors in power circuits.

E.1.2 Handling, Storage, and Protective Equipment Safety Requirements

E.1.2.1 General

1) Handling and transportation equipment shall include provisions for protecting shock sensitive equipment that does not have antishock provisions.

2) Proof-load certification of all lifting and handling equipment shall be specified by the design to be in compliance with the applicable state and local codes. Inspection and recertification shall be identified and accomplished as required by these codes.

3) Shipping containers and protective covers shall be conspicuously marked to identify special instructions such as step, no-step, hoisting point, lifting point, center of gravity, this side up, fold line, etc.

E.1.2.2 Lifting, Handling, and Hoisting Equipment

1) Lifting equipment, including individual slings, cables, and similar devices, shall each have a metal tag or placard displaying the load limit, proof load, date of last proof test, and retest interval.

2) Load limit tags on multipurpose slings shall specify the load limit at vertical, 15, 30, and 45-deg angles formed by the sling cables at the point of attachment to the lifting device.

3) The design shall specify that U-bolt wire rope clips shall be installed so that the U-bolt is in contact with the dead end (short or nonload-carrying end) of the rope.

4) The design shall specify that all nuts on newly installed wire rope clips shall be retightened after 1 h of use.

5) When nicopress sleeves or similar compression type devices are used on wire rope, at least two devices shall be used to attach each hook, link, loop eye, etc.

6) Hooks for lifting equipment, including hooks used on slings and cables, shall incorporate positive safety latching devices across the hook opening.

7) Lifting devices shall have a positive mechanical locking device to prevent inadvertent lowering of the load in the event of lifting mechanism failure.

8) Lifting equipment shall have permanent mechanical stops to preclude exceeding design limitations such as boom angle or traverse limits which could overload the boom or overturn a mobile crane.

9) Adjustable lifting fixtures or other devices used with lifting equipment shall have positive mechanical stops which are permanently installed (e.g., riveted rather than fixed by setscrews) to prevent inadvertent disassembly while being adjusted. The design shall specify that installation of such stops shall be mandatory inspection points and inspection performed.

10) Electrically powered lifting mechanisms shall have independent mechanical and electrical brake systems.

11) Braking systems shall be capable of braking and safely holding a minimum of 150% of the rated load.

12) Cables on lifting equipment shall be positively secured to the take-up drum and shall have a minimum of two full wrappings around the drum when the equipment is at a maximum extended position.

13) Cradles or support devices shall conform to the shape, size, weight, and contour of the load to be transported. They shall incorporate provisions for attachment of tie-downs or a method to adequately secure the load to the support device and provisions to secure the support device to the transportation equipment.

14) All skids, pallets, and shipping containers shall be clearly marked or labeled to identify hoisting points.

E.1.2.3 Mechanical Equipment/Systems

1) Openings (slotted or otherwise) in cabinets, covers, and similar enclosures through which levers, shafts, and similar controls operate shall be provided with protective covers, boots, or sliding plates to prevent personnel injury or equipment damage resulting from inadvertent insertion or entry of foreign objects.

2) All accessible internal and external equipment and structural surfaces including covers, doors, and removable panels shall be free of sharp edges and corners for the protection of personnel and equipment.

3) All fan blades, pump impellers, and similar rotating mechanisms shall have protective devices such as a shear pin, friction clutch, magnetic clutch, or similar device to protect the drive mechanism if the occurrence of an overload condition would result in a potential hazard.

4) Debris guards, screens, filters, and similar devices shall be located at the inlet to rotating mechanisms such as duct-mounted fan assemblies, pumps, and similar assemblies.

5) All critical controls and indicators shall be clearly marked or labeled to indicate system function.

6) Controls which could cause equipment damage or personnel injury if operated out of sequence, or if operated concurrently with other controls intended to be operated independently, shall have warning placards or labels provided at the control location.

7) Emergency and other safety controls (electrical or mechanical) used for shutdown, safing, alarm, or corrective action shall be clearly marked (e. g., placards, red borders, etc), visible, and readily accessible to operating personnel.

8) Handles and knobs on all rotary controls shall be keyed or shaped so that it is physically impossible for them to turn on the shaft. Furthermore, each rotary control assembly shall be positively keyed or pinned to its mounting surface to ensure protection against simultaneous rotation of the handle shaft and control assembly.

9) All handles and controls, including those for mechanisms such as folding platforms, shall be designed with sufficient clearance to adjacent structures or other components to prevent injury to fingers and hands.

10) Access doors, covers, or hatches which are not removable shall remain in the desired open position by use of friction or other devices.

11) All mechanical devices that require alignment or adjustment, including handles, knobs, and latches, shall have alignment indices (may be other than visible) to ensure proper alignment, adjustment, and operation.

12) Visible alignment indices, detents, rigging points, or alignment marks shall be visible for alignment recheck without removal of any component.

13) The setting, position, or adjustment of controls shall not be affected by shock or vibration resulting from transportation, installation, or equipment operation.

14) All equipment required to be lifted or moved by a hoist, crane, forklift, or other equipment shall have provisions for temporary or permanent installation of tie-downs, attach points, lifting eyes, or similar hardware for positive attachment of cable hooks and similar devices.

15) Attach points for tie-downs shall be clearly marked or labeled on all equipment.

16) Gross weight shall be conspicuously identified on all equipment required to be lifted or moved by hoists, cranes, forklifts, and similar handling equipment.

17) Skid-mounted equipment shall have the gross weight clearly identified on each side of the equipment.

18) Skid-mounted equipment shall have forklift inserts as required.

19) Casters on mobile equipment shall have independent locking devices on each caster.

20) Mobile equipment shall have self-contained wheel locking devices.

21) Vehicle stabilization capability (outriggers) shall be provided for vehicles having lifting capability (e.g., manned mobile work platforms or cranes) that must operate on unstable surfaces or sandy desert terrain.

22) Cleaning agents and processes that are compatible with the system (e.g., component materials, metal surfaces, and coatings) shall be specified in the design.

23) All connectors (e.g., electrical, hydraulic, pneumatic) at planned or normal operational disconnect points shall have tethered caps, plugs, or covers to protect against contamination or damage when unmated.

24) All equipment, including shipping containers and vans, shall have warning placards to identify hazardous commodities and restrictions such as "No Smoking," etc.

25) Warning placards, safety tape, color labels, and similar hazard identification material shall be placed in a clearly visible location.

26) All temperature gages, pressure gages, and similar readout devices shall indicate normal system operating range within the center 50% of the total range of the readout device.

27) Critical equipment requiring adjustment during normal operation shall have external adjustment provisions. (Not to include periodic calibrations or adjustment.)

28) Critical equipment shall revert to a safe configuration when an input power loss occurs.

E.2 COLLECTOR SYSTEM REQUIREMENTS

The most significant pilot plant hazard is the concentrated solar beam with its potential to damage unprotected structures and cause serious injury to personnel. An individual heliostat presents no major structural hazards but if personnel are at or near the focal point it can be a human tissue hazard. If more than one heliostat reflects a concentrated beam to a specific location, serious hazards may exist depending upon beam intensity, exposure time, source distance, and source angle. Concentration of an intense heat source on a surface results in potential damage to the structure and potential personnel hazards from re-radiated energy as well as direct thermal damage to the retina of the eye and exposed skin tissue. Exposures of the general public to these beams in the vicinity of the pilot plant, both on the ground and in the air, is a basic safety hazard that must be avoided.

The safety requirements to avoid these hazards are:

1) A heliostat beam eye hazard evaluation for the collector system shall be made.

2) A human tissue and combustible materials hazard evaluation shall be made.

3) A heliostat beam control method/procedure shall be developed and incorporated as a function of the heliostat control system design which will safely control multiple coincident beam positions during standby and stow-acquisition maneuvers. The control method/procedure shall:

   a) Comply with the safe beam projection requirements on the ground.

   b) Comply with the height/beam intensity limits for projections into the airspace above the facility.

   c) Exclude movements of hazardous beam concentrations through normally occupied facility areas.

   d) Avoid movement of beams upon facility structures not specifically protected to withstand concentrated solar flux.

4) The heliostat control system shall incorporate a fail-safe design to ensure that any failure of primary electrical power will not result in an unsafe beam condition where collector/collector field orientation is concerned.

5) Loss of primary electrical power to the heliostat control system shall result in all heliostats being placed to a safe standby position and then to a stow position. A secondary (standby/emergency) power source must be available for safe shutdown of the system upon loss of primary power.

6) Loss of primary electrical power or control response of any heliostat(s) that could result in a safety hazard shall result in the initiation of a fail-safe action by the collector control system. The method selected to perform this action may be initiated at any location within the control system but must comply with the control method/procedure requirements of item (3).

7) The collector field shall not be left in an up-stow position during insolation hours with multiple heliostats having convergent optical axis. Only parallel or divergent heliostat optical axis stow positions, with respect to individual heliostats, will be used during insolation hours.

8) Heliostats shall have ("safe") stow position(s) which will be used during periods of maintenance, high winds, at nights, in stormy weather, or in case of other emergencies.

9) A method/procedure shall be provided to position out-of-limit or malfunctioning heliostats to a safe standby or stow position.

10) If the heliostat design includes the capability of local (manual or electronic) control at the individual heliostat location, all other modes of control shall be locked out when the heliostat is in the local control mode.

11) If the heliostat design does not incorporate the capability for local control, the ability to deactivate the heliostat must exist while work is being performed on the heliostat.

12) The heliostat should be designed so that accessibility to potential maintenance/adjustment points such as electronic units, motors, drives, mirrors, etc presents no inherent personnel hazard.

13) If a single failure mode is possible that would fail a heliostat(s) in a hazardous orientation, the ability to safe the heliostat(s) must exist.

14) The heliostat control system must possess the capability to identify/recognize the existence of a hazardous condition, initiate safe corrective action, and verify that corrective action has occurred.

E.3 RECEIVER SYSTEM REQUIREMENTS

During operation, the receiver system has the inherent hazard of high pressures and temperatures during the generation of superheated steam from the concentration of solar flux on the receiver surfaces. Illumination of the receiver surfaces causes a strong re-radiated light source and is a potential local personnel hazard. These hazards are normal operational characteristics of the solar receiver and can be controlled by personnel exclusion areas, access interlocks, eye protection equipment, and personnel training. However, the hazards associated with high pressures and temperatures and the potential for component/system failure can result in explosions, fragmentation, component/line whipping, and parts falling from the receiver/tower. Personnel working in the receiver/tower may also be subjected to hazards associated with access/egress to or from limited work locations as well as the potential of falling from dangerous heights.

The safety requirements to avoid these hazards are:

1) The receiver shall provide the necessary sensors and control equipment to monitor and control the pressure and temperature of the working fluid and to detect a malfunction and initiate a fail-safe shutdown or corrective action.

2) Venting of pressure vessels and their safety valves shall be in accordance with the ASME Boiler and Pressure Vessel Code and shall be located and/or guarded so that escaping gases or liquids present no personnel hazards.

3) The receiver shall incorporate a redundant fail-safe shutdown or corrective action control system. Locate the redundant paths of the control system so that an event which damages one path is not likely to damage the second.

4) Safety interlocks/access controls shall be provided in the receiver tower to prevent personnel from entering the tower space in the vicinity of the receiver anytime one or more heliostats are directed on the receiver tower. If the tower is of enclosed construction, the access limit should be established at the one-half (1/2) tower height. If the tower is of open construction, no access above ground level should be permitted.

5) The external surfaces of the receiver tower that will be subjected to solar flux radiation must be protected in such a manner as to preclude structural damage to the tower that would create a hazardous condition for operating personnel from falling objects inside or outside of the tower structure.

6) Equipment located within the tower structure shall be grounded and suitable precautions taken to protect the tower and equipment against lightning. If lightning arrestors and grounding wires are installed on the tower structure, they shall be enclosed and shall be located well away from personnel passageways.

E.4 THERMAL STORAGE SYSTEM

The thermal storage system (TSS) presents no unique solar radiation hazards, but the application of this system to a solar plant does present inherent hazards. These hazards are high temperatures and pressures of the storage tanks, high temperatures of the heat storage fluid, and the use of superheated steam in the heat transfer process. The exposure of personnel to heat and pressures of the storage system are the primary concern, but the storage media may also have corrosive or toxic properties. Oil systems also have a fire potential if improper insulation materials are used in areas subject to system leaks. Area isolation and proper work station selection must reduce these hazard potentials to acceptable levels consistent with commercial operations.

Safety requirements to avoid these hazards are:

1) Earth berms and/or retaining walls to contain all the tank liquid must be provided around thermal storage tanks containing flammable or combustible liquids.

2) The TSS shall be evaluated for fire protection, exposure protection, and fire control requirements in accordance with applicable NFPA codes.

3) A protective barrier must be provided between noncompatible substances to prevent mixing.

4) The thermal storage system shall accept and execute control commands, detect a malfunction, and initiate fail-safe shutddown or alternate operating procedures through a control system.

5) The ability must exist to detect hazardous leaks in the thermal storage system and provide a method to isolate this leak from the rest of the system.

6) Adequate monitoring capability shall be provided to detect potentially hazardous conditions (e.g., fluid mix and steam mix; in the various closed loop systems of water, steam, oil, etc), and provide adequate capability to perform corrective action as required.

7) Safety showers and eye wash fountains shall be provided in the vicinity of tanks containing toxic materials.

8) Closed cell insulation is required for all areas where an oil leak may occur. The principal candidate areas for closed cell insulation are at all system penetrations or nonwelded connections, such as instrument connections, valve packing glands, flanges, etc.

9) The design must include provisions to monitor heat transfer media temperatures throughout heat-up operations to ensure that localized temperatures do not exceed system design values.

10) The inert gas blanket system(s) for the TSS shall have a safety relief device to protect against pressure buildup that may exceed design levels.

11) A foam firefighting system shall be provided for the TSS.

12) An auxiliary oil make-up tank shall be provided which will allow the oil in the TSS to be pumped below the gravel surface in case of fire.

E.5 ELECTRIC POWER GENERATING SYSTEM

The electrical power generation system possesses the common utility hazards of exposure to high voltage, superheated steam, and equipment-generated high noise levels as well as high pressures and temperatures.

Safety requirements to avoid these hazards are:

1) The electrical power generation system shall provide the necessary sensors and control equipment to monitor/control critical turbine parameters in accordance with the practices of Southern California Edison Company and the recommendations of the selected turbine supplier.

2) The design shall include provisions to monitor steam inlet temperatures and turbine temperatures to detect temperatures and ramp rates in excess of turbine design values.

3) The system shall have the capability to detect or eliminate by design the occurrence of a steam leak at the closed trip-throttle valve to minimize condensation on the internal surfaces of the turbine which may produce erosion-corrosion problems.

4) The design shall provide for monitors to detect the occurrence of excessive vibration during operation and control excessive temperature during shutdown periods.

5) The design shall ensure that cold steam headers are drained admitting steam, and the drains remain open until the line is sufficiently warmed.

6) All turbine and electrical safety trip controls which require periodic functional verifications shall be identified during design/procurement and their frequency or performance established.

7) Parts or components with elevated temperatures shall be insulated against contact with, or exposure to, personnel.

8) Any moving elements shall be shielded to avoid entanglement and safety override controls shall be provided for servicing.

APPENDIX F

APPENDIX F

APPENDIX G

NOTE - Superseded pgs follow Change & Revision notices. Final OPDD entries remain "up front"!

Department of Energy
San Francisco Operations Office
Solar Ten Megawatt Project Office
9550 Flair Drive, Suite 210
El Monte, California 91731

Assistant Manager for Projects
San Francisco Operations Office
Department of Energy
1333 Broadway
Oakland, California 94612

JUL 25 1978

SOLAR 10 MWe PILOT PLANT OPDD - CHANGE NOTICE NO. 001

Dear Sir:

Enclosed is copy 2 of CN 001 to the subject OPDD.

To enable the OPDD to be a source of current information on the Solar Pilot Plant, you are requested to insert the enclosed change notice pages into your binder.

A. Klein
Project Engineer/STMPO

AK:dc
06-78-164

Encl: OPDD CN 001
Affected Pages (11)

OPDD CHANGE NOTICE

Date 25 JULY 1978

Change Notice No. 001

OPDD Title: 10 MWe SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT

OPDD Number: 40-0-800-1DD

Affected Section(s) of OPDD: Table of Contents, Section 1.

Design Phase: Conceptual Design

Description of Change(s):

1. Establish consistent usage of the terms "System" and Subsystem" on Page 2 of Table of Contents, Pgs. 1-4, 1-7, 1-9, 1-10, of Section 1.

2. Change the term "Schematic" to "Block Diagram" on Page 4 of Table of Contents and Figure 1.1 in Section 1 and correct some editorial features.

3. Modify wording of primary project objectives with respect to repowering on Page 1-3.

4. Expand discussion of MCS requirements to reflect "Stand Alone", Page 1-9 and clarify features, Page 1-10.

5. Include the plant operating mode which involves all subsystems operating simultaneously, Page 1-11 and 1-12.

6. Change wording to reflect 5 years of plant operation after completion of construction and checkout, Page 1-14.

Justification of Change(s):

References

a) STMPO letter, 03-78-58, Establishment of Ten Megawatt Pilot Plant Requirements (Approval of OPDD-Section 1), Schweinberg (STMPO) to Distribution, 14 March 1978.

b) DOE letter, Zingeser & Coleman (DST) to Schweinberg (STMPO), Approval of Pilot Plant Plant Requirements, 30 May 1978.

c) DOE letter, Manning (SAN) to Schweinberg (STMPO), Approval of Pilot Plant Requirements, 31 May 1978

d) SCE letter, Rasband (SCE) to Schweinberg (STMPO), Approval Actions Re: 10 MWe Project, 24 April 1978.

e) STMPO letter, 06-78-162, "Project Requirements-Conditions of Approval," Schweinberg (STMPO) to Zingeser (DST-HQ), 21 June 1978.

f) DOE letter, "Regarding Conditions on Approval of OPDD Section 1", Zingeser (DST-HQ) to Schweinberg (STMPO), 13 July 1978.

g) Telecon Record 07-78-183,"OPDD Section 1 Approval--Conditions of Approval", Klein (STMPO) to Zingeser (DST-HQ), 24 July 1978.

OPDD CHANGE NOTICE

1. Editorial corrections required as conditions of approval from Ref. a).

2. Required by Reference a).

3. Required by current wording of Project Construction Data Sheet (Sch. 44) and consistent with request of Reference c).

4. Consistent with requests and recommendations of Reference a).

5. An additional operating mode should be considered to be steady state to complete the matrix of operating mode options. All possible modes are now included which serves to enhance the plant design and operational flexibility.

6. DOE has exercised the 3 year operating option onto the 2 year resulting in the 5 year requirement.

Cost and Schedule Impacts:

1. None

2. None

3. Neither costs nor schedular impacts can be ascribed to the repowering changes. As presently viewed, the acquisition and analysis of data is within the present scope.

4. None, this was always intended.

5. None, this was always intended.

6. None, the capital costs are not affected, the related operating costs have always been estimated on a five year basis. The construction and testing schedules should be considered in a similar manner.

A. Klein

A. Klein - STMPO
Initiator

Approvals:

N/A

Project Manager - Solar Facilities Design Integrator

Richard N. Schweinberg

R. N. Schweinberg - Director, Solar Ten Megawatt Project Office

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TABLES

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FIGURES

The pilot plant occupies a 130-acre site on land owned by Southern California Edison Company adjacent to the Coolwater Generating Station in Daggett, 12 miles southeast of Barstow in San Bernardino County, California. The pilot plant is a joint undertaking of the U. S. Department of Energy (DOE) and the Associates.

1.1.2 Definitions

The following definitions shall apply to this design description:

Associates – Collectively, the organizations associated with the the U. S. Department of Energy in sponsoring the 10-MWe Solar Thermal Central Receiver Pilot Plant. Individually, the Associates are the Southern California Edison Company, the Los Angeles Department of Water and Power, and the California Energy Resources Conservation and Development Commission.

1.1.3 Abbreviations

The following abbreviations shall apply to this design description:

BCS	Beam Characterization System
CPU	Central Processing Unit
CS	Collector System
DAS	Data Acquisition System
EPGS	Electrical Power Generation System
MCS	Master Control System
OCS	Operational Control System
OPDD	Overall Plant Design Description
PCS	Peripheral Control System
P&ID	Piping and Instrumentation Diagram
PSS	Plant Support System
RS	Receiver System
TSS	Thermal Storage System

1.2.4 Plant Availability

The pilot plant shall be designed to supply power, in response to a demand, at least 90% of the time.

1.2.5 Plant Design Criteria

The pilot plant systems, components, and subsystems shall be designed and demonstrated (by analysis, test, inspection, or other means as appropriate) to conform to Codes and Standards specified in Appendix A, which are accepted by regulatory jurisdictions and by knowledgeable practitioners of the disciplines involved.

1.3 Major Plant Subsystem Requirements

1.3.1 Solar Facilities

The solar facilities shall be designed to provide optimized performance by taking into account the diurnal and seasonal variations in insolation as presented in Appendix C.

1.3.1.1 Collector System (CS). The collector subsystem shall be comprised of an array of individually controlled reflectors (heliostats) which continuously direct the available solar insolation onto an elevated receiver. The heliostats are located in a surround field array.

1.3.1.2 Receiver System (RS). The receiver subsystem shall conduct water from the ground level to the top of a tower where a once-through externally heated steam boiler is located that is the focus for the redirected solar energy. The dry superheated steam shall be returned to the ground level within this subsystem for delivery to other systems.

1.3.1.3 Thermal Storage System (TSS). The thermal storage subsystem shall transfer energy from steam to oil for sensible heat storage in an oil-rock containment vessel. Retransfer from oil back to steam shall also be accomplished within this subsystem, which shall be capable of performing both transfer operations simultaneously. The thermal storage subsystems shall be sized to include auxiliary energy needed by other subsystems as well as that energy stored for reconversion to power for the grid.

1.3.1.4 Beam Characterization System (BCS). The beam characterization subsystem shall be that equipment permitting rapid and automatic measurement of flux delivered by any single heliostat. This shall include the software that controls the ordering, processing, and storing of measurement data.

1.3.2 Conventional Electric Power Generating Facilities (EPGS)

These systems transform thermal energy into mechanical-electrical energy for distribution onto a utility network.

1.3.2.1 Turbine-Generator. The turbine shall be a single automatic admission condensing unit. The high-pressure steam (RS) (950° F, 1500 psia nominal) for 10 MWe shall be supplied to the high-pressure inlet valves, and the low-pressure steam (TSS) (525° F, 385 psia nominal) for 7 MWe shall be supplied to the automatic admission port.

1.3.2.2 Heat Distribution and Rejection. Feedwater heating shall be accomplished. A mechanical draft, wet cooling tower shall be used for condenser heat rejection.

1.3.2.3 Condensate Water Treatment. The condensate water shall be treated in a full-flow polishing demineralizer prior to entering the receiver system.

1.3.2.4 Electrical Systems. The generator shall be connected to the facility main power transformer and shall be connected to the transmission system for grid distribution.

1.3.3 Common Benefit Facilities

1.3.3.1 Master Control Subsystem (MCS). The plant master control subsystem is a computerized supervisory system that shall respond to operator direction to provide integrated plant control. MCS controls the functions of plant startup, shutdown, load following, mode changes, and emergency actions.

1.3.3.2 Plant Support Subsystems (PSS). The plant support subsystems provide for inter-connection of the major subsystems, utility distribution throughout the plant, and the necessary facilities such as roads, lighting, buildings, security, and communications.

1.4 Overall Plant Operation Requirements

1.4.1 Environmental Conditions

The pilot plant will be exposed to the environmental conditions at the Barston-Daggett site. These conditions are provided within Appendix C.

Within the conditions existing at the site, selected environmental factors have been identified for the purposes of plant, subsystem, and component design, which are also contained within Appendix C.

1.4.1.1 Operating Conditions. The plant and its subsystems will provide the performance and implement the operating modes of this OPDD when exposed to the operating conditions of Appendix C.

1.4.1.2 Survival Conditions. The plant and its subsystems shall be capable of withstanding the conditions defined in Appendix C without damage and shall be returned to service within the normal elapsed startup time following a return to operating conditions.

1.4.2 Operating Modes

The pilot plant shall be capable of execution of the following operating modes:

1.4.2.1 Steady-State. The following seven steady-state modes of plant operation shall be available. The capability shall be provided to operate at intermediate levels between 10 MWe net and 2 MWe net.

1) CS-RS driving the EPGS (TSS is not involved)
2) CS-RS driving the EPGS and charging the TSS (normal solar power operation)
3) CS-RS driving the EPGS while the TSS also discharges to share in driving the EPGS (low solar power operation)
4) CS-RS charging the TSS and TSS discharging to drive the EPGS (intermittent cloudiness)
5) CS-RS charges TSS only (thermal storage charging)
6) TSS discharges to drive the EPGS (extended operation) at 7 MWe net (maximum)

7) Overnight shutdown and hold of all plant subsystems (subsystem conditioning).

1.4.2.2 Mode Transitions. The plant shall perform the startup and shutdown procedures. The plant shall be capable of transitioning operation from startup to any of the seven steady-state modes and from any of these to any other.

1.4.2.3 Transients. The pilot plant will be both exposed to transient conditions and required to respond to transient demands.

1) The plant will be exposed to transients resulting from external conditions, defined in Appendix C, such as cloud passage, excess winds, earthquake, power loss, etc.

2) The plant will be operational in a mode where the demand change does not exceed TBD MWe/min over the range of 2 to 10 MWe of plant net power output.

1.5 Overall Plant Test and Evaluation Requirements

The test and evaluation requirements of the pilot plant encompass the design, installation, and operation of the plant. Testing is required for a 2-year experimental period to verify the technical feasibility of equipment and systems. Data acquired during the following 3 years of the pilot plant operation will be used to demonstrate and verify the technical performance of the plant, define actual operating and maintenance requirements, confirm commercial system cost projections, and provide directions to technical improvement and major cost reduction efforts. Detailed requirements are listed in Appendix D.

1.5.1 Plant Test and Evaluation

The pilot plant shall be equipped with additional systems, equipment, instrumentation, and data acquisition facilities necessary to test and evaluate the plant performance and operational characteristics in a pilot or experimental context. Design life requirements of paragraph 1.2.3 do not apply to this type of evaluation equipment.

1.7.3 Receiver Tower Crane

The receiver tower shall be equipped with a crane sized for maintenance including replacement of the absorber panels.

1.7.4 Receiver Tower Elevator

The receiver tower shall be equipped with a service elevator for equipment transportation.

1.7.5 Heliostat Cleaning

Heliostat mirror cleaning equipment and facilities shall be provided as required.

1.8 Facility Services Requirements

1.8.1 Site

1.8.1.1 Area. A 130-acre site shall be provided near SCE's Coolwater Generator Station, Barstow, California. This site shall be available as required solely for plant purposes for a period of at least 2 years and at DOE's option for an additional 3 years following initiation of plant operation.

1.8.1.2 Roads, Parking Lots, and Walkways. An all-weather access road from the public road to the site entrance, and hard-surfaced parking lots in the administrative and warehouse areas shall be provided. Walkways between the parking lots and the buildings and between the buildings shall also be provided.

1.8.1.3 Drainage. Drainage or collection shall be provided for:

1) Normal and storm drainage from the solar collector areas and roads, walkways, parking lots, and buildings in the administrative and warehouse areas.

2) A liquid waste collection system for acid, oil, or other waste not allowed in the sanitary drainage.

1.8.1.4 Area Lighting. Lighting shall be provided at the pilot plant perimeter for security and in working and access areas.

1.8.1.5 Security. Site perimeter fencing shall be provided to control site access. Additional localized control fencing shall be provided where required.

1.8.3.3 Auxiliary Systems: The following shall be provided:

1) A plant compressed air supply for the entire pilot plant. A complete, distribution system shall interconnect all pilot plant systems and buildings.

2) An instrument air supply for the entire pilot plant. A complete distribution system shall interconnect all pilot plant systems and buildings.

3) An inert gas (gaseous nitrogen) supply and distribution system.

4) An auxiliary mirror cleaning fluid treatment system.

Department of Energy
San Francisco Operations Office
Solar Ten Megawatt Project Office
9550 Flair Drive, Suite 210
El Monte, California 91731

OCT 6 1978

SOLAR 10MWe PILOT PLANT OPDD - CHANGE NOTICE NO. 002

Dear Sir:

Enclosed is copy 2 of CN 002 to the subject OPDD. To enable the OPDD to be a source of current information on the Solar Pilot Plant, you are requested to insert the enclosed change notice pages into your binder.

Sincerely,

A. Klein
Project Design Engineer
Solar Ten Megawatt Project Office

AK/RJ

10-78-236

Enclosures: CN 002 (1 Page)
Table Of Contents (2 Pages)
Section 2 (81 Pages)
Appendix C (Bound Booklet)

FILE 3.1.1

OPDD CHANGE NOTICE

Date: OCT 6 1978

Change Notice No: 002

OPDD Title: 10 MWe Solar Thermal Central Receiver Pilot Plant

OPDD Number: 40-0-800-1DD

Affected Section(s) of the OPDD:

Tabel of Contents; Section 2; Appendix C

Design Phase: Conceptual Design

Description of Change(s):

1. Change Table of Contents to reflect issuance of Section 2 and Appendix C.

2. Insert "Section 2"

3. Insert "Appendix C"

JUSTIFICATION OF CHANGE(S):

1, 2, and 3 Initial release and change of these portions of OPDD is with STMPO authority per Project Management Plan (40-F-000 1S)

Cost and Schedule Impacts: None

A. Klein

A. Klein - STMPO
Initiator

APPROVALS:

Project Manager - Solar Facilities Design Integrator

Director - STMPO
R. Schweinberg

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CN 001

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FEB 2 6 1979

See Addressee List

REVISION 1 TO OPDD SECTION 1

OPDD Section 1 has been updated to reflect approved Change Notices 001 of July 25, 1978, and 002 of October 6, 1978. In addition, certain clarifications and minor revisions recently suggested by the SFDI and DO DOE Headquarters have also been incorporated. The recent changes are designated by an "R" (revision) or "N" (new) in the left margin.

You are requested to review the subject changes and provide any comments by March 13, 1979, so that the revisions can be incorporated in a timely manner by the SFDI.

/s/ Richard N. Schweinberg

Richard N. Schweinberg, Director
Solar Ten Megawatt Project Office

Enclosure:
As stated

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Joseph N. Reeves, Deputy Director, Solar Ten Megawatt Project, Southern California Edison

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Harris (for info)
~~File~~
Reading File

HEden:vss 2-79-72

CONCURRENCE: HE 2/26 ___ RNS 2/26/79 ___

Eden Schweinberg

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File 3.1.1

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1.0 DESIGN REQUIREMENTS

CONTENTS

1.0 DESIGN REQUIREMENTS

1.1 Summary

1.1.1 Application

This Overall Plant Design Description (OPDD) constitutes the principal means to establish, describe, and control the design of the 10-MWe Solar Thermal Central Receiver Pilot Plant. Section 1.0 of the OPDD contains the specific functions and design requirements to be satisfied by the design in accordance with overall project technical requirements.

The central receiver configuration has been selected by the U. S. Department of Energy (DOE) for early large-scale research, development, and demonstration. This pilot plant project will be the first integration of hardware and software in a functional power generating facility whose performance and reliability can be assessed in the context of utility operation.

The principal programmatic objectives are:

1) To establish the technical feasibility of ~~a~~ solar thermal power plants of the central receiver type, INCLUDING COLLECTION OF DATA ~~particularly~~ for retrofit applications of solar boilers to existing power plants fueled by oil or natural gas. CN001

2) To obtain sufficient development, production, and operating AND MAINTENANCE data to IDENTIFY ~~indicate the~~ potential economics ~~operation~~ of commercial ~~power~~ SOLAR plants of similar designs, INCLUDING ~~especially~~ retrofit applications on a comparable scale. CN001

3) To determine the environmental impact of solar thermal central receiver plants.

Subsidiary objectives are:

1) To gather operational data that can be analyzed to determine system operating and safety characteristics.

2) To develop both utility and commercial acceptance of solar thermal central receiver systems.

3) To stimulate industry to develop and manufacture solar energy systems.

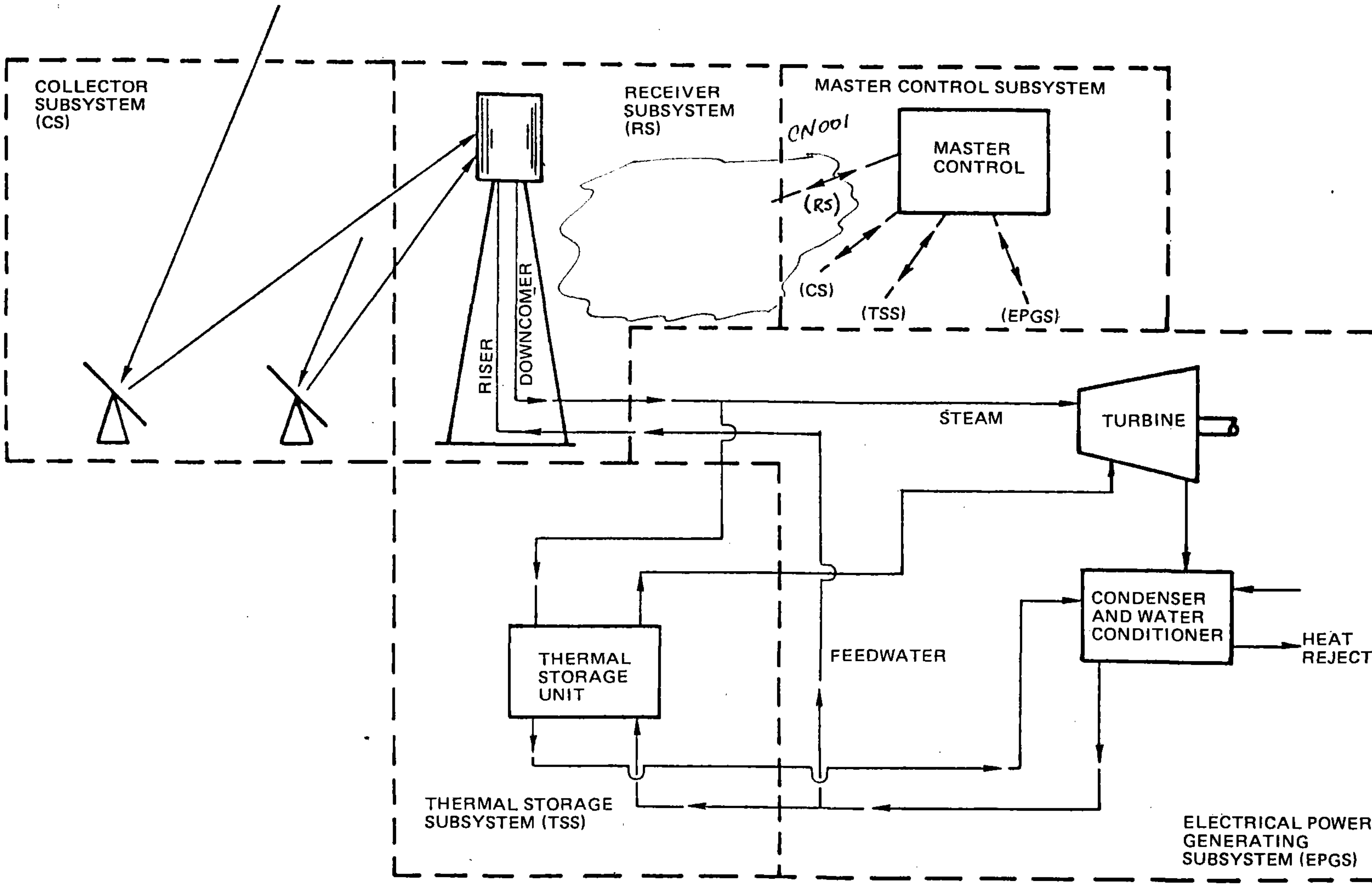
4) To enhance public acceptance and familiarity with solar energy systems.

The requirements which follow (Sections 1.2 through 1.8) represent an interpretation of the programmatic objectives made by the DOE and the Utility Associates. They are based upon the results of studies and experiments and a recognition of the needs for a pilot electrical generating plant. It is intended that these requirements not be changed unless they collectively or individually fail to achieve or address the programmatic objectives. The development of the detailed requirements for subsystems and components, which are described in the subsequent sections of this OPDD, is the essence of the pilot plant design. 100 N)

The central receiver solar thermal power plant (schematically represented in Figure 1.1) consists of five major subsystems: (1) the collector subsystem, (2) the receiver subsystem, (3) the thermal storage subsystem, (4) the electric power generating subsystem, and (5) the master control subsystem.

The collector subsystem (CS) is a 360-deg array of sun-tracking mirrors (heliostats) which reflect the sun's energy to a receiver mounted on a tower. It includes the heliostats themselves, their pedestals and foundations, local controls and drive mechanisms, and a subsystem control console remotely located in the centralized Plant Control Building.

The receiver subsystem (RS) is a water boiler atop a tower located in the heliostat field. It includes the steam generator, feedwater pumps, piping, valves, and instrumentation and controls which comprise the receiver proper, the tower on which it is mounted, and a control console in the Plant Control Building. Feedwater is pumped through a riser to the steam generator, where it is first heated in preheater panels and then evaporated and superheated in a single pass through the tubes of individual boiler panels. The panels of joined vertical tubes are in an outward-facing cylindrical array. Heat is transferred to the tube panels by radiation of reflected solar energy from the surrounding mirror field to the outer surface of the cylinder. Equipment to collect, distribute, and assure that dry steam is delivered to the turbine is provided within this system. The steam is routed through a downcomer to the base of the tower where it is introduced directly to a turbine generator to produce electricity, or to the thermal storage system, or to both simultaneously.



~~RECEIVER~~ SUBSYSTEM MAJOR INTERFACES 9853-1
CN001

Figure 1.1. Central Receiver Thermal Power Plant ~~Schematic~~ BLOCK DIAGRAM
CN001

The thermal storage subsystem (TSS) is a reservoir of heat transfer-thermal capacitance medium which serves as a heat sink for receiver steam. Energy is stored as sensible heat, providing a heat source to generate admission steam for the turbine, thus allowing electric power generation in the absence of sunlight. The TSS consists of tanks, heat exchangers, piping, valves, pumps, instrumentation, and a control console located in the Plant Control Building.

The electric power generating subsystem (EPGS) utilizes conventional power plant equipment such as turbine, generator, condenser, and wet cooling-tower. It includes ancillary equipment, condensate polishing equipment, feed-water heaters, pumps, instrumentation, and a control console located in the Plant Control Building.

The master control subsystem (MCS) is the equipment and software required for integrated and automatic control of the plant, and for gathering and processing plant evaluation data. It is located in the Plant Control Building. The MCS is an overall command, control, and Data Acquisition System (DAS) which performs control management, supervision functions as well as data collection and display functions. Its purpose is to integrate the independent controls of the other four subsystems (CS, RS, TSS, EPGS) and the balance of plant to achieve effective single console control and evaluation capability. Thus, the MCS consists of the plant supervisory controls, the DAS, and the data displays and consoles.

The pilot plant also includes the following two systems which support and connect the major systems:

The beam characterization subsystem (BCS) is tower-mounted equipment which permits measurement of flux delivered by an individual heliostat. Included is the software which controls the ordering, processing, and storing of the measurement data.

The plant support subsystem (PSS) consists of the ancillary equipment and structures required for operating the plants major systems. These include electrical power and mechanical systems such as water, nitrogen, and compressed air. The PSS also includes fire protection and plant security provisions, communications, and facilities for administration and maintenance.

The pilot plant occupies a 130-acre site on land owned by Southern California Edison Company adjacent to the Coolwater Generating Station in Daggett, 12 miles southeast of Barstow in San Bernardino County, California. The pilot plant is a joint undertaking of the U. S. Department of Energy (DOE) and the Associates.

1.1.2 Definitions

The following definitions shall apply to this design description:

Associates — Collectively, the organizations associated with the the U. S. Department of Energy in sponsoring the 10-MWe Solar Thermal Central Receiver Pilot Plant. Individually, the Associates are the Southern California Edison Company, the Los Angeles Department of Water and Power, and the California Energy Resources Conservation and Development Commission.

1.1.3 Abbreviations

The following abbreviations shall apply to this design description:

BCS	Beam Characterization System
CPU	Central Processing Unit
CS	Collector System
DAS	Data Acquisition System
EPGS	Electrical Power Generation System
MCS	Master Control System
OCS	Operational Control System
OPDD	Overall Plant Design Description
PCS	Peripheral Control System
P&ID	Piping and Instrumentation Diagram
PSS	Plant Support System
RS	Receiver System
TSS	Thermal Storage System

1.2 Overall Plant Design Requirements

1.2.1 Plant Rating and Sizing

1) The 10-MWe Solar Thermal Central Receiver Pilot Plant shall deliver 10 MWe of electric power to the Southern California Edison Co. distribution grid. This power level shall be the minimum net output of the plant after subtracting all plant operating requirements and when operating solely from insolation for a period of at least 4 h on the least favorable day of the year. This is the "Plant Design Worst Day" (minimum energy available to the site on a clear day), as defined by the environmental conditions in Appendix C.

2) The pilot plant shall deliver the rated net electric power output of 10 MWe when operating solely from insolation for a period of at least 8 h on the most favorable day of the year. This is the "Plant Design Best Day" (maximum energy available to the site on a clear day), as defined by the environmental conditions in Appendix C.

3) The plant shall be sized for charging of storage with all the energy available in excess of the rated 10 MWe net for 8 h on the Plant Design Best Day for as long as the sun is 0.26 rad above the horizon.

1.2.2 Plant Energy Storage Capacity

The 10-MWe Solar Thermal Central Receiver Pilot Plant shall deliver a minimum of 28 MWe-h of electrical energy to the grid when operating solely from a fully charged thermal storage subsystem. The net power shall be 7 MWe (minimum).

1.2.3 Plant Design Life

The pilot plant and its subsystems and components shall be designed to meet a 30-year plant lifetime expected in a utility usage context. The requirements for design are established by the environmental constraints and the operational life cycle exposures as detailed in Appendices B and C, respectively.

1.2.4 Plant Availability

The pilot plant shall be designed to supply power, in response to a demand, at least 90% of the time.

1.2.5 Plant Design Criteria

The pilot plant systems, components, and subsystems shall be designed and demonstrated (by analysis, test, inspection, or other means as appropriate) to conform to Codes and Standards specified in Appendix A, which are accepted by regulatory jurisdictions and by knowledgeable practitioners of the disciplines involved.

1.3 Major Plant Subsystem Requirements

1.3.1 Solar Facilities

Any of the following major subsystems shall be capable of being operated by a plant operator independent of the MCS.

The solar facilities shall be designed to provide optimized performance by taking into account the diurnal and seasonal variations in insolation as presented in Appendix C.

1.3.1.1 Collector System (CS). The collector subsystem shall be comprised of an array of individually controlled reflectors (heliostats) which continuously direct the available solar insolation onto an elevated receiver. The heliostats are located in a surround field array.

1.3.1.2 Receiver System (RS). The receiver subsystem shall conduct water from the ground level to the top of a tower where a once-through externally heated steam boiler is located that is the focus for the redirected solar energy. The dry superheated steam shall be returned to the ground level within this subsystem for delivery to other systems.

1.3.1.3 Thermal Storage System (TSS). The thermal storage subsystem shall transfer energy from steam to oil for sensible heat storage in an oil-rock containment vessel. Retransfer from oil back to steam shall also be accomplished within this subsystem, which shall be capable of performing both transfer operations simultaneously. The thermal storage subsystems shall be sized to include auxiliary energy needed by other subsystems as well as that energy stored for reconversion to power for the grid.

1.3.1.4 Beam Characterization Subsystem (BCS). The beam characterization subsystem shall be that equipment permitting rapid and automatic measurement of flux delivered by any single heliostat. This shall include the software that controls the ordering, processing, and storing of measurement data. CN001

1.3.2 Conventional Electric Power Generating Subsystem Facilities (EPGS) CN001

These systems transform thermal energy into mechanical-electrical energy for distribution onto a utility network.

1.3.2.1 Turbine-Generator. The turbine shall be a single automatic admission condensing unit. The high-pressure steam (RS) (950° F, 1500 psia nominal) for 10 MWe shall be supplied to the high-pressure inlet valves, and the low-pressure steam (TSS) (525° F, 385 psia nominal) for 7 MWe shall be supplied to the automatic admission port.

1.3.2.2 Heat Distribution and Rejection. Feedwater heating shall be accomplished. A mechanical draft, wet cooling tower shall be used for condenser heat rejection.

1.3.2.3 Condensate Water Treatment. The condensate water shall be treated in a full-flow polishing demineralizer prior to entering the receiver system.

1.3.2.4 Electrical Systems. The generator shall be connected to the facility main power transformer and shall be connected to the transmission system for grid distribution.

1.3.3 Common Benefit Facilities

1.3.3.1 Master Control Subsystem (MCS). The plant master control subsystem is a computerized supervisory system that shall respond to operator direction to provide integrated plant control. MCS controls the functions of plant startup, shutdown, load following, mode changes, and emergency actions. MCS also includes a data acquisition system (DAS) and a peripheral control system (PCS) which operate independently from the plant supervisory operational control system. These MCS features shall support the requirements of paragraph 1.5. CN001

1.3.3.2 Plant Support Subsystems (PSS). The plant support subsystems provide for inter-connection of the major subsystems, utility distribution throughout the plant, and the necessary facilities such as roads, lighting, buildings, security, and communications.

1.4 Overall Plant Operation Requirements

1.4.1 Environmental Conditions

The pilot plant will be exposed to the environmental conditions at the Barston-Daggett site. These conditions are provided within Appendix C.

Within the conditions existing at the site, selected environmental factors have been identified for the purposes of plant, subsystem, and component design, which are also contained within Appendix C.

1.4.1.1 Operating Conditions. The plant and its subsystems will provide the performance and implement the operating modes of this OPDD when exposed to the operating conditions of Appendix C.

1.4.1.2 Survival Conditions. The plant and its subsystems shall be capable of withstanding the conditions defined in Appendix C without damage and shall be returned to service within the normal elapsed startup time following a return to operating conditions.

1.4.2 Operating Modes

The pilot plant shall be capable of execution of the following operating modes:

1.4.2.1 Steady-State. The following ~~seven~~ EIGHT steady-state modes of plant operation shall be available. The capability shall be provided to operate at intermediate levels between 10 MWe net and 2 MWe net.

1) CS-RS driving the EPGS (TSS is not involved)
2) CS-RS driving the EPGS and charging the TSS (normal solar power operation)
3) CS-RS driving the EPGS while the TSS also discharges to share in driving the EPGS (low solar power operation)
4) CS-RS charging the TSS and TSS discharging to drive the EPGS (intermittent cloudiness)
5) CS-RS charges TSS only (thermal storage charging)
6) TSS discharges to drive the EPGS (extended operation) at 7 MWe net (maximum)
7) CS-RS charging TSS and driving T-GS and TSS discharging to drive T-GS simultaneously (all subsystems in operation).

8 ~~7~~) Overnight shutdown and hold of all plant subsystems (subsystem conditioning). CN001

1.4.2.2 Mode Transitions. The plant shall perform the startup and shutdown procedures. The plant shall be capable of transitioning operation from startup to any of the ~~seven~~ EIGHT steady-state modes and from any of these to any other. CN001

1.4.2.3 Transients. The pilot plant will be both exposed to transient conditions and required to respond to transient demands.

1) The plant will be exposed to transients resulting from external conditions, defined in Appendix C, such as cloud passage, excess winds, earthquake, power loss, etc.

2) The plant will be operational in a mode where the demand change does not exceed TBD MWe/min over the range of 2 to 10 MWe of plant net power output.

1.5 Overall Plant Test and Evaluation Requirements

The test and evaluation requirements of the pilot plant encompass the design, installation, and operation of the plant. Testing is required for a 2-year experimental period to verify the technical feasibility of equipment and systems. Data acquired during the following 3 years of the pilot plant operation will be used to demonstrate and verify the technical performance of the plant, define actual operating and maintenance requirements, confirm commercial system cost projections, and provide directions to technical improvement and major cost reduction efforts. Detailed requirements are listed in Appendix D.

1.5.1 Plant Test and Evaluation

The pilot plant shall be equipped with additional systems, equipment, instrumentation, and data acquisition facilities necessary to test and evaluate the plant performance and operational characteristics in a pilot or experimental context. Design life requirements of paragraph 1.2.3 do not apply to this type of evaluation equipment.

1.6 Plant Safety Requirements

1.6.1 Plant Operations

Plant systems shall be designed to prevent creation of unsafe or potentially hazardous conditions within or outside the facility. The design shall consider potential risks generated by the unique character of this installation as a solar central receiver facility.

1.6.2 Plant Protection System

The plant protection systems shall be designed, installed, and maintained such that no single component and/or system failure, human error, or design feature will cause an accident that results in major injury or death to personnel or excessive damage to equipment or property. Detailed requirements are listed in Appendix E.

1.6.3 Plant Controls

Upon detection of an unsafe condition, the plant shall automatically sequence to a safe condition.

1.6.4 Codes and Standards

The plant shall be designed, constructed, maintained, and operated in accordance with nationally and locally recognized and accepted Codes and Standards applicable to the disciplines involved. Appendix A establishes the applicability of such Codes and Standards.

1.7 Plant Maintenance Requirements

1.7.1 Routine Maintenance

Plant systems shall be designed to enable routine maintenance without loss of operating time.

1.7.2 Employee Skills

Plant systems shall be designed to permit maintenance by power plant operating employees.

1.7.3 Receiver Tower Crane

The receiver tower shall be equipped with a crane sized for maintenance including replacement of the absorber panels.

1.7.4 Receiver Tower Elevator

The receiver tower shall be equipped with a service elevator for equipment transportation.

1.7.5 Heliostat Cleaning

Heliostat mirror cleaning equipment and facilities shall be provided as required.

1.8 Facility Services Requirements

1.8.1 Site

1.8.1.1 Area. A 130-acre site shall be provided near SCE's Coolwater Generator Station, Barstow, California. This site shall be available as required solely for plant purposes for a period of at least ~~2~~ 5 years ~~and at DOE's option for an additional 3 years~~ following initiation of plant operation.

1.8.1.2 Roads, Parking Lots, and Walkways. An all-weather access road from the public road to the site entrance, and hard-surfaced parking lots in the administrative and warehouse areas shall be provided. Walkways between the parking lots and the buildings and between the buildings shall also be provided.

1.8.1.3 Drainage. Drainage or collection shall be provided for:

1) Normal and storm drainage from the solar collector areas and roads, walkways, parking lots, and buildings in the administrative and warehouse areas.

2) A liquid waste collection system for acid, oil, or other waste not allowed in the sanitary drainage.

1.8.1.4 Area Lighting. Lighting shall be provided at the pilot plant perimeter for security and in working and access areas.

1.8.1.5 Security. Site perimeter fencing shall be provided to control site access. Additional localized control fencing shall be provided where required.

1.8.1.6 Sewage. Sewage drainage shall be provided from all site areas to a sewage treatment system for the pilot plant.

1.8.1.7 Helistop. A helistop (i.e., heliport without refueling provisions) shall be provided near or at the plant site.

1.8.2 Buildings

The following buildings shall be provided:

1) An administration building with an area of approximately 3000 ft^2. This building shall contain areas and facilities for plant management, visitor control, and technical support for the pilot plant.

2) A plant control building with facilities and space for operation of the plant. A central room approximately 25 ft by 45 ft within the building shall permit centralized control of the plant through the MCS. This building shall also provide space for switchgear and associated electrical equipment.

3) A building of approximately 6000 ft^2 area shall house warehouse, assembly, and maintenance functions.

4) The necessary foundations and structures to support and house the turbine-generator and associated electrical and steam and feedwater equipment.

5) A security building at the site entrance.

6) A visitor's center near or at the plant site.

1.8.3 Utilities

1.8.3.1 Power. Normal and emergency power shall be provided as follows:

1) Generate own normal power during generator operation.

2) Site to be provided with limited power for emergencies and off periods.

1.8.3.2 Water. Water systems shall be provided as follows:

1) A well (potable) water supply to the site for all plant uses.

1.8.3.3 Auxiliary Systems: The following shall be provided:

1) A plant compressed air supply for the entire pilot plant. A complete distribution system shall interconnect all pilot plant systems and buildings.

2) An instrument air supply for the entire pilot plant. A complete distribution system shall interconnect all pilot plant systems and buildings.

3) An inert gas (gaseous nitrogen) supply and distribution system.

4) ~~An~~ A ~~auxiliary~~ mirror cleaning fluid treatment system. I CN 001

DOE Form AD-10A
(12-77)

Pms
9/8/79

U.S. DEPARTMENT OF ENERGY

memorandum

File 3.1.1

DATE: May 24, 1979

REPLY TO
ATTN OF:

SUBJECT: Approval of OPDD, Section 1, Revised April 23, 1979

TO: Joel Zingeser

The subject OPDD revision is satisfactory, subject to your resolution of the following comments:

1. I would like to better understand; i.e., quantitatively, the performance penalties associated with limiting solar thermal charge rates to less than peak receiver output. By the same token, it would be helpful to understand the cost penalty associated with higher charge rates than presently specified.

2. The requirement that the receiver be designed to accommodate a peak incident heat flux of at least 0.3 MW thermal needs to be tightened up. Specifically, it is not clear how we would determine if the designer had satisfied this requirement.

A related concern. In my discussions with STMPO, which you arranged, I got the vague impression that the OPDD is being viewed as not a set of requirements, but more as an instrument for documenting design choices as they are made. I think it is important that this document be viewed as the technical envelope for STMPO and its contractors. In this context, leaving no room for debate as to how you would determine whether the technical requirements set forth have been met is quite important.

Gerald W. Braun

DOE Form AD-10A
(12-77)

U.S. DEPARTMENT OF ENERGY

memorandum

DATE: MAY 31 1979

File 3.1.1

REPLY TO ATTN OF:

SUBJECT: Approval of OPDD, Section 1, Revised April 23, 1979

TO: R. Schweinberg, Director
Solar Ten Megawatt Project Office

The Overall Plan Design Description, Section 1, as revised April 23, 1979 is approved. It is my understanding that you will add a description of the DOE/Associates interfaces as defined in the Cooperative Agreement. This may be in the form of a drawing and/or narrative.

Joel

Joel P. Zingeser
Project Officer
10 MWe Pilot Plant
Division of Central Solar Technology

RECEIVED
JUN 11 '79
STMPO

DOE Form AD-10A
(12-77)

U.S. DEPARTMENT OF ENERGY

memorandum

DATE: JUN 7 1979

File 3.1.1

REPLY TO
ATTN OF:

SUBJECT: Braun Memo (5/24/79) Regarding OPDD Questions

TO: R. N. Schweinberg, Director
Solar Ten Megawatt Project Office

Attached is a copy of the subject memorandum. I believe it is self-explanatory; however, please call if you have any questions. I would like you to provide me a written response with a copy to Gerry and George.

Thank you.

Joel

Joel P. Zingeser
Project Officer
10 MWe Pilot Plant
Division of Central Solar Technology

Attachment

RECEIVED
JUN 12 '79
STMPO

Department of Energy
San Francisco Operations Office
Solar Ten Megawatt Project Office
9550 Flair Drive, Suite 210
El Monte, California 91731

SEP 25 1979

TO: Joel P. Zingeser, Project Officer, Central Solar Technology, HQ

SUBJECT: Distribution of Approved OPDD, Section 1

REFERENCES:

1. DOE Memo from J. P. Zingeser, to R. N. Schweinberg May 31, 1979
2. DOE Memo from G. W. Braun to J. P. Zingeser, May 24, 1979
3. Letter to Sandia Livermore, Alan C. Skinrood, May 1, 1979

In accordance with Reference (1), the finalized OPDD Section 1 is issued as Enclosure 1 of this memorandum.

Several questions were raised in Reference 2, some of which have been resolved by the latest revision of Section 1, and the remainder are answered herein.

A detailed explanation of sizing the thermal storage (TSS) heat exchanger (HX) was forwarded to Sandia-Livermore via Reference 3. It should be recognized that sizing the TSS charging HX is, to a certain extent, a philosophical decision, with some cost reduction associated with decrease in size. Basically, the TSS charging HX was designed to handle the thermal equivalent of 10 MWe (net turbine output), rather than the 12.4 MWe maximum output of the receiver. The current charging HX capacity of 10 MWe is well above the maximum discharge rate of the thermal storage subsystem (7 MWe), and the receiver can operate at full power when the turbine is on line. The only compromise made in the current design is that the receiver will only be able to operate at 80% of full power with the turbine completely off-line. This situation is not expected to occur often, and a cost avoidance will be realized (on the order of $100 K - STMPO rough estimate).

Section 1 of the OPDD is the portion of the OPDD that represents the top level design requirement for the plant, and this requirement has been clearly asserted in Article 1.1.1, Application. The SFDI has been religiously adhering to Section 1 as a design requirement. The balance of the OPDD is a detailed system description of the pilot plant design, as it should be.

Sincerely,

J M Slaminski

for Richard N. Schweinberg, Director
Solar Ten Megawatt Project Office

Enclosure

9-79-339

cc: Ray W. Hallet, SFDI, MDAC
R. Gervais, SFDI, MDAC
A. Skinrood, Sandia-Livermore
J. Reeves, Southern California Edison
C. Winarski, Southern California Edison

DEPARTMENT OF ENERGY SOLAR TEN MEGAWATT PROJECT OFFICE CHANGE REQUEST	CHANGE REQUEST NO. DOE-001 CONTRACT NUMBER PAGE 1 OF 1

SYSTEM/COMPONENT AFFECTED OPDD Section 1

REQUESTED BY SFDI, DOE HQ & STMPO DATE Feb. TM H. Eden

DESCRIPTION OF CHANGE:

Revision 1 to OPDD, Section 1

NOTE! Rev. 1 was not approved by HQ - further discussion led to rev 2 approved 5/31/79 & distributed 9/25/79

JUSTIFICATION:

Headquarters comments and pre-contractual review by the SFDI identified the need for an update to the definition of the overall pilot plant requirements.

CCB PRELIMINARY REVIEW:

CCB TECHNICAL APPROVAL ☐ YES ☐ NO

ADDITIONAL DATA REQUIRED ☐ YES ☐ NO

DOE SAN APPROVAL REQUIRED ☐ YES ☐ NO

DOE HEADQUARTERS APPROVAL REQUIRED ☐ YES ☐ NO

CCB CHAIRMAN ______ DATE ______

CCB FINAL REVIEW:

CHANGE REQUEST APPROVED ☐ YES ☐ NO

OPDD CHANGE REQUIRED ☐ YES ☐ NO

ICD CHANGE REQUIRED ☐ YES ☐ NO

CONTRACT CHANGE REQUIRED ☐ YES ☐ NO

CCB CHAIRMAN ______ DATE ______

CCB COMMENTS:

sheet 1

	DEPARTMENT OF ENERGY SOLAR TEN MEGAWATT PROJECT OFFICE CHANGE REQUEST	CHANGE REQUEST NO. CONTRACT NUMBER PAGE ___ OF ___

DOCUMENTATION AFFECTED:

SCHEDULE:

COST:

CONTENTS

1.0 DESIGN REQUIREMENTS

CONTENTS

1.0 Design Requirements

1.1 Summary

1.1.1 Application

This Overall Plant Design Description (OPDD) constitutes the principal means to establish, describe, and control the design of the 10 MWe Solar Thermal Central Receiver Pilot Plant. Section 1.0 of the OPDD contains the specific functions and design requirements to be satisfied by the design in accordance with overall project technical requirements.

The central receiver configuration has been selected by the U.S. Department of Energy (DOE) for early large-scale research, development, and demonstration. This pilot plant project will be the first integration of hardware and software in a functional power generating facility whose performance and reliability can be assessed in the context of utility operation.

The principal programmatic objectives are:

1) To establish the technical feasibility of solar thermal power plants of the central receiver type, including collection of data for retrofit applications of solar boilers to existing power plants fueled by oil or natural gas.

2) To obtain sufficient development, production, and operating and maintenance data to identify potential economics of commercial solar plants of similar design, including retrofit applications on a comparable scale.

3) To determine the environmental impact of solar thermal central receiver plants.

Subsidiary objectives are:

1) To gather operational data that can be analyzed to determine system operating and safety characteristics.

2) To develop both utility and commercial acceptance of solar thermal central receiver systems.

3) To stimulate industry to develop and manufacture solar energy systems.

4) To enhance public acceptance and familiarity with solar energy systems.

The requirements which follow (Sections 1.2 through 1.8) represent an interpretation of the programmatic objectives made by the DOE and the Utility Associates. They are based upon the results of studies and experiments and a recognition of the needs for a pilot electrical generating plant. It is intended that these requirements not be changed unless they collectively or individually fail to achieve or address the programmatic objectives. The development of the detailed requirements for subsystems and components, which are described in the subsequent sections of this OPDD, is the essence of the pilot plant design.

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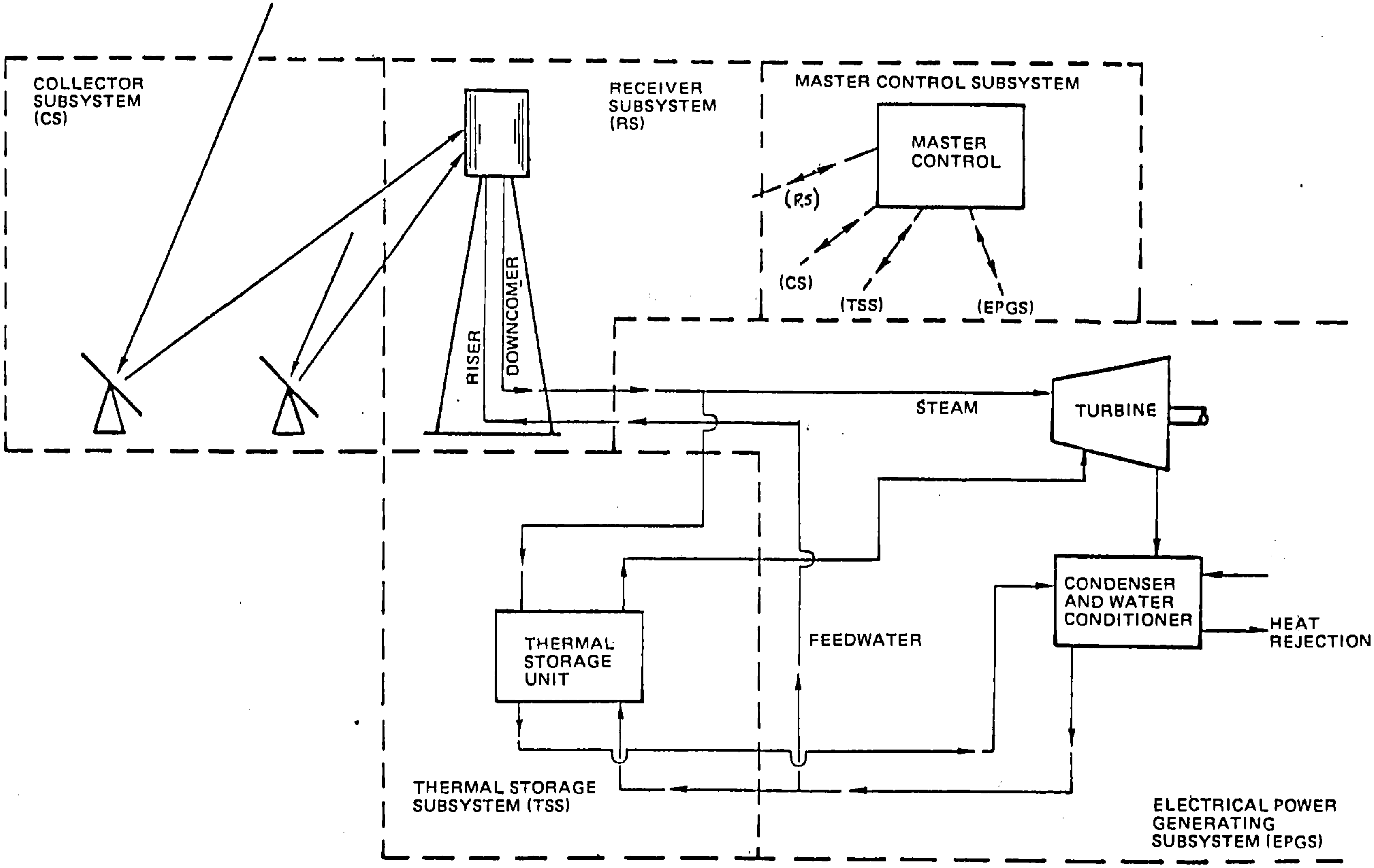
R The receiver subsystem (RS) includes all of the hardware and software necessary to convert feedwater into superheated steam by utilizing redirected solar energy from the collector subsystem. It consists of a tower-mounted water boiler (steam generator), support tower, and feedwater pumps, piping, valves, and instrumentation and controls necessary for water/steam circulation and flow control as well as a control console in the Plant Control Building. Feedwater is pumped through a riser to the steam generator, where it is first heated in preheater panels and then evaporated and superheated in a single pass through the tubes of individual boiler panels. The panels of joined vertical tubes are in an outward-facing cylindrical array. Heat is transferred to the tube panels by radiation of reflected solar energy from the surrounding mirror field to the outer surface of the cylinder. Equipment to collect, distribute, and assure that dry steam is delivered to the turbine is provided within this system. The steam is routed through a downcomer to the base of the tower where it is introduced directly to a turbine generator to produce electricity, or to the thermal storage system, or to both simultaneously.



SUBSYSTEM MAJOR INTERFACES

9853-1

Figure 1.1. Central Receiver Thermal Power Plant Block Diagram

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RS	Receiver Subsystem
TSS	Thermal Storage Subsystem

1.2 Overall Plant Design Requirements

1.2.1 Plant Rating and Sizing

1) The 10 MWe Solar Thermal Central Receiver Pilot Plant shall deliver 10 MWe of electric power to the Southern California Edison Co. distribution grid. This power level shall be the minimum net output of the plant after subtracting all plant operating requirements and when operating solely from insolation for a period of at least 4 h on the least favorable day of the year. This is the "Plant Design Worst Day" (minimum energy available to the site on a clear day), as defined by the environmental conditions in Appendix C.

2) The pilot plant shall deliver the rated net electric power output of 10 MWe when operating solely from insolation for a period of at least 8 h on the most favorable day of the year. This is the "Plant Design Best Day" (maximum energy available to the site on a clear day), as defined by the environmental conditions in Appendix C.

R 3) The maximum thermal storage charge rate (thermal power absorbed into the TSU) shall be equivalent to the thermal power level required to operate the turbine at a 10 MWe net output level.

1.2.2 Plant Energy Storage Capacity

The 10 MWe Solar Thermal Central Receiver Pilot Plant shall deliver a minimum of 28 MWe-h of electrical energy to the grid when operating solely from a fully charged thermal storage subsystem. The net power shall be 7 MWe (minimum).

1.2.3 Plant Design Life

The pilot plant and its subsystems and components shall be designed to meet a 30-year plant lifetime expected in a utility usage context. The requirements for design are established by the environmental constraints and the operational life cycle exposures as detailed in appendices B and C, respectively.

1.2.4 Plant Availability

R The pilot plant shall be designed to accept solar energy and supply power, in response to a demand, at least 90% of the time it could normally be functioning.

1.2.5 Plant Design Criteria

The pilot plant systems, components, and subsystems shall be designed and demonstrated (by analysis, test, inspection, or other means as appropriate) to conform to Codes and Standards specified in Appendix A, which are accepted by regulatory jurisdictions and by knowledgeable practitioners of the disciplines involved.

1.3 Major Plant Subsystem Requirements

R The plant shall be capable of operation with a single operator through MCS and manual operation at the major subsystem control level independent of the MCS.

The solar facilities shall be designed to accommodate the diurnal and seasonal variations in insolation as presented in Appendix C.

1.3.1.1 Collector Subsystem (CS). The collector subsystem shall be comprised of an array of individually controlled reflectors (heliostats) which continuously direct the available solar insolation onto an elevated receiver. The heliostats are located in a surround field array.

1.3.1.2 Receiver Subsystem (RS). The receiver subsystem shall conduct water from the ground level to the top of a tower where a once-through externally heated steam boiler is located that is the focus for the redirected solar energy. The dry superheated steam shall be returned to the ground level within this subsystem for delivery to other subsystems.

N The receiver boiler shall be designed so that the peak incident heat flux shall be at least 0.3 $MWth/m^2$.

1.3.1.3 Thermal Storage Subsystem (TSS). The thermal storage subsystem shall transfer energy from steam to oil for sensible heat storage in an oil-rock containment vessel. Retransfer from oil back to steam shall also be accomplished within this subsystem, which shall be capable of performing both transfer operations simultaneously. The thermal storage subsystem shall be sized to include auxiliary energy needed by other subsystems as well as that energy stored for reconversion to power for the grid.

1.3.1.4 Beam Characterization Subsystem (BCS). The beam characterization subsystem shall be that equipment permitting rapid and automatic measurement of flux delivered by any single heliostat. This shall include the software that controls the ordering, processing, and storing of measurement data.

1.3.2 Conventional Electric Power Generating Subsystem Facilities (EPGS)

These facilities transform thermal energy into mechanical-electrical energy for distribution onto a utility network.

1.3.2.1 Turbine-Generator. The turbine shall be a single automatic admission condensing unit. The high-pressure steam (RS) (950° F, 1465 psia nominal) for 10 MWe shall be supplied to the high-pressure inlet valves, and the low-pressure steam (TSS) (525° F, 385 psia nominal) for 7 MWe shall be supplied to the automatic admission port. The turbine shall be capable of operating solely from either N high pressure or low pressure inlet steam or from both steam sources simultaneously.

1.3.2.2 Heat Distribution and Rejection. Feedwater heating shall be accomplished with thermal energy extracted from the turbine R or available from the TSS or auxilliary sources. A mechanical draft, wet cooling tower shall be used for condenser heat rejection.

1.3.2.3 Condensate Water Treatment. Water treatment equipment R shall be provided to maintain feedwater and steam chemistry at the levels specified for receiver and turbine operation.

1.3.2.4 Electrical Systems. The generator shall be connected to the facility main power transformer and shall be connected to the transmission system for grid distribution.

1.3.3 Common Benefit Facilities

1.3.3.1 Master Control Subsystem (MCS). The plant master control subsystem is a computerized overall command, control, and data acquisition system which performs control management and supervision functions as well as data collection and display functions. It R integrates the independent controls of the other four subsystems (RS, CS, TSS and EPGS) to achieve effective single location control and evaluation capability. The MCS consists of the plant supervisory and operational controls (OCS), a data acquisition (DAS), and a peripheral control (PCS) which is a backup to the OCS and which controls the data displays on the respective subsystem consoles.

1.3.3.2 Plant Support Subsystems (PSS). The plant support subsystems provide for inter-connection of the major subsystems, utility distribution throughout the plant, and the necessary facilities such as roads, lighting, buildings, security, and communications.

1.4 Overall Plant Operation Requirements

1.4.1 Environmental Conditions

The pilot plant will be exposed to the environmental conditions at the Barstow-Daggett site. These conditions are provided within Appendix C.

Within the conditions existing at the site, selected environmental factors have been identified for the purposes of plant, subsystem, and component design, which are also contained within Appendix C.

1.4.1.1 Operating Conditions. The plant and its subsystem will provide the performance and implement the operating modes of this OPDD when exposed to the operating conditions of Appendix C.

1.4.1.2 Survival Conditions. The plant and its subsystems shall be capable of withstanding the conditions defined in Appendix C without damage and shall be returned to service within the normal elapsed startup time following a return to operating conditions.

1.4.2 Operating Modes

The pilot plant shall be capable of execution of the following operating modes:

R 1.4.2.1 Steady-State. The following eight steady-state modes of plant operation shall be available. The capacity shall be provided to operate at a minimum steady state power output level of 2 MWe net. Mode 1, 2, 3 and 7 shall also be capable of providing at least 10 MWe net power as specified in Paragraph 1.2.1 while Mode 4 and 6 shall be capable of providing at least 7 MWe net power as specified in Paragraph 1.2.2.

1) CS-RS driving the EPGS (TSS is not involved)

2) CS-RS driving the EPGS and charging the TSS (normal solar power operation)

3) CS-RS driving the EPGS while the TSS also discharges to share in driving the EPGS (low solar power operation)

4) CS-RS charging the TSS and TSS discharging to drive the EPGS (intermittent cloudiness)

5) CS-RS charges TSS only (thermal storage charging)

6) TSS discharges to drive the EPGS (extended operation) at 7 MWe net (maximum)

7) CS-RS charging TSS and driving T-GS and TSS discharing to drive T-GS simultaneously (all subsystems in operation).

8) Overnight shutdown and hold of all plant subsystems (subsystem conditioning)

R 1.4.2.2 Mode Transitions. The plant shall perform the startup and shutdown procedures. The plant shall be capable of transitioning between operating modes in a preprogrammed manner.

1.4.2.3 Transients. The pilot plant will be both exposed to transient conditions and required to respond to transient demands.

1) The plant will be exposed to transients resulting from external conditions, defined in Appendix C, such as cloud passage, excess winds, earthquake, power loss, etc.

R 2) The plant will be operational in a mode where the demand change does not exceed TBD MWe/min over the acceptable range of plant net power output for that mode.

1.5 Overall Plant Test and Evaluation Requirements

The test and evaluation requirements of the pilot plant encompass the design, installation, and operation of the plant. Testing is required for a 2-year experimental period to verify the technical feasibility of equipment and systems. Data acquired during the following 3 years of the pilot plant operation will be used to demonstrate and verify the technical performance of the plant, define actual operating and maintenance requirements, confirm commercial system cost projections, and provide directions to technical improvement and major cost reduction efforts. Detailed requirements are listed in Appendix D.

1.5.1 Plant Test and Evaluation

The pilot plant shall be equipped with additional systems, equipment, instrumentation, and data acquisition facilities necessary to test and evaluate the plant performance and operational characteristics in a pilot or experimental context. Design life requirements of paragraph 1.2.3 do not apply to this type of evaluation equipment.

1.6 Plant Safety Requirements

1.6.1 Plant Operations

Plant systems shall be designed to prevent creation of unsafe or potentially hazardous conditions within or outside the facility. The design shall consider potential risks generated by the unique character of this installation as a solar central receiver facility.

1.6.2 Plant Protection System

The plant protection system shall be designed, installed and maintained such that no single component and/or system failure or design feature will cause an accident that results in major injury or death to personnel or excessive damage to equipment or property. N The plant shall be designed to minimize the possibility of human error which can lead to an accident hazardous to equipment or personnel. Detailed requirements are listed in Appendix E.

1.6.3 Plant Controls

Upon detection of an unsafe condition, the plant shall automatically sequence to a safe condition.

1.6.4 Codes and Standards

The plant shall be designed, constructed, maintained, and operated in accordance with nationally and locally recognized and accepted Codes and Standards applicable to the disciplines involved. Appendix A establishes the applicability of such Codes and Standards.

1.7 Plant Maintenance Requirements

1.7.1 Routine Maintenance

R Plant systems shall be designed to enable routine maintenance with a minimum loss of operating time.

1.7.2 Employee Skills

Plant systems shall be designed to permit maintenance by power plant operating employees.

1.7.3 Receiver Tower Crane

The receiver tower shall be equipped with a crane sized for maintenance including replacement of the absorber panels.

1.7.4 Receiver Tower Elevator

The receiver tower shall be equipped with a service elevator for equipment transportation.

1.7.5 Heliostat Cleaning

Heliostat mirror cleaning equipment and facilities shall be provided as required.

1.8 Facility Services Requirements

1.8.1 Site

1.8.1.1 Area. A 130-acre site shall be provided near SCE's Coolwater Generator Station, Barstow, California. This site shall be available as required solely for plant purposes for a period of at least 5 years following initiation of plant operation.

1.8.1.2 Roads, Parking Lots, and Walkways. An all-weather access road from the public road to the site entrance, and hard-surfaced parking lots in the administrative and warehouse areas shall be provided. Walkways between the parking lots and the buildings and between the buildings shall also be provided.

1.8.1.3 Drainage. Drainage or collection shall be provided for:

1) Normal and storm drainage from the solar collector areas and roads, walkways, parking lots, and buildings in the administrative and warehouse areas.

2) A liquid waste collection system for acid, oil, or other waste not allow in the sanitary drainage.

1.8.1.4 Area Lighting. Lighting shall be provided at the pilot plant perimeter for security and in working and access areas.

1.8.1.5 Security. Site perimeter fencing shall be provided to control site access. Additional localized control fencing shall be provided where required.

1.8.1.6 Sewage. Sewage drainage shall be provided from all site areas to a sewage treatment system for the pilot plant.

1.8.1.7 Helistop. A helistop (i.e., heliport without refueling provisions) shall be provided near or at the plant site.

1.8.2 Buildings

The following buildings shall be provided:

1) An administration building with an area of approximately 3000 ft^2. This building shall contain areas and facilities for plant management, visitor control, and technical support for the pilot plant.

2) A plant control building with facilities and space for operation of the plant. A central room approximately 25 ft by 45 ft within the building shall permit centralized control of the plant through the MCS. This building shall also provide space for switchgear and associated electrical equipment.

3) A building of approximately 6000 ft^2 area shall house warehouse, assembly, and maintenance functions.

4) The necessary foundations and structures to support and house the turbine-generator and associated electrical and steam and feedwater equipment.

5) A security building at the site entrance.

6) A visitor's center near or at the plant site.

1.8.3 Utilities

1.8.3.1 Power. Normal and emergency power shall be provided as follows:

1) Generate own normal power during generator operation.

2) Site to be provided with limited power for emergencies and off periods.

1.8.3.2 Water. Water systems shall be provided as follows:

1) A well (potable) water supply to the site for all plant uses.

1.8.3.3 Auxiliary Systems: The following shall be provided:

1) A plant compressed air supply for the entire pilot plant. A complete distribution system shall interconnect all pilot plant systems and buildings.

2) An instrument air supply for the entire pilot plant. A complete distribution system shall interconnect all pilot plant systems and buildings.

3) An inert gas (gaseous nitrogen) supply and distribution system.

4) A mirror cleaning fluid treatment system.

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SEP 19 1980

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SUBJECT: Errata for OPDD Appendix C, Aerospace ATR-78 (7695-05)-05, 15 August 1978

ATTACHMENT: Figure 6, Design Response Spectrum for Barstow, California

Dear Bob:

In the course of the multiple reproductions taking place in the production of the above referenced report the labels on the curve shown in Figure 6 (P.11) were changed to incorrect values. A corrected curve prepared by M. L. Eskijian of Aerospace is attached. This problem was brought to our attention by Dr. Ramesh Shah, a consultant to Southern California Edison.

A second error in this report occurs in Section C.3.2.1 on page 9. The minimum ambient temperature should be +9^{o}F rather than -9^{o}F. The -13^{o}C is the correct value.

Please incorporate these changes into your final revision and submittal of the Environmental Specification.

Sincerely,

H. D. Eden

H. D. Eden
Technical Monitor

cc: M. Slaminski
R. Schweinberg
C. Randall - Aerospace

9-80-366