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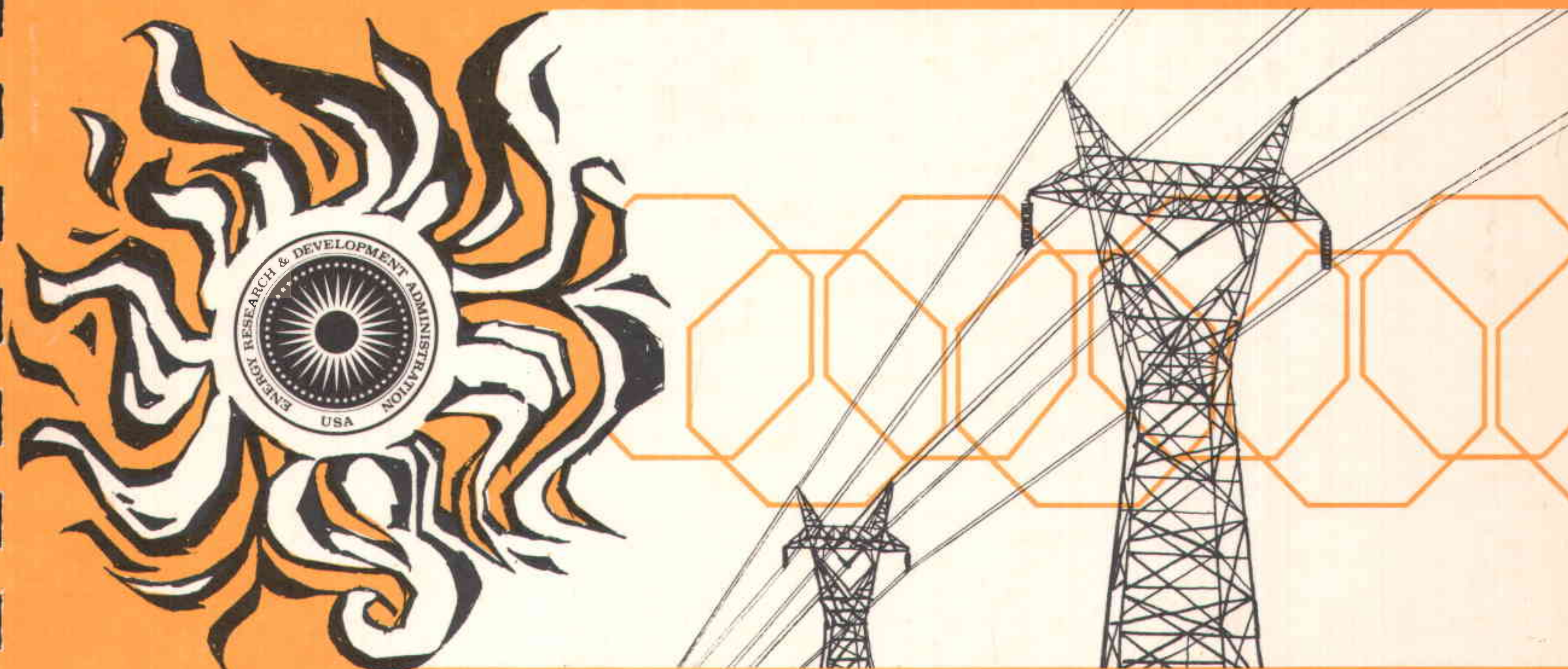

CENTRAL RECEIVER SOLAR THERMAL POWER SYSTEM, PHASE I

Volume 2 System Requirements Specification

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

MCDONNELL DOUGLAS CORPORATION

MDAC □ Rocketdyne □ Sheldahl □ Stearns-Roger □ University of Houston

MCDONNELL DOUGLAS

CENTRAL RECEIVER SOLAR THERMAL POWER SYSTEM, PHASE 1

VOLUME 2
System Requirements Specification

APRIL 1975

MDC G5942P

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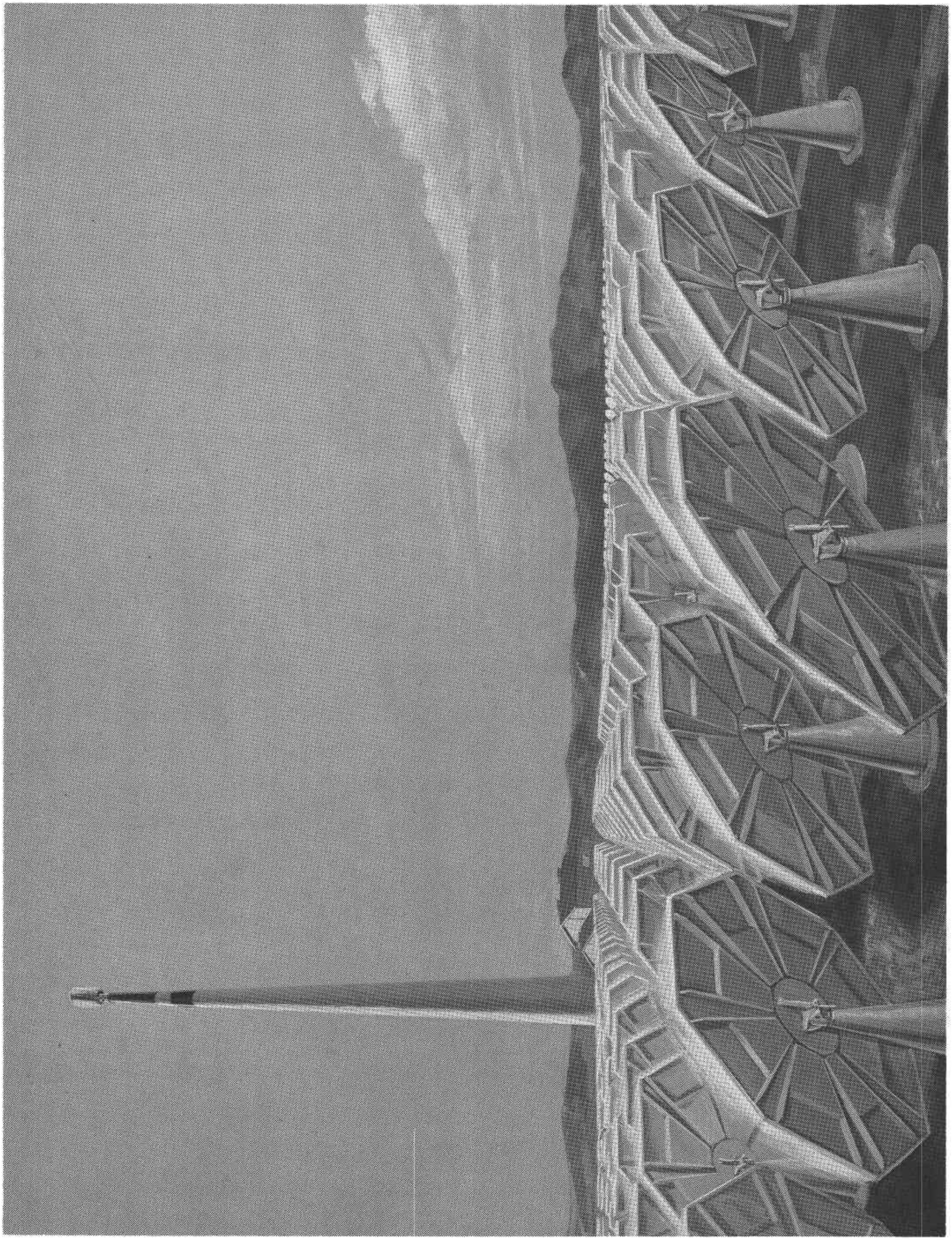
MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

5301 Bolsa Avenue, Huntington Beach, CA 92647



PREFACE

This proposal is submitted to the Energy Research and Development Administration in response to Request for Proposals No. 75-124. It presents a plan by the McDonnell Douglas Astronautics Company to perform Phase 1 of the Central Receiver Solar Thermal Power System Program. The proposal is submitted in five volumes:

Volume 1	**Technical Proposal**
Volume 2	**System Requirements Specification**
Volume 3	**Subsystem Research Experiments Test Plan**
Volume 4	**Program Plan**
Volume 5	**Cost Proposal**

Recognizing that the technical demands of the program cover a broad spectrum of expertise, we have assembled a team we believe to be best suited to conduct Phase 1 and to carry on throughout all subsequent phases as well.

THE TEAM

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

System integration
Collector subsystem design, fabrication, and test
Thermal storage subsystem integration

ROCKETDYNE DIVISION OF ROCKWELL INTERNATIONAL

Receiver assembly design, fabrication, and test
Thermal storage unit design, fabrication, and test

STEARNS-ROGER, INC.

Tower and riser/downcomer design
Electrical power generation subsystem design
Environmental impact data

UNIVERSITY OF HOUSTON

Collector field optimization

SHELDAHL, INC.

Heliostat reflective surface

WEST ASSOCIATES

Utility consultant

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CONTENTS

TBD/TBF SUMMARY

The following is a summary of values or ranges provided for the TBDs and TBFs in the specifications (Annex 1 and Appendixes 1, 2, 3, and 4) of RFP 75-124.

System Requirements Specification

RFP Annex 1, Para.	Variable TBD/TBF	Volume 2 Part 1, Para.	Value
3.1.1 d)	Output Voltage	3.1.1 (d)	13.2 kV
3.2.1	Thermal Storage Power Output	3.2.1	See Figure 6
3.2.1.1	Dynamic Load Variations	3.2.1.1.3	See text
3.2.1.2	Minimum Insolation	3.2.1.2	840 W/m^2
3.2.1.2	Plant Maintenance Cycle	3.2.1.2	30 days/year
3.2.1.3	Annual Net Energy	3.2.1.3.1	See text
3.2.2 d)	Output Voltage	3.2.2.5	13,200 volts

Collector Subsystem Requirements Specification

Appendix 1, Para.	Variable TBD/TBF	Appendix 1, Para.	Value
3.2.1	Reflected Energy Pattern	3.2.1	0.3 MW/m^2 maximum
3.2.1	Reflectance Measurement	3.2.1	80% (See text)
3.2.1	Surface Life	3.2.1	30 years
3.2.1	Optical Spreading	3.2.1	Less than 0.05°
3.2.1	Pointing Accuracy	3.2.1	3 milliradians
3.2.1	Stowage Time	3.2.1	15 min for storms 30 min for maintenance
3.2.5	Wind Conditions	POCE 3.2.6.3.3 SRE 3.2.3.3.3	Operational: 8.9 m/sec (20 mph) with 11.6 m/sec (25.9 mph gusts) Nonoperational: 35.7 m/sec (79.9 mph) with 46.4 m/sec (103.8 mph) gusts
4.1.1.2	Wind Loading	SRE 3.2.3.3.3	35.7 m/sec (79.9 mph) with 46.4 m/sec (103.8 mph) gusts

Receiver Subsystem Requirements Specification

Appendix 2, Para.	Variable TBD/TBF	Appendix 2, Para.	Value
3.1.2.1 a	Header Water Pressure	3.1.2.5 (a)	11.4 MN/m^2 (1650 psia)
3.1.2.1 b	Steam Header Flow Rate	3.1.2.5 (a)	7.2 m/sec (23 fps)
3.1.2.1 c	Tower Height	3.2.2	95 m (312 ft) (plus receiver unit)

RFP		Volume 2	

Receiver Subsystem Requirements Specification (Cont)

Appendix 2, Para.	Variable TBD/TBF	Appendix 2, Para.	Value
3.1.2.2	Energy Intercepted	3.1.2.1	99 percent
3.1.2.2	Image Size	3.1.2.1	6.6 m by 17 m (21.6 ft by 56 ft)
3.1.2.2	Array Angle	3.1.2.1	360°
3.1.2.2	Receiver Absorption/Losses	3.1.2.1	0.90 absorptivity
		3.2.1	Minimum emittance (see text)
3.1.2.3	Detail Piping Design	Detail pipe interfaces TBD in Phase 1	
3.1.2.3 a	Maximum Flow Rate	3.1.2.2 (a)	17.3 kg/sec (38 lb/sec)
3.1.2.3 a	Static Pressure	3.1.2.2 (a)	10.4 MN/m^2 (1500 psia)
3.1.2.3 a	Temperature	3.1.2.2 (a)	475 degrees C (890 degrees F)
3.1.2.3 b	Static Pressure	3.1.2.2 (b)	11.4 MN/m^2 (1650 psia)
3.1.2.3 b	Flow Rate	3.1.2.2 (b)	17.3 kg/sec (38 lb/sec)
3.1.2.3 b	Temperature	3.1.2.2 (b)	205 degrees C (400 degrees F)
3.1.2.4	Detail Piping Design	Detail pipe interfaces TBD in Phase 1	
3.1.2.4 a	Flow Rate	3.1.2.3 (a)	17.3 kg/sec (38 lb/sec)
3.1.2.4 a	Pressure	3.1.2.3 (a)	10.4 MN/m^2 (1500 psia)
3.1.2.4 a	Temperature	3.1.2.3 (a)	475 degrees C (890 degrees F)
3.1.2.4 b	Pressure	3.1.2.3 (b)	11.4 MN/m^2 (1650 psia)
3.1.2.4 b	Flow Rate	3.1.2.3 (b)	17.3 kg/sec (38 lb/sec)
3.1.2.4 b	Temperature	3.1.2.3 (b)	205 to 260 degrees C (400 to 500 degrees F)
3.2.1 b	Pressure Differential	3.2.1 (b)	0.55 to 0.83 MN/m^2 (80 to 120 psia)
3.2.2	Operating Weight	3.2.2	103,000 kg (wet) (225,000 lb)
3.2.2	Vertical Dimension	3.2.2	25 meters (76 ft)
3.2.2	Horizontal Dimension	3.2.2	9 meters (28 ft)
4.1.1.2	Wind Loading	SRE 4.2.1	3 to 51 m/sec (6.7 to 114 mph)
4.1.2.1	Ambient Temperature	SRE 4.2.2	-20 to 60 degrees C (-4 to 140 degrees F)

Thermal Storage Subsystem Requirements Specification

Appendix 3, Para.	Variable TBD/TBF	Appendix 3, Para.	Value
3.1.2.1	Detail Piping Design	Detail pipe interfaces TBD in Phase 1	
3.1.2.1	Energy Rate	3.1.2.1	42.3 MWth
3.2.1	Storage Hold Time	3.2.1.1	24 hours/2 percent loss
3.2.1	Steam Pressure	3.2.1.4	2.8 MN/m^2 (400 psia)
3.2.1	Steam Temperature	3.2.1.4	274 degrees C (525 degrees F)

RFP		Volume 2	

Thermal Storage Subsystem Requirements Specification (Cont)

Appendix 3, Para.	Variable TBD/TBF	Appendix 3, Para.	Value
3.2.1 b	Thermal Losses	3.2.1.1	2 percent in 24 hours
3.2.5	Seismic Conditions	3.2.6.3.7	Baseline conditions. See text
3.2.5	Wind Velocities	3.2.6.3.3	35.7 m/sec (79.9 mph) with 46.4 m/sec (103.8 mph) gusts
3.2.5	Earthquake Conditions	3.2.6.3.7	Baseline conditions. See text

Electrical Power Generation Subsystem Requirements Specification

Appendix 4, Para.	Variable TBD/TBF	Appendix 4, Para.	Value
3.1	Output Voltage	3.1	13,200 volts
3.1.2.1	Detail Piping Design	Detail pipe interfaces TBD in Phase 1	
3.1.2.1 a)	Steam Flow Rate	3.1.2.1 (a)	14 kg/sec (110,000 lb/hr)
3.1.2.1 a)	Steam Pressure	3.1.2.1 (a)	10 MN/m^2 (1450 psia)
3.1.2.1 a)	Steam Temperature	3.1.2.1 (a)	475 degrees C (890 degrees F)
3.1.2.1 b)	Feedwater Flow Rate	3.1.2.1 (b)	14 kg/sec (110,000 lb/hr)
3.1.2.1 b)	Feedwater Pressure	3.1.2.1 (b)	2.85 MN/m^2 (410 psia)
3.1.2.1 b)	Feedwater Temperature	3.1.2.1 (b)	205 degrees C (400 degrees F)
3.1.2.2	Detail Piping Design	Detail pipe interfaces TBD in Phase 1	
3.1.2.2 a)	Steam Flow Rate	3.1.2.2 (a)	12.9 kg/sec (101,000 lb/hr)
3.1.2.2 a)	Steam Pressure	3.1.2.2 (a)	2.8 MN/m^2 (400 psia)
3.1.2.2 a)	Steam Temperature	3.1.2.2 (a)	275 degrees C (525 degrees F)
3.1.2.2 b)	Feedwater Flow Rate	3.1.2.2 (b)	12.9 kg/sec (101,000 lb/hr)
3.1.2.2 b)	Feedwater Pressure	3.1.2.2 (b)	2.85 MN/m^2 (410 psia)
3.1.2.2 b)	Feedwater Temperature	3.1.2.2 (b)	105 degrees C (220 degrees F)
3.1.2.3	Output Voltage	3.1.2.5	13,200 volts
3.2.1	Output Voltage	3.2.1	13,200 volts
3.2.5	Plant Site	TBF in Phase 1	
3.2.5	Seismic Zone	TBF	Conditions in para. 3.2.6
3.2.5	Wind Velocity	3.2.6.3.3	35.7 m/sec (79.9 mph) with 46.4 m/sec (103.8 mph) gusts
3.2.5	Earthquake Conditions	3.2.6.3.7	Baseline conditions. See text

INTRODUCTION

This volume of the proposal contains the baseline performance and design requirements for the POCE system and subsystems as defined by MDAC and its subcontractors for use in the proposed contract effort. The data contained in these specifications are responsive to the requirements identified in the specifications included by ERDA as Annex 1 and Appendixes 1 through 4 to the RFP. The specifications are formatted in accordance with MIL-STD-490 instructions.

Volume 1 contains the justification for the selection of the baseline requirements contained in the following sections of this volume, while Volumes 3 and 4 contain the definition and explanation of what will be done to accomplish the subsystem research experiments and central receiver POCE preliminary design in a manner which is consistent with the specifications.

The MDAC approach to writing the specifications contained in this proposal volume was to prepare texts which approach those required at preliminary design review, to provide nominal values wherever possible, to identify the range of values in cases where it is appropriate and an unambiguous range is presently defined, and to provide TBD's where the definition of the specific value or range is dependent upon further trade studies and analyses to be performed during Phase 1. It is intended that all system and subsystem requirement values that affect SRE will be established during the first two months of the contract in preparation for the preliminary design baseline review. The balance of the values will be determined, and the POCE specifications will be completed, by PDR.

Nine separate specifications are contained in this volume. The first specification is for the POCE system, with the next four treating the collector, receiver, thermal storage, and electrical power generation subsystems, respectively. An additional specification has been added to define the master control function, which interfaces with each of the subsystems and is a key element of the total system operation. The preliminary POCE master control specification presents a description of the conceptual performance and design requirements. Since these requirements are well within the state-of-the-art, no significant master control development problems are anticipated in Phase 2. Consequently, as indicated in Volume 4, the completion of this specification during Phase 1 will be subordinated to the completion of Appendixes 1, 2, 3, and 4.

Finally, separate specifications are provided for the collector, receiver, and thermal storage subsystems research experiment test hardware. These specifications provide additional visibility to ERDA by defining and describing subsystem requirements which are different for the SRE's than for the POCE. This separation of SRE and POCE specifications will also facilitate Phase 1 contracting.

All nine specifications represent a significant expansion of the basic specification requirements presented in the RFP, Volume IV, Part 2. In addition, an effort has been made to clarify many of the original requirements or make them more specific. However, in no case are exceptions or deviations to those requirements intended.

PART 1 POCE SYSTEM REQUIREMENTS

SYSTEM REQUIREMENTS SPECIFICATION

FOR

CENTRAL RECEIVER SOLAR THERMAL POWER SYSTEM

PROOF OF CONCEPT EXPERIMENT (PILOT PLANT)

VOLUME 2
PART 1

CONTENTS

CONTENTS (Continued)

1.0 SCOPE

This document defines performance, design, and test requirements for the Central Receiver Proof-of-Concept Experiment (POCE) Pilot Plant System. The Central Receiver POCE Pilot Plant is hereinafter referred to as the POCE.

2.0 APPLICABLE DOCUMENTS

The equipment, materials, design, and construction of the POCE shall comply with all Federal, state, local, and user standards, regulations, codes, laws, and ordinances which are currently applicable for the selected site and the using utility. These shall include but not be limited to the government and non-government documents itemized below. If there is an overlap in or conflict between the requirements of these documents and the applicable Federal, state, county or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent shall take precedence.

The following documents of the issue in effect on the date of request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Government Documents

2.1.1 Specifications

Regulations of the Occupational Safety and Health Administration (OSHA)

Regulations of the California Occupational Safety and Health Administration (CAL/OSHA) - if required

The International System of Units, 2nd Revision, NASA SP-7012

Regulations of the Federal Aviation Administration

Regulations of the Civil Aeronautics Board

2.1.2 Standards

MIL-STD-1472, Human Engineering Design Criteria

2.1.3 Other Publications

U.S. Weather Bureau Maximum Wind Velocities, 50-year Mean Recurrence, Fastest Mile (1 Minute)

Design Handbook on Electromagnetic Compatibility (AFSC DH1-4)

Checklist of General Design Criteria (AFSC DH1-X)

Instrumentation Grounding and Noise Minimization Handbook (AFRPL-TR-65-1)

National Motor Freight Classification 100B - Classes and Rules Apply on Motor Freight Traffic

Uniform Freight Classification 11 - Railroad Traffic Ratings Rules and Regulations

CAB Tariff 96 - Official Air Transport Rules Tariff

CAB Tariff 169 - Official Air Transport Local Commodity Tariff

R. H. Graziano's Tariff 29 - Hazardous Materials Regulations of the Department of Transportation

CAB Tariff 82 - Official Air Transport Restricted Articles Tariff

2.2 Non-Government Documents

2.2.1 Specifications

Specifications for Aluminum Structures of the Aluminum Association

2.2.2 Standards

American National Standards Institute, B31.1, Power Piping

Manual of Steel Construction, 7th Edition, 1974, American Institute of Steel Construction

American National Standards Institute (Y10.19-1969 and C1.1-1971)

Building Code Requirements For Reinforced Concrete (ACI 318-71), American Concrete Institute

Building Code Requirements For Reinforced Concrete Chimneys (ACI 307), American Concrete Institute

National Electric Code, NFPA 70-1971 (ANSI C1-1971)

NFPA Bulletin No. 78 (ANSI C5. 1)

National Electrical Manufacturers Association Standards

Seismology Committee Structural Engineers Association of California

American Society of Mechanical Engineers, Boiler and Pressure Vessel Code:

Section 1, Rules for Construction and Power Boilers

Section 2, Material Specifications

Section 5, Non-destructive Examination

Section 8, Unfired Pressure Vessels

Section 9, Welding and Brazing Qualifications

Uniform Building Code - 1973 Edition, Vol 1 by International Conference of Building Officals

American Society for Testing Manuals Standards

3.0 REQUIREMENTS

The POCE system shall comply with all requirements specified herein and in the detail specifications presented in Appendixes 1, 2, 3, 4, and 5.

3.1 Central Receiver Proof-of-Concept Experiment Pilot Plant Definition

3.1.1 General Description. The POCE shall be described in the International System of Units in accordance with NASA SP-7012 and ANSI Y10. 19-1969, but all reporting shall be in both systems of units, i.e., 0 degrees C (32 degrees F). The POCE is comprised of:

(a) The collector subsystem shall consist of a series of individual tracking heliostats that continuously reflect the direct incident solar insolation onto a central tower mounted receiver at sufficient power levels to operate a steam Rankine turbine-generator set capable of providing 10 MW net electrical power to a grid and/or recharge the thermal storage subsystem. The subsystem shall include all hardware and software identified in Appendix 1.

(b) The receiver (central receiver) shall provide a means of transferring the incident radiant flux energy from the collector subsystem into superheated steam which serves as the fluid (1) for generating electrical power by the electrical power generation subsystem, (2) for conversion to stored thermal energy by the thermal storage subsystem, and (3) for generating electrical power by the electrical power generation subsystem while also charging the thermal storage subsystem.

The receiver subsystem shall consist of an elevated receiver unit to intercept the radiant flux from the collector subsystem, the tower structure to support the receiver unit, the riser from the ground and the downcomer from the receiver to the ground. The receiver unit shall include the absorber (boiler/superheater); the receiver structural support; the pumps, bypass valves and receiver control necessary to regulate the fluid flow, temperature and pressure; and the required thermal control necessary for safe and efficient operation, startup, shutdown, and standby of the receiver subsystem.

(c) The thermal storage subsystem shall consist of a heat exchanger(s), one or more thermal storage media, storage structure, pumps, steam generators, feed heaters, desuperheaters, valves, piping and subsystem control as necessary to accept thermal energy from the receiver subsystem and store the energy for later reconversion to steam for use by the electrical power generation subsystem or for use in the receiver subsystem for thermal management.

(d) The electrical power generation subsystem shall consist of a steam Rankine turbine-generator set, power conditioning equipment, heat rejection unit, and water treatment facility. The turbine-generator set shall transform the thermal energy of the steam originating in the receiver and/or thermal storage subsystem into 60 Hz electric power at 10, 000 kilowatts net at 13, 200 volts. The power conditioning equipment shall transform, switch, regulate, and control the electrical output of the turbine-generator set to insure compatible integration into an existing electrical power transmission network. The heat rejection unit shall reject waste heat from the turbine-generator set in a manner consistent with all site restrictions and limitations and producing no deleterious effects on the collector subsystem. The water treatment facility shall condition local water to the purity and chemical composition required by the receiver subsystem as stipulated in Appendix 2.

(e) The master control is a computer control unit responsible for the overall POCE system operation. The master control shall interface with the central network control and initiate any externally induced operational commands. The master control shall provide the logic and the intersubsystem communication required for coordinated subsystem operation during all normal steady state and transient operational modes including startup, shutdown, and transitions between modes. It shall continuously monitor system status and initiate proper corrective action required to maintain the POCE system operation after component failure and/or initiate action to prevent or minimize system damage. A backup central computer along with self-check logic and control handoff capability shall be utilized to insure master control reliability. A manual override capability shall be incorporated into the master control to ensure complete system control at all times.

3.1.2 POCE Application. Central receiver solar thermal power plants are expected to provide electrical power to the electrical transmission/distribution network. These solar thermal plants, initially sited in the Southwestern United States, would produce power to meet peak and intermediate demands. The objective of the POCE is to perform a proof-of-concept experiment to establish the technical feasibility and indicate the potential economic feasibility of the central receiver concept.

3.1.3 System Diagrams

3.1.3.1 Central Receiver Solar Thermal Power System Diagram. The central receiver solar thermal power system and the relationships of the various subsystems are shown in block form in Figure 1 and pictorially in Figure 2.

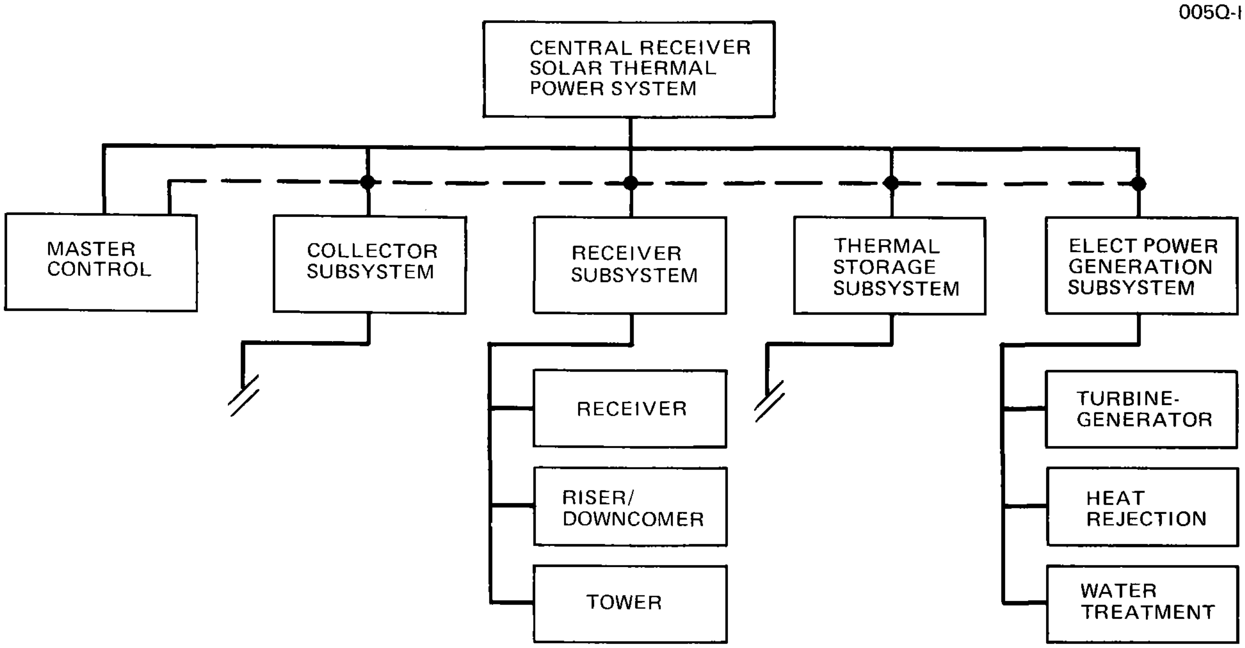

Figure 1. Central Receiver Solar Thermal Power System

3.1.3.2 Functional Block Diagram. The central receiver POCE (pilot plant) functional block diagrams depicting normal solar, low solar power, intermittent cloudiness, and nighttime operational modes are shown in Figure 3.

3.1.3.3 Central Receiver POCE (Pilot Plant) Layout. The plant layout for the POCE pilot plant is shown in Figure 4 and major system characteristics are presented in Table 1.

3.1.4 Interface Definition. The POCE shall be physically and functionally compatible with the electrical power interface of the using utility, and physically compatible with the selected site. The POCE shall also be physically and functionally compatible between all elements of the system. Subsystem interface requirements shall be as specified in Appendixes 1, 2, 3, 4, and 5.

3.1.4.1 Electrical Power Transmission Network/POCE Interface. Electric power shall be provided to the electrical power transmission network at a power level of 7 to 10 MWe at a voltage of 13.2 kV. The frequency shall be 60 Hz. Physical connections shall be through standard high tension cables per the standard of the National Electrical Manufacturers Association. An

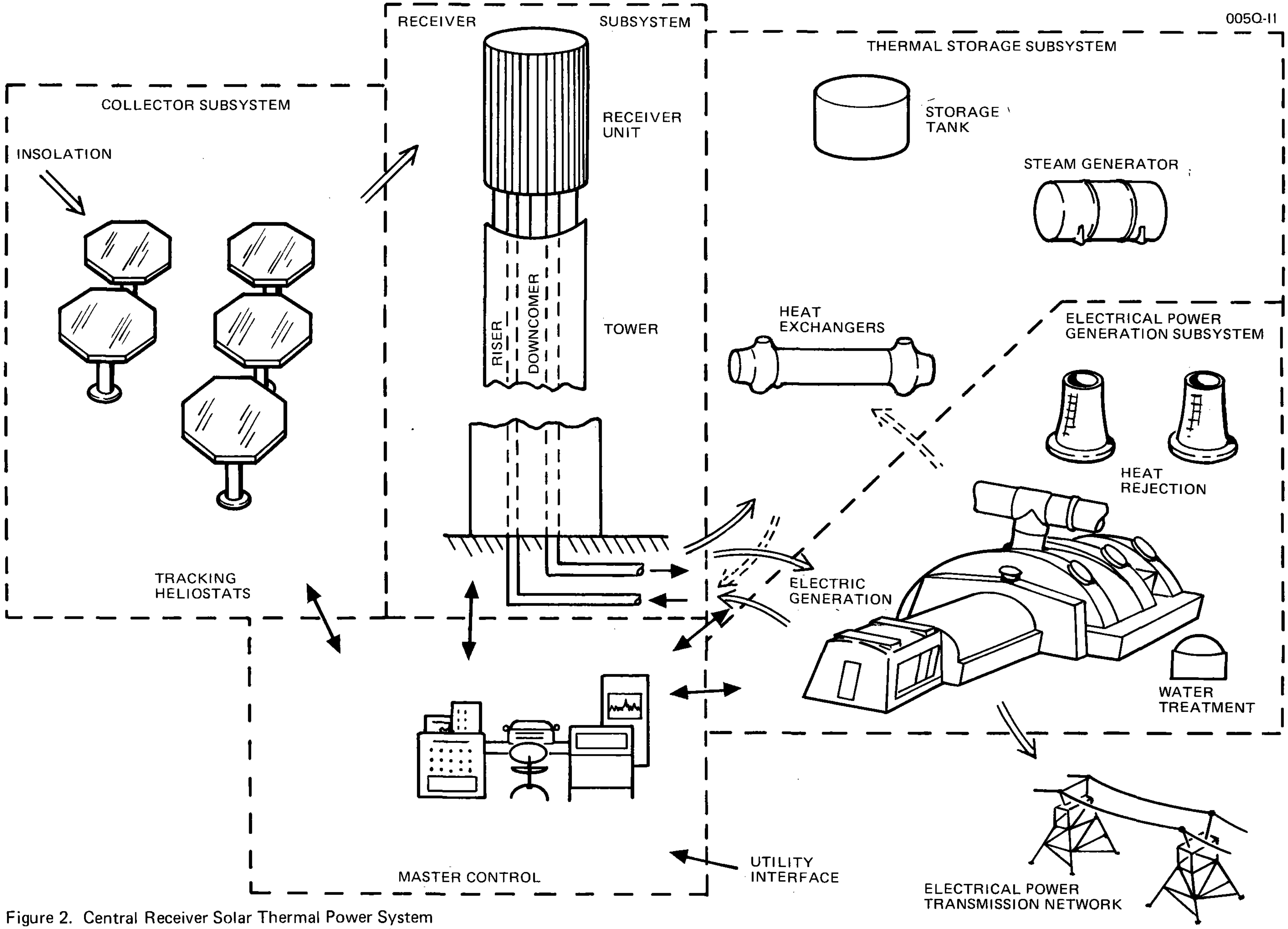

Figure 2. Central Receiver Solar Thermal Power System

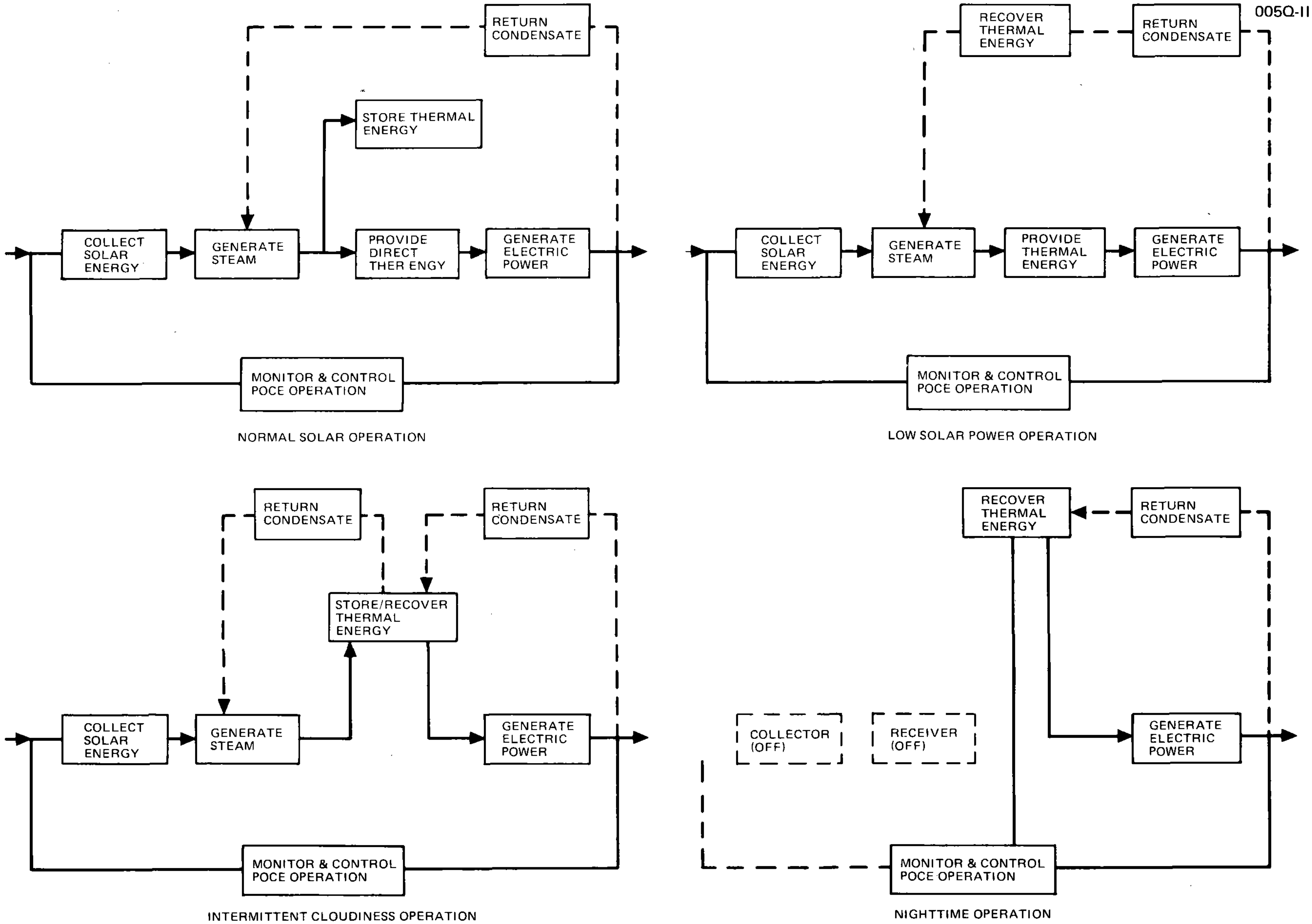

Figure 3. Central Receiver POCE Functional Block Diagram

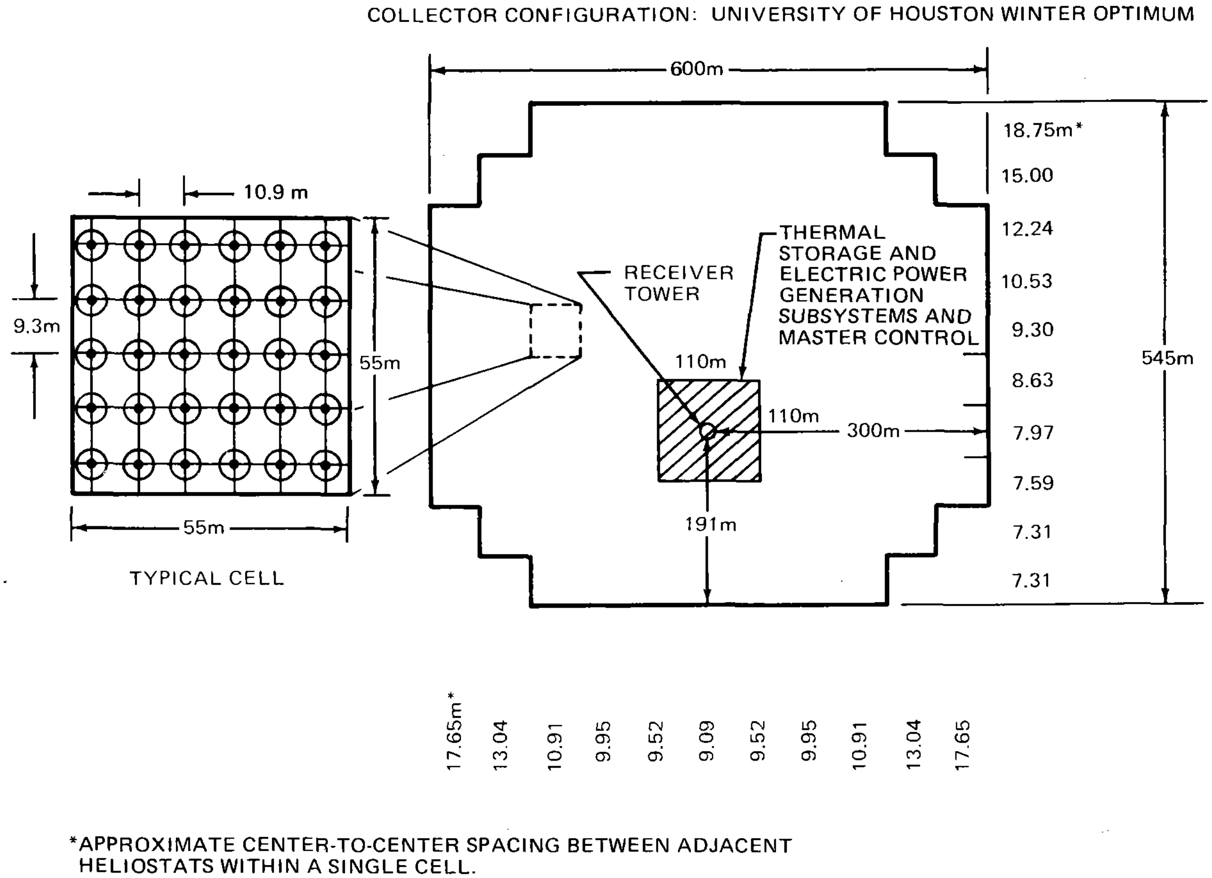

Figure 4. POCE Pilot Plant Layout

auxiliary source of electrical power shall be available to provide parasitic power during nonoperational periods of the turbine-generator set. The parasitic power level shall never exceed 640 kWe.

3.1.4.2 <u>POCE/Site Interface</u>. The POCE pilot plant shall be compatible in design with the environmental and soil conditions of the selected POCE site as modified for the purpose and in accordance with applicable codes, ordinances, statutes, and regulations. A source of water shall be provided which can supply 150 to 300 gal/min on a continuous basis for heat transfer fluid makeup, cooling water, and heliostat cleaning water during the operational periods of the POCE system.

Table 1
POCE SYSTEM CHARACTERISTICS

CHARACTERISTICS	
Tower Height:	95m (312 ft)
No. Heliostats:	2,470
Heliostat Configuration:	6.1m diameter octagonal
Receiver Characteristics:	cylindrical
Height	17m (56 ft)
Diameter	7m (23 ft)
Peak Incident Heat Flux:	51.5 MW (Summer Noon)
Design Incident Heat Flux:	42.6 MW (2 PM Winter Solstice)
Thermal Storage Capacity:	195 MWH
Design Net Electrical Power Output:	10 MWe (2 PM Winter Solstice) 7 MWe (Thermal Storage)
Parasitic Power Load:	2 points on plant efficiency (0.64 MW)
Plant Efficiencies:	Daytime Gross = 31.1% Daytime Net = 29.1% Nighttime Gross = 23.4% Nighttime Net = 21.8%

*Parasitic load reduced at night because collector field is not operating

3.1.5 Operational and Deployment Concepts

3.1.5.1 Basic Performance. The POCE shall be sized to deliver 10 MW net busbar electricity at 2 PM on a clear day at winter solstice. The POCE shall be sized to allow for all system energy losses including all thermal storage subsystem energy losses and still deliver at least 7 MWe net busbar power for a period of 6 hours while operating solely from the thermal storage. It shall be available 90 percent of the time based on reliability and maintainability exclusive of insolation conditions.

3.1.5.2 Operational Concept. The POCE is to be a proof-of-concept experiment to establish the technical feasibility and indicate the economic feasibility of supplying electrical power with a central receiver solar thermal power system. It is intended that the POCE pilot plant design concepts can be utilized by scaling or, in the case of the heliostats, as modular building blocks for construction of a 100 to 300 MWe commercial size central receiver power plant to demonstrate the economic feasibility of the central receiver concept on a commercial scale. The POCE shall be designed for use in a power production mode and a system research mode.

3.1.5.2.1 Power Production Mode. In the power production mode, power from the pilot plant will be used by the utility to partially meet the electrical demand. The pilot plant will establish the operational capability of supplying electrical busbar power using thermal energy from the storage subsystem, or thermal energy directly from the receiver subsystem. The power producing mode shall be capable of automatic operation within and between the operational modes described in paragraph 3.1.5.2.2.

3.1.5.2.2 Research Testing Mode. In the research testing mode, stable controlled operation of the POCE shall be demonstrated in the following operational modes.

3.1.5.2.2.1 Normal Startup. An integrated system startup shall be coordinated through the master control. The startup shall occur when the sun is 10° above the horizon. The following events shall constitute system startup. Heliostats shall be grossly oriented to their respective startup positions. Water flow shall be initiated through the receiver. Heliostats shall be brought on line as the sensors acquire sight of the sun's image. This process shall start when the sun is 10° above the horizon with all heliostats being activated by the time the sun reaches an elevation angle of 20°. Hot water/low quality steam developed in the receiver shall be recycled through the receiver, bypassing the turbine until high-quality dry steam is available. Steam shall be introduced into the turbine at a controlled rate for turbine heatup and spinup. The turbine shall be loaded and the electrical power shall be synchronized with the interconnecting power network. The option shall exist in startup to divert all of the steam to the thermal storage subsystem and delay the start of the electrical power generation subsystem until a desired state of storage has been produced.

3.1.5.2.2.2 Normal Solar Operation. Normal solar power operation is defined as any period when sufficient thermal energy is available and transient fluctuations are sufficiently small so that the electrical power generation subsystem can operate at its design point within the equipment guarantee specifications provided by the manufacturer. This condition corresponds to a receiver unit outlet steam condition of 475 degrees C (890 degrees F) at a pressure of 10.4 MN/m^2 (1,500 psia) and at a minimum steam rate of 14.0 kg/sec (110,000 lb/hr) entering the turbine.

3.1.5.2.2.3 Low Solar Power Operation. A low solar power operation mode exists when the steam rate to the turbine is between 9.8 and 14 kg/sec (77 to 110 x 10^3 lb/hr). During this period, turbine extraction for feedwater heating is reduced and supplemental feedwater heating is accomplished with the thermal storage subsystem. At the lower steam rate, the generator output shall approach 7 MW net electrical power to the busbar.

3.1.5.2.2.4 Intermittent Cloudiness Operation. During periods of intermittent cloud cover when the time rate of change of mass flow to the turbine is likely to exceed (TBD), all of the collected thermal energy shall be directed to the thermal storage subsystem. The electrical power generation subsystem shall be simultaneously operated from steam produced by the thermal storage subsystem and be capable of producing 7 MW net electrical power to the busbar.

3.1.5.2.2.5 Normal Shutdown. An integrated system shutdown shall be coordinated through the master control. The shutdown cycle shall commence when the steam rate from the receiver falls below (TBD) during the sundown period. The master control shall gradually "power down" the receiver while simultaneously activating the thermal storage subsystem steam generator. The steam rate and state to the turbine shall be maintained at such a level that the net electrical output to the busbar never declines below 7 MW. When operating with steam developed by the thermal storage subsystem, the shutdown of the electrical power generation subsystem shall be automatically initiated when the outlet temperature of the thermal storage heat transfer fluid falls below 292 degrees C (560 degrees F).

At this point, the generator shall be taken off line and the steam flow to the turbine shall be reduced in a manner consistent with the turbine specifications. Once the turbine rotation stops, a turning gear shall be activated to provide for slow turbine rotation in order to prevent differential cooling.

3.1.5.2.2.6 Emergency Shutdown. The master control shall monitor the status of all subsystems and shall be capable of diagnosing subsystem malfunctions. In the event a malfunction is deemed "serious" (leading to potential equipment damage or safety hazard) and no redundancy is available, an emergency shutdown procedure shall be automatically initiated with manual backup. The procedure shall depend on the nature of the failure but in all cases shall be designed to maximize safety while minimizing equipment damage.

In the event of approaching adverse environmental conditions (wind, sandstorm, rain, hail, etc.), a system shutdown and heliostat reorientation shall be executed within 15 minutes after issuance of command by the master control. The heliostats shall be off targeted in a controlled manner to ensure a controlled receiver shutdown. They shall then be directed to a minimum damage orientation as described in paragraph 3.7.1.1.4. The system shutdown may be limited to the collector and receiver portions if sufficient energy exists in the thermal storage subsystem to maintain power plant operation.

3.1.5.2.2.7 Subsystem Conditioning. During nonoperational periods, subsystems shall be protected from damage due to environmental or cooling effects. This shall include the prevention of freezing of components containing water and the use of turning gear to prevent permanent set in the turbine rotor.

3.1.5.3 Deployment Concept. The POCE will be installed and operated in the Southwestern portion of the United States. The terrain shall have local slope no greater than 10° and no natural obstructions that prevent the view of the solar disc at all times when it is 20° above the horizontal plane. The tower or reflected light shall in no way adversely affect aircraft, complying with FAA and CAB regulations.

The POCE site shall be located in an area where the mean surface wind does not exceed 45 km/hr (28 mph) more than 1 percent of the time. High wind areas to be avoided shall include areas below mountain passes and regions just below mouths of canyons. Areas displaying alluvial fans, water erosion, or depositional features shall be avoided due to the high probability of flash flooding and water damage. Areas in which sand or other granular material is deposited in the lee of obstacles or where rocks exhibit grooved, faceted, or fluted characteristics shall be avoided due to the high probability of blowing sand. All areas immediately adjacent to major active seismic faults shall be avoided.

3.2 Characteristics

3.2.1 Performance. The POCE shall perform to the conditions illustrated in Figure 5. Two operational specifications for the receiver flowrate are required to accommodate the condensate return temperature mismatch between the electrical power generation and thermal storage subsystems. This condition is dictated by the inability of a 10 MWe turbine to sufficiently preheat feedwater to a point where it matches the thermal storage condensate temperature. The receiver unit shall be capable of producing 10.4 MN/m^2 (1,500 psia), 475 degrees C (890 degrees F) outlet steam for inlet temperatures ranging from 205 degrees C (400 degrees F) to 245 degrees C (475 degrees F) at receiver power levels greater than the threshold value (TBD) and less than 42.3 MWth associated with summer noon. The receiver unit shall be designed for the worst case condition which corresponds to a 205 degrees C (400 degrees F) inlet temperature at the 42.3 MWth flux level. The corresponding flowrate shall be 17.3 kg/sec (137,000 lb/hr) with flow control components being sized to handle a 10 percent overflow condition. The thermal storage shall be designed to the worst case condition which corresponds to a 245 degrees C (475 degrees F) receiver inlet temperature at the 42.3 MWth flux level. The corresponding flowrate shall be 18.8 kg/sec (150,000 lb/hr).

The POCE shall be capable of (1) delivering 10 MWe net power to the electrical transmission network when operating on energy directly from the receiver subsystem, (2) of simultaneously or separately storing thermal

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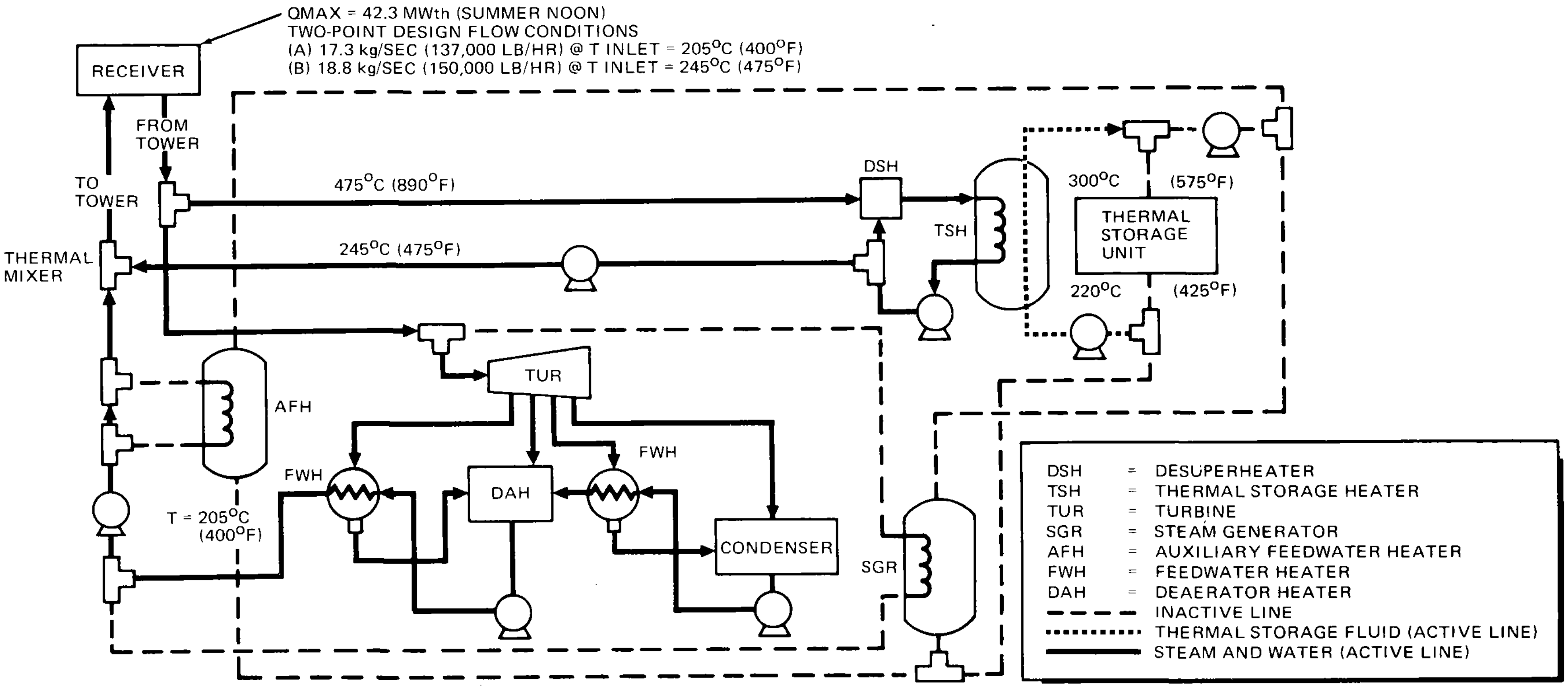

Figure 5. Plant Schematic for Normal Charging Operation

energy at a maximum power in excess of 40 MWth in the thermal storage subsystem for later conversion to electrical power, (3) of delivering at least 7 MW net electrical power for a period of 6 hours and lesser power levels for longer periods of time to the electrical transmission network when operating on energy drawn from the thermal storage subsystem (see Figure 6), and (4) of delivering at least 7 MWe net power to the electrical transmission network when operating on energy from both the receiver subsystem and thermal storage subsystem.

3.2.1.1 Dynamic Performance

3.2.1.1.1 Startup. The POCE system shall be capable of developing full power within 6 hours from a cold startup condition. The POCE system shall be capable of developing full power within 20 minutes after a 10-hour shutdown when sufficient solar insolation is available to produce 14.0 kg/sec (110,000 lb/hr) of steam at a temperature of 475 degrees C (890 degrees F) and a pressure of 10.4 MN/m^2 (1,500 psia) at the receiver assembly outlet. The system shall be designed for an anticipated 300 hot startups and 5 cold startups annually.

3.2.1.1.2 Emergency Shutdown. The POCE system shall be capable of a coordinated emergency shutdown. The time for such shutdown shall be determined to minimize equipment damage and provide maximum safety. The minimum shutdown times shall occur as a result of a water circulation

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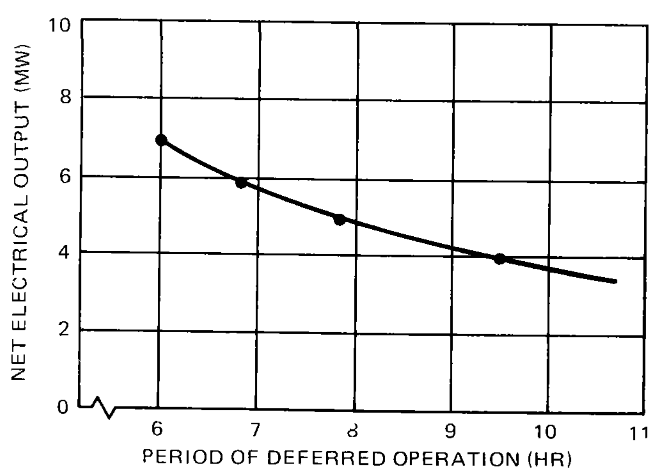

Figure 6. Net Electrical Output Characteristics at Reduced Power Level

failure in the receiver. Shutdown time shall be determined in a manner to prevent or minimize receiver damage but shall in no event exceed 10 seconds.

3.2.1.1.3 System Dynamic Variation. The POCE system shall be capable of stable controlled operations during the passage of an opaque cloud traveling at 20 m/sec (45 mph). The frequency of the electrical network varies about a nominal 60 Hz in a manner which reflects grid load. Once synchronized, the POCE shall provide power to the network when its frequency exceeds that of the grid. During periods when a POCE frequency lag exists, the POCE shall be motored by the network per normal utility practices.

3.2.1.2 Endurance Capability. The hardware shall be designed to have a 30-year operational lifetime with normal maintenance while exposed to the environmental conditions specified in paragraph 3.2.6. During this 30-year period the POCE shall supply 10 MWe net busbar electrical power during all periods when the insolation exceeds 840 W/m^2 and the heliostat reflectivity is maintained at its design value as stipulated in Appendix 1. Exceptions to this occur during nominal startup and shutdown periods associated with, (1) the diurnal cycle, (2) cloudy periods, (3) periods with winds exceeding the operating environmental conditions of paragraph 3.2.6, and (4) the normal scheduled plant maintenance cycle of 30 days per year. During the cloudy and windy periods, the thermal storage subsystem shall act as a buffer capable of furnishing the required thermal energy as specified in paragraph 3.2.1.

3.2.1.3 Other Performance Requirements

3.2.1.3.1 Annual Power Output. The expected annual power output of the POCE shall be (TBD) based on consideration of the combined effects of the limiting variables including daily cloud cover time and density distributions, time distribution of unscheduled system downtime, time distribution of downtime due to environmental conditions other than clouds (e.g., winds, dust), and probable required operating mode as dictated by utility requirements.

3.2.1.3.2 Collector Operations. The collector subsystem shall not inflict damage on any system element or present a safety hazard due to a misdirection of the reflected solar energy.

3.2.2 Physical Characteristics

3.2.2.1 System Characteristics. The pilot plant shall possess the physical characteristics identified in Table 1. Vehicular traffic shall have access to all major parts of the system. Sufficient ingress, egress, and access shall be provided to all areas of the system for maintenance purposes. Major roadways shall be paved to minimize traffic-induced dust. Field protection shall be provided by suitable fencing. Ground foliage shall be permitted to grow in all areas unless it impacts the operation and/or maintenance of the system.

3.2.2.2 Collector Subsystem Characteristics. The collector subsystem shape limitations shall be determined only by the collector field layout, shadowing restraints and servicing functions together with the resulting receiver tower height. The collector field layout shall be developed to optimize collector performance at 2 PM on winter solstice. Spacing between heliostats in the field must permit access by service vehicles, utility lines, and ground maintenance personnel. Heliostat weight and size shall be limited only by manufacturing, transportation, operation, maintenance and servicing constraints, pointing accuracy requirements, and structural requirements. Heliostats shall have a stored or safe position for use at night, during periodic maintenance, and during periods when the pilot plant is subjected to environmental conditions exceeding those specified in paragraph 3.2.6.

3.2.2.3 Receiver Subsystem Characteristics. The basic receiver shape shall be cylindrical, oriented such that it is illuminated by the collector subsystem on all curved surfaces. Physical characteristics of the receiver shall be such that it will accommodate a peak incident solar flux of 0.3 MW/m^2. The receiver shall be designed such that it can be erected and removed from the top of the tower in a limited number of pieces. The receiver shall be designed for easy repair and maintainability. The contractor shall provide access to the receiver by means of permanent or temporary platforms. The tower shall be designed to provide ingress, egress, and access for maintenance and inspection of tower structure, receiver steam lines, utilities, and other subsystem elements. Adequate provisions shall be made to ensure crew safety at all times for required operation, inspection, maintenance, and repair.

3.2.2.4 Thermal Storage Subsystem Characteristics. The thermal storage subsystem shall be designed to maximize the economic and safe recovery of useful thermal energy from storage and to minimize thermal energy losses. Specific size, shape, and configuration constraints will be governed only by the pilot plant layout and design to facilitate efficient and safe operation and maintenance. The thermal storage subsystem shall be designed to provide safe and reasonable ingress, egress, and access for proper inspection, maintenance and repair of the structure, storage medium, steam lines, utilities, instrumentation and controls. The thermal storage subsystem shall be so configured and located within or adjacent to the pilot plant to minimize adverse interfaces with or operations of the other subsystems.

3.2.2.5 Electrical Power Generation Subsystem Characteristics. The electrical power generation subsystem shall be designed to efficiently convert the available thermal energy into 60 Hz electrical power at 13,200 volts and to provide feedwater heating at a rate compatible with the steam available for extraction. The power conditioning equipment shall be designed to condition a maximum of 10 MW electrical power to be compatible with the existing power grid. The heat rejection unit shall be capable of rejecting a maximum of 25 MW (85×10^6 Btu/hr) of thermal power. The water treatment facility shall be capable of treating and purifying 3.6×10^{-4} m^3/sec (5.7 gal/min) of water to a sufficient state to satisfy the receiver water chemistry requirement, Appendix 4. The specific size, shape, and configuration constraints imposed on the individual components shall be governed only by the pilot plant layout and design to facilitate efficient and safe operation and maintenance, to minimize the effects of thermal shock on the turbine power loop, and to provide for rapid response to variations in the working fluid inlet conditions. The electrical power generation subsystem shall be designed to provide safe and reasonable ingress, egress, and access for proper inspection, maintenance and repair of the structure, fluid flow lines, utilities, heat rejection unit, instrumentation and controls for each element or component. The elements and components of this subsystem shall be so configured and located within or relative to other portions of the pilot plant as to minimize adverse interfaces with or operations of the other subsystems.

3.2.2.6 Master Control. The master control shall be designed to ensure the stable integrated operation of the POCE system. The actual system control shall be accomplished by redundant central computers along with the required computer interface electronics and self-check/control handoff logic with a manual override capability. Computer peripheral equipment shall include redundant disk files, line printer, typewriter, and magnetic tape unit. Control and display consoles shall be available for overall system control as well as individual units dedicated to each subsystem. Digital data bus and subsystem interface equipment shall be utilized to provide intersub-system communication. The characteristics of these individual pieces of equipment are presented in Appendix 5.

3.2.3 Reliability. High reliability shall be achieved in the system design by providing adequate operating margins, maximizing the use of proven standard parts, and using conservative design practices such that the reliability performance shall not degrade the capability to achieve the availability specified in paragraph 3.2.5 when operated in the environments specified in paragraph 3.2.6.

Single-point failures that disable the automatic mode of system operation shall be eliminated wherever practical. In cases where it is impossible to eliminate such failure modes, suitable devices shall be used to detect and warn of the occurrence of a failure.

3.2.4 Maintainability. Maintainability shall be considered in all elements of the POCE design to ensure minimum cost for maintenance and servicing throughout the 30-year system life, and a downtime consistent with the availability requirement of paragraph 3.2.5. A pilot plant maximum allowable downtime shall be determined based on trade studies which consider system reliability and cost. This requirement shall be allocated to the various subsystems and major components of the system. Maintainability predictions prepared in support of subsystem design shall provide median and maximum (90 percentile) values, assuming an overall log normal distribution.

In order to achieve the required system maintainability, the POCE shall be designed such that:

(a) Items that are critical to availability (because of high failure risk, high downtime, or major effect on system performance) shall be provided with automatic failure detection and fault isolation.

(b) Potential maintenance points can be easily reached and components such as electronic units, sensors, motors, drives, etc., can be readily replaced.

(c) Elements subject to wear or damage such as supporting wheels, gears, etc., are easily serviced or replaced.

(d) Test points and calibration adjustments are accessible and repairs can be accomplished by module replacement.

(e) The POCE can be serviced by personnel of normal skills requiring a minimum of specialized equipment or tools.

(f) On-line maintenance may be conducted without reducing subsystem performance.

3.2.5 Availability. The POCE shall operate in accordance with paragraph 3.2.1 performance requirements 90 percent of its scheduled operating time, based on reliability and maintainability exclusive of insolation conditions, using a period of one year as a time reference, and assuming 30 days annual downtime for scheduled maintenance. Availability is defined as the percent of the total scheduled time that the system is able to operate in accordance with the specified POCE system performance requirements.

The POCE availability is calculated according to the formula

$$A_s = 1 - \sum_{J=1}^{N} (1 - A_{(J)})$$

where

$A_{(J)}$ = Availability of the Jth subsystem for one year of scheduled operation.

The availability of each subsystem ($A_{(J)}$) shall be calculated according to the formula

$$A_{(J)} = \frac{T_U - T_D}{T_U},$$

where

T_U = Total scheduled operating time in one year for the Jth subsystem.

T_D = Expected (or realized) downtime during the scheduled operating time for subsystem maintenance to return the subsystem to full performance as required by paragraph 3.2.1 of the applicable subsystem specification.

T_D is defined as the median of the probability distribution of downtime for maintenance of the Jth subsystem.

3.2.6 Environmental Conditions. The POCE subsystems shall be designed to withstand the environmental conditions defined in the appropriate detail specification of Appendixes 1, 2, 3, 4, or 5. Those conditions shall be considered to represent the minimum environmental design requirements.

3.2.7 Transportability. Subsystem components shall be designed for transportability within applicable Federal and state regulations by highway and railroad carriers utilizing standard transport vehicles and materials handling equipment. The components, in their packaged condition, shall be capable of withstanding the climatic conditions and shock and vibration environments defined in the applicable subsystem specification.

3.3 Design and Construction. Design and construction standards compatible with the end use shall be employed.

3.3.1 Materials, Processes, and Parts. To the maximum extent possible, standard materials and processes shall be employed. Highly stressed components and unusual materials shall be avoided. As far as practical, off-the-shelf components used in industry shall be employed. Materials and components susceptable to environmental deterioration shall be protected with a suitable coating or protective layer.

3.3.2 Electrical Transients. POCE operation shall not be adversely affected by external or internal power line transients caused by normal switching or fault clearing. Switching transients and fault clearing functions will require less than six cycles of the fundamental frequency (100 milliseconds) and shall be limited to 1.7 P.U. voltage (1.7 per unit or 170 percent). The POCE system shall also be immune to the effects of lightning stroke termination and the resultant power transients created. No subsystem control elements shall be damaged by the transients created and the master control shall be capable of continued operation during the event.

The system design shall include an air terminal(s) on the top of the receiver tower, separate air terminal masts at the perimeter of the collector field and interconnecting overhead conductors to preclude direct lightning stroke damage to any of the collector subsystem elements. The air terminal design and installation shall be in accordance with NFPA Bulletin No. 78 (ANSI C5.1). Design level used shall be for the important case as described in NFPA No. 78.

3.3.3 Electromagnetic Radiation. The POCE system shall be designed to minimize susceptibility to electromagnetic interference and to minimize the generation of conducted or radiated interference. The design criteria contained in the following Air Force design handbooks shall be used to assure electromagnetic compatibility: Design Handbook on Electromagnetic Compatibility (AFSC DH1-4), Checklist of General Design Criteria (AFSC DH1-X), and Instrumentation Grounding and Noise Minimization Handbook (AFRPL-TR-65-1).

3.3.4 Nameplate and Product Marking. All deliverable end items shall be labeled with a permanent nameplate listing, as a minimum, manufacturer name, part number, change letter, serial number, and date of manufacture.

All access doors to replaceable/repairable items shall be labeled to show equipment installed in that area, and any safety precautions or special considerations to be observed during servicing.

3.3.5 Workmanship. The level of workmanship shall conform to practices defined in the codes, standards, and specifications applicable to the selected site and the using utility. Where specific skill levels or certifications are required, current certification status shall be maintained with evidences available for examination. Where skill levels or details of workmanship are not specified, the work shall be accomplished in accordance with the level of quality currently in use in the construction, fabrication, and assembly of commercial power plants. All work shall be finished in a manner such that it presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a generally uniform appearance.

3.3.6 Interchangeability. Major components and circuit cards and other items with a common function shall be produced with standard tolerances and connector locations to permit interchange for servicing. Components that have similar appearances but different functions shall incorporate protection against inadvertent, erroneous installation through the use of such devices as keying, connector size, or attachment geometry.

3.3.7 Safety. The POCE shall be designed to eliminate or acceptability control safety hazards to operating and service personnel and to equipment. Sufficient analyses shall be conducted to assure that system designs and operational procedures consider the following:

(a) Controlling and minimizing the potential damage to personnel, equipment, and material of hazards which cannot be avoided or eliminated.

(b) Isolating hazardous substances, components, and operations from other activities, areas, personnel, and incompatible materials.

(c) Incorporating "fail-safe" principles where a failure would disable the system to prevent a catastrophe either through injury to personnel or damage to equipment.

(d) Locating equipment components so that access to them by personnel during operation, maintenance, repair, or adjustment shall not require exposure to hazards such as burns, electrical shock, cutting edges, sharp points, insecure footing, or toxic atmospheres.

(e) Avoiding undue exposure of personnel to physiological and psychological stresses which might cause errors leading to mishaps.

(f) Providing suitable warning and caution notes in operations, assembly, maintenance, and repair instructions; and distinctive markings on hazardous components, equipment, or facilities for personnel protection.

(g) Grounding and insulating electrical supplies and components and insulating parts or components with elevated temperatures or shock potential to prevent contact with or exposure to personnel.

(h) Shielding moving elements to avoid entanglements and providing safety override controls and/or interlocks for servicing.

(i) Providing emergency shutoff valves and switches, fire extinguishers and fire escape paths for areas that have hazardous material or ignition sources.

(j) Establishing criteria and recommendations for restricted operations or personnel access.

(k) Providing appropriate circuit and line safeguard devices (such as current limiters, voltage regulators, relief valves and interlocks) for power source, personnel, and equipment protection.

3.3.8 Human Engineering. The system shall be designed to facilitate manual operation, adjustment, and maintenance as needed. Human engineering studies shall be performed to determine the optimum allocation of functions for personnel or automatic control. Particular human engineering attention shall be applied in the receiver subsystem for location of equipment in relation to elevators, walkways, and ladders, provision of adequate lighting for night maintenance and placarding of hazardous work areas. MIL-STD-1472, Human Engineering Design Criteria, shall be used as a guide in designing control stations and equipment, including human considerations for displays, controls, labels and placards, equipment handling, and providing a desirable working environment.

3.4 Documentation. Documentation of subsystem design, performance, operating, and test characteristics; instructions; construction drawings, procedures and parts lists and related information shall be prepared in accordance with the requirements of Appendixes 1, 2, 3, 4, and 5.

3.5 Logistics. The elements required to support the POCE are:

Support and test equipment

Technical publications

Personnel and training

Facilities

Spares, repair parts, and consumables

Transportation, handling and packaging

Data file

Field service

The requirements for the elements shall be established as a result of a support requirements analysis for each subsystem to be prepared by the contractor. The results of the analyses shall be documented in accordance with the contract.

3.5.1 Maintenance. Maintenance activities shall be categorized as follows:

Level 1, On-line maintenance

Level 2, Off-line on-site maintenance

Level 3, Off-line off-site maintenance

Maintenance actions for each level are identified in the subsystem specifications of Appendixes 1, 2, 3, 4, and 5.

A maintenance plan shall be prepared by the contractor which identifies scheduled and unscheduled maintenance requirements. The maintenance plan shall reflect the results of the SRA and shall specify the following as appropriate.

Use of multi-purpose test equipment

Items to be repaired

Items to be replaced

Maintenance and repair cycles

Use of operational support equipment for maintenance

Level, frequency, and location of maintenance action

Facilities, equipment, and tools.

3.5.2 Supply. The selection and positioning of spares, repair parts, and consumables shall be in accordance with the levels of repair determined by the SRA, and shall use the following criteria:

Protection Level - Items shall be packaged in accordance with the requirements of Section 5.0.

Demand Rate - The mean-time-between-maintenance-actions provided by the maintainability analyses shall be the departure point for spares determinations. The quantities and mix for each subsystem shall be such that there is a (TBD) percent probability of a part being available on demand.

Pipeline - Pipeline quantities shall be determined on the basis of system location demand rate and repair cycle times. Resupply methods, distribution and location of system stocks shall be determined after site selection.

Procurement and Release for Production - Long lead time supply items shall be procured or released early enough to be on site 30 days prior to initial operation. Other items shall be procured or released lead time away so as to minimize obsolescence due to design changes, except for those items for which significant cost savings can be achieved through acquisition concurrent with production.

Minimum/Maximum Levels - Minimum and maximum quantities of spares and repair parts to be stocked shall initially be determined by use of predicted failure rates. These levels are to be adjusted as actual usage rates are established.

3.5.3 Facilities and Facility Equipment. To be determined after site selection.

3.6 Personnel and Training

3.6.1 Personnel. The POCE pilot plant is to be installed, checked out, and tested as a proof-of-concept experiment by contractor personnel; then taken over and operated as a commercial power plant by utility personnel. Operation and maintenance personnel requirements shall be satisfied by recruitment from the established utility labor pool. The system interface and unique aspects of the system dictate a need for training existing utility people but do not establish a need for new skills or trades. The types and numbers of utility personnel requiring training, along with the unique tasks, are listed in the detail specifications (Appendixes 1, 2, 3, 4, and 5).

3.6.2 Training. The contractor shall prepare and conduct a training program for contractor personnel as necessary for performance of the POCE. The contractor shall conduct a training program for utility personnel in accordance with contractual requirements.

3.7 Functional Area Characteristics

3.7.1 POCE Functional Characteristics. The POCE pilot plant shall perform the subsystem functions delineated below.

3.7.1.1 Collector Subsystem Functional Modes. The collector subsystem shall comply with the requirements of the collector subsystem requirements specification (Appendix 1) during normal tracking, synthetic tracking, and emergency operation modes as well as while slewing to nonoperational heliostat positions.

3.7.1.1.1 Normal Operation. The heliostats shall begin to acquire the sun in a controlled manner when it is visible and 10° above the horizon. The sun's image shall be reflected onto the receiver unit with a maximum pointing error of 3 mrad. The reflected sunlight shall be applied to the receiver target at predetermined aim points to prevent the peak receiver heat flux from exceeding 0.3 MW/m^2. Normal operation shall be maintained until the direct solar insolation falls to (TBD) percent of the maximum direct summer noon insolation. Reflected beam position updates shall be provided with sufficient frequency to maintain each heliostat image within 0.5m of the nominal target point. A portion of the collector subsystem shall be disabled upon command of the master control to prevent the overcharging of the thermal storage subsystem.

3.7.1.1.2 Synthetic Tracking Operation. Heliostat tracking shall be maintained by the master control during periods of obscured sunlight in a manner to permit the resumption of normal operation within 120 seconds after passage of the shadow. At no time during the synthetic tracking operation shall reflected sunlight from the affected heliostats cause damage to any system component or pose a safety hazard.

3.7.1.1.3 Emergency Operational Mode. The solar radiation incident on the receiver shall be reduced to less than 0.02 MW/m^2 within 10 seconds after the issuance of an "off target" command.

3.7.1.1.4 Nonoperational Modes. The orientation of all heliostats shall be automatically controllable such that a minimum damage orientation can be reached by all heliostats within 15 minutes of issuance of such a command. The minimum damage orientation shall be horizontal for high wind conditions, and 70° from horizontal aligned parallel to prevailing wind during severe hail, sleet, or ice storm. All heliostats shall be capable of automatic reorientation within 30 minutes of issuance of command to facilitate cleaning or maintenance.

3.7.1.2 Collector Subsystem Functional Interfaces. The collector subsystem shall interface directly with the receiver unit, the master control, and the physical site.

3.7.1.2.1 Collector Subsystem/Receiver Unit Interface. The collector subsystem shall be operated in a manner such that at least 99 percent of the redirected energy is intercepted by the absorber. At no time shall the local incident heat flux on the absorber be greater than 0.3 MW/m^2.

3.7.1.2.2 Collector Subsystem/Electrical Power Generation Subsystem Interface. The collector subsystem and the electrical power generating subsystem shall be interconnected by the AC power distribution cabling. The electrical power generation subsystem shall be capable of supplying 3 KVA at 277 V single phase to each collector control from two separate power sources. The power distribution primary transformer shall be capable of 100 percent overload for 90 seconds.

3.7.1.2.3 Collector Subsystem/Master Control Interface. The collector subsystem shall respond to all control commands issued by the master control. The master control shall receive, store, and/or respond to all information originating from the collector subsystem. All interface connections shall be physically and electrically compatible.

3.7.1.2.4 Collector Subsystem/Site Interface. All foundations and supporting structures contained in the collector subsystem shall be designed and installed in a manner to ensure that all collector subsystem specifications listed in Appendix 1 can be satisfied over the 30-year design lifetime.

3.7.1.3 Receiver Subsystem Functional Modes. The receiver subsystem shall exhibit stable, controlled operation during normal, startup, shutdown, emergency, and transient operation.

3.7.1.3.1 Normal Operation. The receiver unit shall accept preheated feedwater from the riser exit and convert it to superheated steam at the entrance to the downcomer during all periods when normal collector subsystem conditions exist per paragraph 3.7.1.1.1 (excluding the startup and shutdown phases). The water temperature entering the receiver unit shall be 205-245 degrees C (400-475 degrees F) at an inlet pressure of 11.4 MN/m^2 (1,650 psia). The outlet steam shall be maintained at a temperature of 475 degrees C (890 degrees F) and pressure of 10.4 MN/m^2 (1,500 psia) at a peak power level of 42.3 MWth. The steam passing through the downcomer shall be regulated so that a predetermined amount of available steam is admitted into the turbine. The remaining flow shall be bypassed to charge the thermal storage unit. An option shall exist to divert all of the steam to the thermal storage subsystem. The riser shall accept water from the electrical power generation subsystem at a flowrate identical to that entering the power generation subsystem and at a temperature of 105-205 degrees C (220-400 degrees F). The flow in the riser shall either pass through an alternate feedwater heater or be mixed with the bypass flow returning from the thermal storage subsystem.

3.7.1.3.2 Receiver Startup. The receiver unit shall be started in a controlled manner to insure local flow stability in the absorber panels of the receiver. An initial water flow rate of (TBD) shall be utilized prior to the acquisition of the sun by the collector subsystem.

The water temperature shall be allowed to rise until the average heat flux on a panel is (TBD). At this point, the boiling process will initiate and the panel flow controllers will regulate the flow to produce 10.4 MN/m^2 (1,500 psia), 475 degrees C (890 degrees F) steam at the outlet of the absorber panel.

3.7.1.3.3 Receiver Shutdown. When the average heat flux to a panel falls below (TBD), the inlet flow controllers shall be adjusted to increase the water flowrate to a sufficient level to prevent boiling. As the heat flux on remaining panels falls below the above value, the same process shall be repeated. Flow shall be continued until the heliostats are off targeted.

3.7.1.3.4 Emergency Shutdown. In the event an overheating condition is observed locally in the receiver, the master control shall command the receiver control to institute maximum flow into the affected panel while off targeting the appropriate heliostats affecting the panel. In the event of a gross receiver failure, all water control valves shall be automatically adjusted to full open.

3.7.1.3.5 Transient Operation. The inlet water flow to the absorber panels of the receiver unit shall be controlled automatically to maintain a constant outlet steam condition of 10.4 MN/m^2 (1,500 psia) and 475 degrees C (890 degrees F). When the average power absorbed by a panel falls below (TBD), the panel shutdown procedure shall be initiated. With the increase of incident thermal power to a value greater than the above, the panel startup procedure shall be reinitiated.

3.7.1.4 Receiver Subsystem Functional Interfaces. The receiver subsystem shall interface directly with the collector, thermal storage, and electrical power generation subsystems as well as the master control.

3.7.1.4.1 Receiver Subsystem/Thermal Storage Subsystem Interface. The thermal storage subsystem shall be physically compatible with the bypass legs from the downcomer and riser. The steam rate in the downcomer bypass shall be automatically controlled between 0 and 18.8 kg/sec (150,000 lb/hr) at a pressure of 10.0 MN/m^2 (1,450 psia) and temperature of 475 degrees C

(890 degrees F). The return water flow shall enter the riser interface at 245 degrees C (475 degrees F) at a flowrate equal to that leaving the downcomer interface.

3.7.1.4.2 Receiver Subsystem/Electrical Power Generation Subsystem Interface. The receiver downcomer shall terminate at the entrance of the electrical power generation subsystem where physical compatibility is required. The steam shall enter the electrical power generation subsystem at 10.0 MW/m^2 (1,450 psia) and 475 degrees C (890 degrees F). The return water flow from the power generation subsystem shall enter the riser inlet at a temperature of 105-205 degrees C (220-400 degrees F). A physically compatible interface is required.

3.7.1.4.3 Receiver Subsystem/Master Control Interface. The receiver subsystem shall respond to all control commands issued by the master control. The master control shall receive, store, and/or respond to all information originating from the receiver subsystem. All interface connections shall be physically and electrically compatible.

3.7.1.5 Thermal Storage Subsystem Functional Modes. The thermal storage subsystem shall exhibit stable, controlled operations during charging, steam generation, and feedwater preheating operations and required transitions between these operational modes.

3.7.1.5.1 Charging Operation. The thermal storage subsystem shall be capable of circulating a heat transfer fluid through a heat exchanger at a flowrate required to permit the fluid temperature to increase from 220 degrees C (425 degrees F) to 300 degrees C (575 degrees F) while transferring 42.3 MW of thermal power. Steam shall be supplied from and condensate shall be resupplied to the receiver subsystem in conditions and quantities identified in paragraph 3.7.1.4.2. The heated heat transfer fluid shall be stored and subsequently used for steam generation and feedwater heating options.

3.7.1.5.2 Steam Generation Operation. The high temperature heat transfer fluid shall be supplied to the steam generator in sufficient quantities to produce 275 degrees C, 2.8 MN/m^2 (525 degrees F, 400 psia) steam at a flowrate of 13.8 kg/sec (109,000 lb/hr) while reducing the temperature of the fluid to 220 degrees C (425 degrees F).

3.7.1.5.3 Feedwater Preheating Operation. The high temperature heat transfer fluid shall be supplied to the alternate feedwater heater in sufficient quantities to raise the temperature of the feedwater from a minimum of 105 degrees C (220 degrees F) to 205 degrees C (400 degrees F) at feedwater flowrates of 9.8 kg/sec to 14 kg/sec (77,000 lb/hr to 110,000 lb/hr) while reducing the temperature of the fluid to 220 degrees C (425 degrees F).

3.7.1.6 Thermal Storage Subsystem Functional Interfaces. The thermal storage subsystem shall interface directly with the receiver and electrical power generating subsystems as well as the master control.

3.7.1.6.1 Thermal Storage Subsystem/Electrical Power Generation Subsystem Interface. The piping, connections, and mounting fixture shall be physically compatible with those of the electrical power generation subsystem. The steam entering the electrical power generation subsystem shall be at a temperature of 275 degrees C (525 degrees F), a pressure of 2.8 MN/m^2 (400 psia), and a flowrate of 13.8 kg/sec (109,000 lb/hr). The water shall return to the thermal storage unit at a temperature of 105 degrees C (220 degrees F).

3.7.1.6.2 Thermal Storage Subsystem/Master Control Interface. The thermal storage subsystem shall respond to all control commands issued by the master control. The master control shall receive, store, and/or respond to all information originating from the thermal storage subsystem. All interface connections shall be physically and electrically compatible.

3.7.1.7 Electrical Power Generation Subsystem Functional Modes. The electrical power generation subsystem shall exhibit stable, controlled operation during normal and deferred operational modes as well as during the transition between modes.

3.7.1.7.1 Normal Operation. During normal operational periods, the electrical power generation subsystem shall draw steam directly from the receiver subsystem at the conditions specified in paragraph 3.7.1.4.2. Steam extraction from the turbine for feedwater heating shall be controlled such that the net electrical power is maintained at 10 MW for the peak flowrate and 7 MW for the minimum flowrate. The return condensate temperature shall be maintained greater than 205 degrees C (400 degrees F) through feedwater preheating at all times during this mode of operation.

3.7.1.7.2 Deferred Operation. During deferred operation, the electrical power generation subsystem shall operate on steam produced in the thermal storage steam generator at the steam conditions defined in paragraph 3.7.1.5.2. The condensate shall be preheated to 105 degrees C (220 degrees F) with extracted steam before it is returned to the steam generator. At all times during this operational mode, the net electrical power delivered to the busbar shall be maintained at 7 MW.

3.7.1.8 Electrical Power Generation Subsystem Functional Interfaces. The electrical power generation subsystem shall interface directly with the receiver and thermal storage subsystems as well as the master control.

3.7.1.8.1 Electrical Power Generation Subsystem/Master Control Interface. The electrical power generation subsystem shall respond to all control commands issued by the master control. The master control shall receive, store, and/or respond to all information originating from the electrical power generation subsystem. All interface connections shall be physically and electrically compatible.

3.7.1.9 Master Control Functional Modes. The function of the master control is to monitor and control all POCE subsystems in an integrated fashion in order to ensure stable, controlled system operation and proper procedures during emergency periods to maximize safety and minimize potential equipment damage.

3.7.1.9.1 System Mode Determination. The master control shall be capable of identifying the proper mode of system operation and generating the required commands to the appropriate subsystems to properly execute the required functions. The master control shall be capable of anticipating required changes in operational modes in response to insolation or environment factors and initiate the appropriate transition. Normal operational modes shall include system startup, normal solar, low solar power, intermittent cloudiness, collector field shutdown, night operation, final nighttime shutdown, and a self-check mode conducted after final shutdown in which all subsystems are interrogated as to their operational status.

3.7.1.9.2 <u>Emergency Detection and Operation.</u> At all times during the system operation, all subsystems shall be continuously monitored to verify operation in accordance with this specification and Appendixes 1, 2, 3, 4, and 5. In the event of a malfunction, the activation of redundant elements shall be initiated where possible. For those situations in which no redundancy exists, the impact of the malfunction shall be assessed. In the event that the situation can lead to a safety problem or result in additional equipment damage, a system shutdown shall be initiated. The nature of the shutdown procedure shall depend on the nature of the malfunction.

3.7.1.9.3 <u>Operational Information.</u> The master control shall be capable of displaying pertinent data required to completely determine the status of the POCE system. System performance projections shall be available based on current and past subsystem performance and on future system supply capabilities, including availability of stored thermal energy and solar insolation.

3.7.1.10 <u>Master Control Functional Interfaces.</u> The master control shall interface with the collector, receiver, thermal storage, and electrical power generation subsystems.

3.8 <u>Environmental Impact.</u> The POCE system shall be designed so that the environmental impact associated with construction, installation, maintenance, and operation of the system conforms to that authorized for the selected site in accordance with applicable environmental control regulations. Environmental impact data as required by the contract shall be developed for the specified site and submitted to ERDA.

3.9 Precedence. The order of precedence of requirements of the POCE system characteristics shall be as follows:

(a) Performance (including scalability to commercial power levels)

(b) Safety

(c) Capability to withstand natural environmental conditions

(d) Flexibility

(e) Cost

Specific characteristics and requirement precedence shall be established based on system cost effectiveness sensitivity analyses. This specification has precedence over documents referenced herein. The contractor shall notify the procuring activity of each instance of conflicting, or apparently conflicting, requirements within this specification or between this specification and a referenced document.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Tests. All tests shall be performed by the contractor. These tests may be witnessed by ERDA or its representatives or the witnessing may be waived. In either case, substantive evidence of hardware compliance with all test requirements is required.

4.1.2 General Test Requirements. Tests required for the subsystems and the master control shall be as defined in the detail requirements specifications. The test of a subsystem in conjunction with another subsystem or the master control (e.g., an integration test) is regarded as a system test and shall be as required by this specification. The contractor shall prepare a test plan for ERDA approval. Tests shall be classified in the test plan as follows:

(a) Compatibility tests, which must be performed on site to establish that POCE hardware is ready for hookup, or that interfaces can be completed, or that subsystems and the master control are operable. Compatibility tests may include tests of components, subassemblies, assemblies, or subsystems. Such tests shall be as defined at the appropriate specification level.

(b) Operation tests, which are tests of the integrated system.

Compatibility tests and operational tests at the system level shall be defined for verifications as indicated in subsection 4.3, Table 2.

4.1.3 Previous Tests. Maximum use shall be made of test data available from the subsystem research experiments, from POCE subsystem tests and other hardware tests already completed. Where conformance to this specification can be established at less cost by analysis of such data, tests shall not be repeated.

4.2 Specific System Test Requirements. The following tests and examinations are defined herein specifically for verification of POCE system requirements and shall be applied as necessary for the purposes of subsection 4.3, Table 2.

4.2.1 Examination of Installations. The contractor shall perform an examination of POCE installations to verify that subsystems, master control, and interfaces conform to physical requirements before functional testing.

4.2.2 Operations Tests (Integrated System). Functional demonstration of the POCE (pilot plant) system shall be performed by the contractor to the extent specified in the negotiated POCE test plan. The test plan shall include, as a minimum, the operational testing of the integrated system necessary to verify conformance to requirements identified for this method of verification in subsection 4.3, Table 2.

4.2.3 Life Tests and Analysis. One set of each major subassembly of the POCE design shall be subjected to extended life testing in accordance with the applicable subsystem requirements specifications.

4.3 Verification of Conformance. Verification that the requirements of Sections 3 and 5 of this specification are fulfilled shall be performed by the contractor by the methods specified in Table 2. The methods of verification are defined following the table.

Table 2

REQUIREMENT VERIFICATION MATRIX

Verification Methods

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

Test Categories

A. Compatibility Test

B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.1 Central Receiver POCE (Pilot Plant) Definition	N/A	N/A	
3.1.1 General Description	1, 2	N/A	
3.1.1(a) Collector Subsystem	1, 2, 5	B	
3.1.1(b) Receiver Subsystem	1, 2, 5	B	
3.1.1(c) Thermal Storage Subsystem	1, 2, 5	B	
3.1.1(d) Electrical Power Generation Subsystem	1, 2, 5	B	
3.1.1(e) Master Control	1, 2, 5	B	
3.1.2 POCE Application	N/A	N/A	

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.1.3 System Diagrams	N/A	N/A	
3.1.3.1 Central Receiver Solar Thermal System Diagram	N/A	N/A	
3.1.3.2 Functional Block Diagram	N/A	N/A	
3.1.3.3 Central Receiver POCE (pilot plant) Layout	N/A	N/A	
3.1.4 Interface Definition	1, 2, 5	B	
3.1.4.1 Electrical Power Transmission Network/ POCE Interface	1, 2, 5	B	
3.1.4.2 POCE/Site Interface	1, 2	N/A	
3.1.5 Operational and Deployment Concepts	N/A	N/A	
3.1.5.1 Basic Performance	2, 5	B	
3.1.5.2 Operational Concept	2	N/A	

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.1.5.2.1 Power Production Mode	2, 5	B	
3.1.5.2.2 Research Test Mode	5	B	
3.1.5.2.2.1 Normal Startup	2, 5	B	Included as test required by 3.1.5.2.2
3.1.5.2.2.2 Normal Solar Operation	2, 5	B	same
3.1.5.2.2.3 Low Solar Power Operation	2, 5	B	same
3.1.5.2.2.4 Intermittent Cloudiness Operation	2, 5	B	same
3.1.5.2.2.5 Normal Shutdown	2, 5	B	same
3.1.5.2.2.6 Emergency Shutdown	2, 5	B	Verified in part by tests in the Master Control Subsystem Specification.
3.1.5.2.2.7 Subsystem Conditioning	2, 5	B	Turning of rotor is to be demonstrated.

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.1.5.3 Deployment Concept	2	N/A	
3.2 Characteristics	N/A	N/A	
3.2.1 Performance	5	B	
3.2.1.1 Dynamic Performance	N/A	N/A	
3.2.1.1.1 Startup	2, 5	B	
3.2.1.1.2 Emergency Shutdown	2, 4	A	Water circulation failure may be simulated for test.
3.2.1.1.3 System Dynamic Variation	2, 5	B	Cloud effect may be simulated for test.
3.2.1.2 Endurance Capability	2, 4	→	See subsystem specifications for applicable life tests.
3.2.1.3 Other Performance Requirements	N/A	N/A	
3.2.1.3.1 Annual Power Output	2	N/A	

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.2.1.3.2 Collector Operations	2, 4	⟶	See collector subsystem specification.
3.2.2 Physical Characteristics	N/A	N/A	
3.2.2.1 System Characteristics	1, 2	N/A	
3.2.2.2 Collector Subsystem Characteristics	1, 2	N/A	See collector subsystem specification.
3.2.2.3 Receiver Subsystem Characteristics	1, 2	N/A	See receiver subsystem specification.
3.2.2.4 Thermal Storage Subsystem Characteristics	1, 2	N/A	See receiver subsystem specification.
3.2.2.5 Electrical Power Generation Subsystem Characteristics	1, 2	N/A	See electrical power generation subsystem specification.
3.2.2.6 Master Control	1, 2	N/A	See master control specification.

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.2.3 Reliability	2	N/A	
3.2.4 Maintainability	2	N/A	
3.2.5 Availability	2	N/A	
3.2.6 Environmental Conditions	2	N/A	See applicable subsystem specification.
3.2.7 Transportability	2	N/A	See applicable subsystem specification.
3.3 Design and Construction	2	N/A	See applicable subsystem specification.
3.3.1 Materials, Processes, and Parts	1, 2	N/A	See applicable subsystem specification. Inspection is to verify protective coating.
3.3.2 Electrical Transients	2, 4, 5	A, B	
3.3.3 Electromagnetic Radiation			

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.3.4 Nameplate and Product Marking	1	N/A	
3.3.5 Workmanship	1	N/A	
3.3.6 Interchangeability	2	N/A	Verify by design check and approval system.
3.3.7 Safety	1, 2	N/A	
3.3.8 Human Engineering	2		Design Review item.
3.4 Documentation	2	N/A	
3.5 Logistics	2	N/A	
3.5.1 Maintenance	2	N/A	
3.5.2 Supply	2	N/A	
3.5.3 Facilities and Facility Equipment	TBD	TBD	To be determined after site selection.

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.6 Personnel and Training	N/A	N/A	
3.6.1 Personnel	2	N/A	
3.6.2 Training	5	N/A	
3.7 Functional Area Characteristics	N/A	N/A	
3.7.1 POCE Functional Characteristics	N/A	N/A	
3.7.1.1 Collector Subsystem Functional Modes	2, 5	B	
3.7.1.1.1 Normal Operation	5	B	
3.7.1.1.2 Synthetic Tracking Operation	2, 5	B	
3.7.1.1.3 Emergency Operational Mode	5	B	
3.7.1.1.4 Nonoperational Modes	5	B	

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.7.1.2 Collector Subsystem Functional Interfaces	2	N/A	
3.7.1.2.1 Collector Subsystem/ Receiver Interface	2, 4	A	
3.7.1.2.2 Collector Subsystem/ Master Control Inter-face	1, 2, 4, 5	A, B	
3.7.1.2.3 Collector Subsystem/ Site Interface	1, 2	N/A	
3.7.1.3 Receiver Subsystem Functional Modes	2, 5	B	
3.7.1.3.1 Normal Operation	5	B	
3.7.1.3.2 Receiver Startup	5	B	
3.7.1.3.3 Receiver Shutdown	5	B	
3.7.1.3.4 Emergency Shutdown	2, 4, 5	A, B	Receiver failure and overheating condition shall be simulated for test.

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.7.1.3.5 Transient Operation	4, 5	A, B	
3.7.1.4 Receiver Subsystem Functional Interface	2	N/A	
3.7.1.4.1 Receiver Subsystem/ Thermal Storage Subsystem Interface	2, 4, 5	A, B	
3.7.1.4.2 Receiver Subsystem/ Electrical Power Generation Subsystem	1, 2, 5	B	
3.7.1.4.3 Receiver Subsystem/ Master Control Interface	1, 2, 4, 5	A, B	
3.7.1.5 Thermal Storage System Functional Modes	2, 5	B	
3.7.1.5.1 Charging Operation	2, 4, 5	A, B	
3.7.1.5.2 Steam Generation Operation	4, 5	A, B	

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.7.1.5.3 Feedwater Preheating Operation	4, 5	A, B	
3.7.1.6 Thermal Storage Subsystem Functional Interfaces	2	N/A	
3.7.1.6.1 Thermal Storage Subsystem/Electrical Power Generation Subsystem Interface	1, 2, 5	B	
3.7.1.6.2 Thermal Storage Subsystem/ Master Control Interface	1, 2, 4, 5	A, B	
3.7.1.7 Electrical Power Generation Functional Modes	2, 5	B	
3.7.1.7.1 Normal Operation	5	B	
3.7.1.7.2 Deferred Operation	5	B	
3.7.1.8 Electrical Power Generation Subsystem Functional Interfaces	2	N/A	

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.7.1.8.1 Electrical Power Generation Subsystem/ Master Control Interface	1, 2, 4, 5	A, B	
3.7.1.9 Master Control Functional Modes	N/A	N/A	
3.7.1.9.1 System Mode Determination	2, 4, 5	A, B	
3.7.1.9.2 Emergency Detection and Operation	2, 4, 5	A, B	
3.7.1.9.3 Operational Information	2, 4, 5	A, B	
3.7.1.10 Master Control Functional Interfaces	N/A	N/A	
3.8 Environmental Impact	1, 2	N/A	
3.9 Characteristics of POCE System	N/A	N/A	

Table 2

REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Compatibility Test B. Operational Test (integrated system)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.10 Precedence	N/A	N/A	
5. Preparation for Delivery	N/A	N/A	

(a) Inspection - examiniation and measurement of product.

(b) Analysis - examination of the design and associated data, which may include relevant test information.

(c) Similarity - demonstration or acceptable evidence of the performance of sufficiently similar product to permit conformance to be inferred.

(d) Test - functional operation or exposure under specified conditions to evaluate product performance.

(e) Demonstration - exhibition of the product or service in its intended modes and conditions.

4.3.1 Hardware Acceptance. The contractor shall provide a method whereby conformance of hardware to the design and to the applicable detail specifications will be verified. This shall be accomplished progressively as system elements are manufactured. As the POCE system is integrated, conformance to design at that level shall be verified. For purposes of

POCE (pilot plant) acceptance, this verification of conformance includes proof-by-assembly and the examination of records as elements of inspection. Satisfactory system demonstration shall be accomplished. In addition, evidence shall be maintained of satisfactory accomplishment of inspections and tests required by codes and standards that apply for the system.

4.4 Formal Qualifications. For the POCE system, formal design qualification shall require satisfactory completion of all contractually required tests, including those specified for POCE subsystems, and the completion of all other required verifications and the integrated system demonstration tests in the negotiated test plan.

5.0 PREPARATION FOR DELIVERY

POCE pilot plant equipment shall be prepared for delivery in accordance with section 5.0 of the appropriate detail specification of Appendix 1, 2, 3, 4, or 5.

10.0 APPENDIXES

Detail POCE subsystem (prime item) specifications are provided under separate cover as appendixes to this specification identified as follows:

Appendix 1, Collector Subsystem Requirements Specification

Appendix 2, Receiver Subsystem Requirements Specification

Appendix 3, Thermal Storage Subsystem Requirements Specification

Appendix 4, Electrical Power Generation Subsystem Requirements Specification

Appendix 5, Master Control Requirements Specification

APPENDIX 1 POCE Collector Subsystem

COLLECTOR SUBSYSTEM
REQUIREMENTS SPECIFICATION

VOLUME 2
PART 1
APPENDIX 1

CONTENTS

CONTENTS (Continued)

1.0 SCOPE

This specification establishes the performance, design, and test requirements for the POCE collector subsystem.

2.0 APPLICABLE DOCUMENTS

The equipment, materials, design, and construction of the collector subsystem shall comply with all Federal, state, local, and user standards, regulations, codes, laws, and ordinances which are currently applicable for the selected site and the using utility. These shall include but not be limited to the government and non-government documents itemized below. If there is an overlap in or conflict between the requirements of these documents and the applicable Federal, state, county or municipal codes, laws or ordinances, that applicable requirement which is the most stringent shall take precedence.

The following documents of the issue in effect on the date of request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Government Documents

2.1.1 Specifications

DD-G-451C, Glass, plate, sheet, figured (float, flat, for glazing, corrugated, mirrors and other uses).

DD-M-00411b (GSA-FSS), Mirrors, Glass.

MIL-E-4158, Electronic Equipment Ground; General Requirements For.

Regulations of the Occupational Safety and Health Administration (OSHA).

Regulations of the California Occupational Safety and Health Administration (CAL/OSHA) - if required.

2.1.2 Standards

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

Federal Test Method Standard No. 101B for "Preservation, Packaging, and Packaging Materials: Test Procedures", January 15, 1969.

MIL-STD-454, Standard General Requirements for Electronic Equipment.

MIL-STD-889, Dissimilar Metals.

MIL-STD-1261A, Welding Procedures for Constructional Steels.

MIL-STD-1472, Human Engineering Design Criteria.

2.1.3 Other Publications

AFSC—Design Handbook on Electromagnetic Compatibility, DH1-4

Checklist of General Design Criteria, DH1-X

Instrumentation Grounding and Noise Minimization Handbook, AFRPL-TR-65-1

National Motor Freight Classification 100B - Classes and Rules Apply on Motor Freight Traffic

Uniform Freight Classification 11 - Railroad Traffic Ratings Rules and Regulations

CAB Tariff 96 - Official Air Transport Rules Tariff

CAB Tariff 169 - Official Air Transport Local Commodity Tariff

R. H. Graziano's Tariff 29 - Hazardous Materials Regulations of the Department of Transportation

CAB Tariff 82 - Official Air Transport Restricted Articles Tariff

2.2 Non-Government Documents

2.2.1 Standards

National Electrical Manufacturers Association (NEMA) Standards

Manual of Steel Construction, 7th Edition, 1974, American Institute of Steel Construction.

Building Code Requirements for Reinforced Concrete, ACI 318-71, American Concrete Institute.

Uniform Building Code - 1973 Edition, Vol. I by International Conference of Building Officials.

National Electric Code, NFPA 70-1971 (ANSI C1-1971)

2.2.2 Other Publications

A Ground Lightning Environment for Engineering Usage, Stanford Research Institute Project No. 1834.

"Wind Forces on Structures", ASCE Paper No. 3269 Transactions, American Society of Civil Engineers, Vol. 126, Part II, 1961.

3.0 REQUIREMENTS

3.1 Collector Subsystem Definition. The collector subsystem comprises an array of heliostats and supporting power and control elements which interact with the master control. The heliostat array reflects solar radiation onto the elevated absorber (boiler/superheater) of the receiver subsystem in a manner which satisfies receiver incident heat flux requirements. In addition, the collector subsystem executes alternative drive modes in response to commands from the master control for emergency defocusing of the reflected energy and for protection of the array of heliostats against environmental extremes. Selective heliostat positioning for repair or maintenance is accomplished in response to either master control or local commands. The collector subsystem shall be capable of scaling to a commercial central receiver power generation system ranging in size from 100 to 300 MWe by the addition of modular elements (or fields) of heliostats and supporting equipment.

The two principal collector subsystem components are described below.

(a) Heliostat

(1) Reflective surface (includes glass, silver, and protective coating(s))

(2) Structural support

(3) Drive unit (motors, drive trains, housings and gimbal joints)

(4) Control sensors (beam sensor, potentiometers, and tachometers)

(5) Pedestals and foundations for drive unit and beam sensor

(b) Field Controller

(1) Digital processor

(2) AC/DC power conversion

(3) Analog control electronics (servoamplifiers, sample and hold circuitry, switching)

(4) Digital/analog and analog/digital conversion units

(5) Heliostat cabling

3.1.1 Collector Subsystem Diagram. Figure 1 describes the heliostat functional elements and Figure 2 shows the collector subsystem electrical elements and interfaces.

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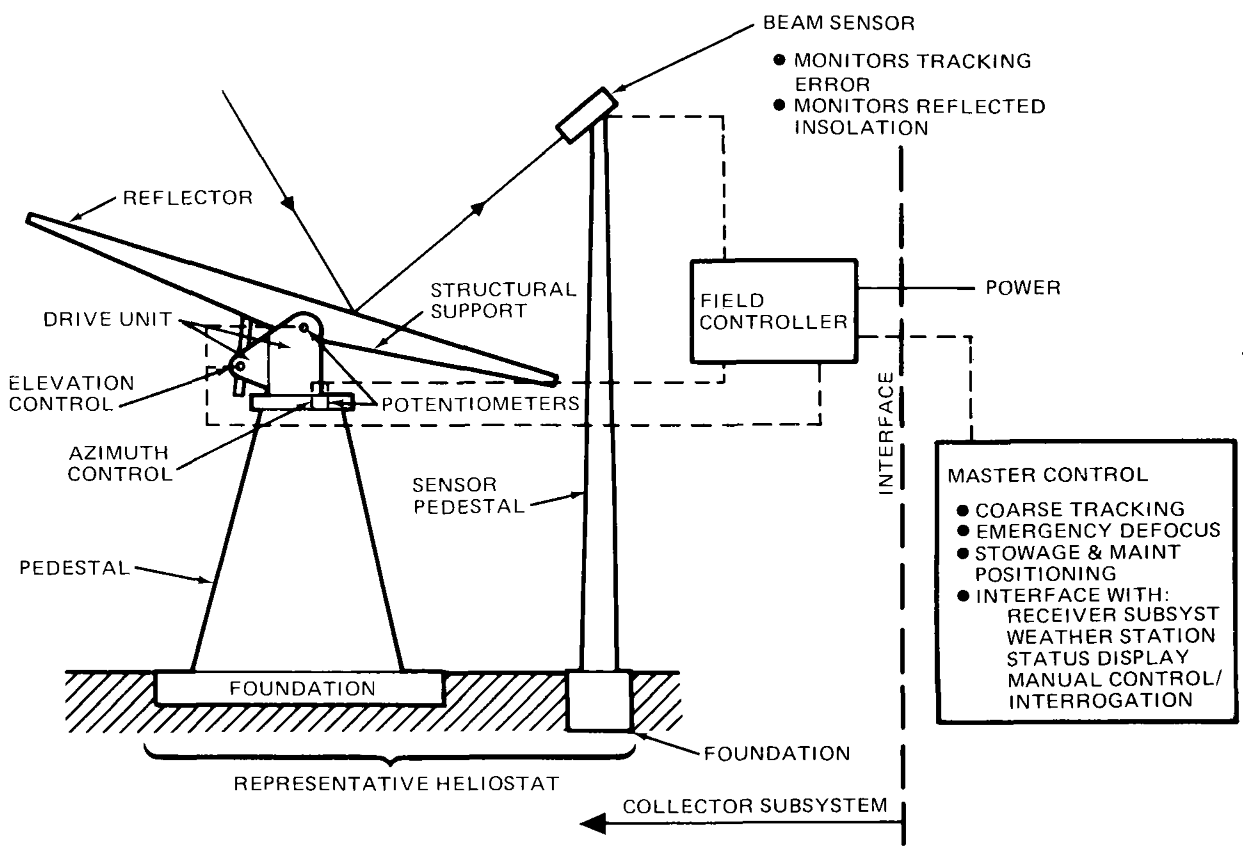

Figure 1. Heliostat Functional Elements

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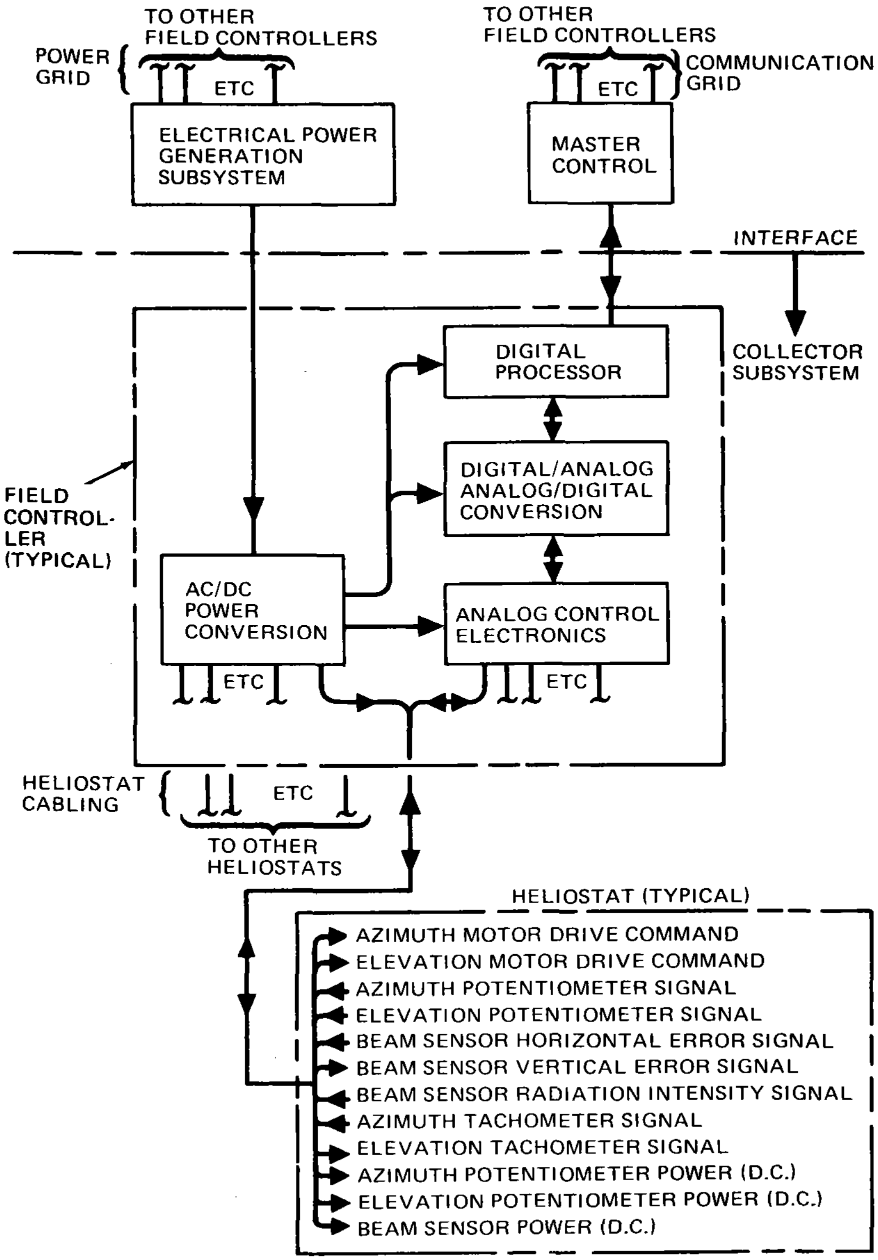

Figure 2. Collector Subsystem Electrical Interfaces

3.1.2 Interface Definition. External and internal physical and functional interfaces of the collector subsystem are as follows.

3.1.2.1 Physical Site. The physical arrangement and boundaries of the array of heliostats shall be optimized to most cost effectively concentrate the requisite solar energy on the receiver absorber. The final POCE arrangement shall reflect balanced consideration of heliostat shading, blocking, and geometric parameters to produce an optimal heliostat field layout. A representative layout is shown in Figure 3. Heliostat and beam sensor pedestal foundations shall be consistent with site-peculiar stratigraphy and surface soil conditions.

3.1.2.2 Receiver Subsystem. The collector subsystem shall concentrate at least 99 percent of the redirected energy onto the receiver absorber.

3.1.2.3 Master Control. A two-way digital data communication grid shall interconnect the collector subsystem and the master control. The grid shall consist of 16 evenly loaded half-duplexed time-multiplexed baseband data buses. Communication may take the form of mandatory commands, information transferral, and information requests. All heliostats and field controllers shall be uniquely addressable.

3.1.2.4 Electrical Power Generation Subsystem. The collector subsystem and the electrical power generation subsystem shall be interconnected by the power grid. The electrical power generation subsystem shall be capable of

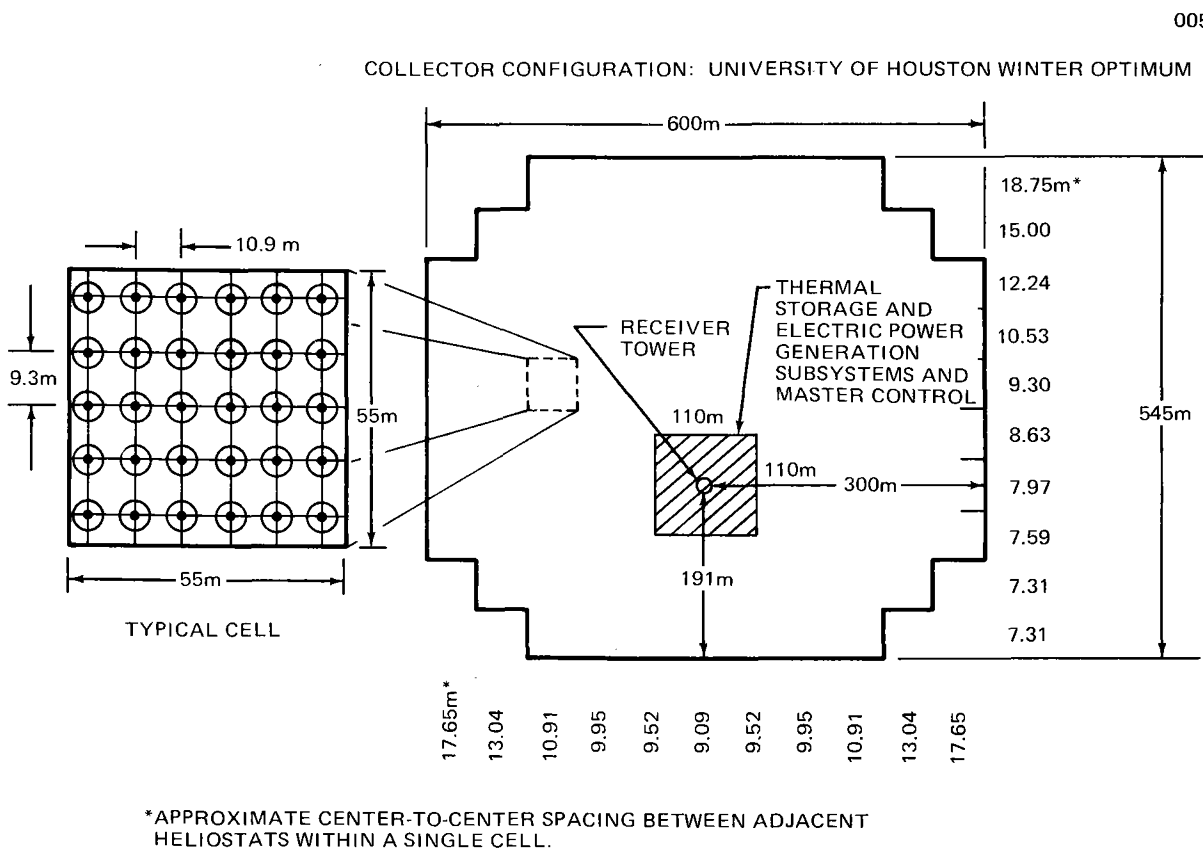

Figure 3. Representative Field Layout

supplying 3 KVA at 277V single phase to each field controller from two separate power sources. The power distribution primary transformer shall be capable of 100 percent overload for 90 seconds.

3.1.2.5 Internal Interfaces. Principal interfaces within the collector subsystem include:

(a) Digital Processor/Analog Control Electronics

These two functional elements are interconnected by analog/digital and digital/analog signal converters, permitting two-way signal transmission and digital interactions with the heliostat control servos including signal conditioning, transformation, and summation.

(b) Field Controller/Heliostat

The field controller is interconnected with the heliostat by the heliostat cabling, providing for transmission of motor drive commands, beam sensor signals, potentiometer signals, tachometer signals, and sensor power.

(c) AC/DC Power Conversion

This functional element receives AC power from the electrical power generation subsystem via the power grid and converts it into DC power at various voltages suitable for excitation of the beam sensors and potentiometers. This power is supplied to the individual heliostats via the heliostat cabling. The AC/DC power conversion circuitry also supplies DC power to the analog control electronics, digital processor, and analog/digital-digital/analog elements within the field controller.

3.2 Characteristics

3.2.1 Performance. The collector subsystem shall reflect solar radiation onto the elevated absorber of the receiver subsystem with a maximum beam pointing error of 3 mrad whenever the insolation exceeds 86 W/m^2 and the sun is more than 20° above the horizon, under the normal operational environmental conditions specified in paragraph 3.2.6.3.

The collector subsystem shall be capable of concentrating 43 MWth radiant energy on the absorber at 2 P.M. local sun time on a clear day at winter solstice and 52 MWth at noon local sun time on a clear day at summer solstice, with a peak flux density not to exceed 0.3 MW/m^2. The collector subsystem shall be capable of automated emergency defocusing to reduce incident radiation on the receiver to less than 0.02 MW/m^2 within 10 seconds, and shall automatically provide synthetic heliostat tracking during obscuration (shadowing) such that normal tracking is resumed within 120 seconds after removal of the obscuration.

Automatic nonoperational heliostat slewing provisions shall be incorporated such that the entire array of heliostat reflectors can be (1) aligned horizontally within 15 minutes to accommodate high winds/sand storm conditions, (2) aligned 70° from horizontal and parallel to prevailing winds within 15 minutes in anticipation of severe hail, sleet, or ice storms, and (3) aligned in any preferred orientation within 30 minutes to facilitate cleaning or maintenance.

The collector subsystem shall be designed such that normally unradiated portions of the receiver subsystem are not exposed to concentration ratios greater than (TBD) at any time. Reflectance of clean heliostat reflective surfaces shall exceed 80 percent average over an air mass 2 solar spectrum and within a 4-milliradian cone. A surface life of 30 years is required, and surface degradation rate shall be minimized. The optical spreading due to surface irregularities shall be less than 0.05°. The heliostat structural support shall be designed to prevent reflective surface deflection from exceeding 0.1° under the normal operational wind conditions specified in paragraph 3.2.6.3. The heliostat shall incorporate limit switches to avoid overdriving the reflector and to limit windup of heliostat wiring. An override provision shall be included in the drive unit to permit manual feathering of the reflector at the heliostat.

3.2.2 Physical Characteristics. The maximum heliostat weight shall be governed by cost, transportation, and servicing constraints, structural requirements and power consumption of the drive components. Reflector shape limitations shall be imposed only by the collector field layout, shadowing and blocking constraints and servicing requirements. Spacing between heliostats in the field shall permit access by service vehicles, control and power lines, and maintenance personnel.

The foundation design selected shall include consideration of soil stratigraphy, preservation of vegetation, and geological phenomena. Physical security provisions shall be included for the collector field to protect against damage by animals, sabotage, or vandalism.

3.2.3 Reliability. High reliability shall be achieved in the collector subsystem design by providing adequate operating margins, maximizing the use of proven standard parts, and using conservative design practices such that the reliability performance shall not degrade the capability to achieve the availability specified in paragraph 3.2.5 when operated in the environments specified in paragraph 3.2.6.

Single-point failures that disable the automatic mode of system operation shall be eliminated wherever practical. In cases where it is impossible to eliminate such failure modes, suitable devices shall be used to detect and warn of the occurrence of a failure.

3.2.4 Maintainability. The collector subsystem shall be designed such that required service can be accomplished by personnel of normal skills, with a minimum of nonstandard tools or special equipment.

The collector subsystem shall be designed to provide malfunction indication and fault isolation information data required by the master control concerning critical components (TBD). Critical components are those components that, because of failure risk, downtime or effect on the overall POCE performance, materially affect the capability to achieve the system availability requirements.

Items which do not have a redundant mode of operation shall incorporate maximum capability for on-line repair or replacement. These items might include, for example, sensors and actuators. The collector subsystem shall be designed such that potential maintenance points can be easily reached, the reflector can be readily cleaned, components such as electronic modules and sensors can be readily replaced, and elements subject to wear or damage can be easily serviced or replaced.

3.2.5 Availability. The collector subsystem shall operate in accordance with paragraph 3.2.1 performance requirements 96.6 percent of its scheduled operating time based on reliability and maintainability exclusive of insolation conditions. Determinations of availability shall use as a time reference a period of one year.

3.2.6 Environmental Conditions

3.2.6.1 General. The conditions described in the following paragraphs are representative of the transportation and operating site environments to be encountered by the collector subsystem. For design purposes safety margins shall be used commensurate with availability and performance requirements to ensure operation in accordance with paragraph 3.2.1 during or after exposure to these conditions.

3.2.6.2 Transportation and Handling. The following conditions occurring separately or in combination may be encountered by packaged equipment during handling and transportation.

3.2.6.2.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.6.2.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.6.2.3 Transportation Vibration and Shock. Vibration and shock as encountered during transport. Conditions are as follows:

VIBRATION

Transportation Mode	Continuous Excitations (Steady-State) in g's	Discrete Impulse (Transient) in g's	Predominant Frequency Range
Highway	0.06	1.5	2 to 200 Hz
Rail	0.05	1.5	2 to 200 Hz
Air (Jet Aircraft)	0.05	1.5	2 to 500 Hz

SHOCK (g's)

(Normal Load Limits)

Transport Media	Longitudinal	Lateral	Vertical	Average Pulse Time msec
Air	2.0	1.5	2.0	11-40
Highway	2.0	1.5	3.0	11-40
Rail (Rolling)(1)	3.0	0.75	3.0	11-40
Cushion Car (Humping)	3.0	2.0	3.0	11-40

(1) Shock loads are for rail cars equipped with standard draft gears.

All critical (frangible) components of the collector subsystem shall be designed or packaged such that the conditions described above do not induce a dynamic environmental condition which exceeds the structural capability of the component. These conditions reflect careful handling and firmly constrained (tied down) transporting via common carrier. All components shall be designed to withstand handling/hoisting inertial loads up to 2 g's considering number, location, and type of hoisting points.

3.2.6.2.4 Handling Shock. Handling shocks may result from drops of packaged equipment. Corresponding acceleration peaks may be of the order of 7 g's vertical and 4 g's horizontal with a (TBD) wave profile and a duration of 10 to 50 milliseconds.

3.2.6.2.5 Other Conditions. The equipment may encounter other conditions during transportation and handling including wind, rain, snow, ice, hail, and blowing sand and dust. These are not expected to exceed the operational conditions of paragraph 3.2.6.3.

3.2.6.3 Operational. The following conditions occurring separately or in combination may be encountered by the collector subsystem during the pilot plant 30-year operational life. Unless specified otherwise, the collector subsystem shall be designed to perform in accordance with paragraph 3.2.1 during and after exposure to these conditions.

3.2.6.3.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.6.3.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.6.3.3 Wind. Sustained surface winds up to 8.9 m/sec (20 mph) for a period of (TBD) hours with gust RMS velocities up to 11.6 m/sec (25.9 mph). The collector subsystem shall survive, in a nonoperational state with the reflector in any position, sustained surface wind velocities up to 20.5 m/sec (45.9 mph) for (TBD) hours with gust RMS velocities up to 26.7 m/sec (59.7 mph). In addition, nonoperational survival in a feathered position shall be maintained in surface winds of 35.7 m/sec (79.9 mph) for periods up to (TBD) hours with gust RMS velocities to 46.4 m/sec (103.8 mph). These are derived from 35.7 m/sec (79.9 mph) base, 50 year fastest mile (Reference ASCE Paper 3269, Vol. 126). Maximum steady winds with gusts during operation are to be considered throughout a complete daylight operational period. Practices recommended in the ASCE Paper 3269, Vol. 126 and the Uniform Building Code, 1973, Vol. 1 shall be employed in designing the collector subsystem for winds.

3.2.6.3.4 Vibration (Wind-Induced). The natural wind environment to which the collector subsystem will be periodically exposed induces a vibratory response. Based on the wind conditions specified in paragraph 3.2.6.3.3, the fluctuating loads on the large exposed surfaces of the heliostat assemblies are as follows:

Frequency of Resonances	Fatigue Equivalent Wind Velocity	Equivalent Static Moment	Modal Force	Duration (at resonance)
0 - 40 Hz	14.7 m/sec (48.2 ft/sec)	22,500 in-lb	530 kg (1,165 lb)	2.1×10^7 sec

To preclude fatigue due to these fluctuating loads, the structure shall be designed such that stresses are below the endurance limits for this loading. These pressures are to be assumed in-phase over the structure.

The fluctuating pressure induced response results in mechanical vibration of the heliostat assemblies. Components or mechanical assemblies shall be capable of withstanding these vibrations which are represented by sinusoidal excitation of the following amplitudes:

Frequency	Amplitude
1-6 Hz	1-inch double amplitude
6-200 Hz	2 g's 0-peak

3.2.6.3.5 Sand and Dust. The collector subsystem shall not evidence operational degradation or component destruction following exposure to sand and dust storms. The design shall withstand dust fluxes of 10^{-4} g/cm^2-sec at velocities up to (TBD) meters/second. Dust is defined to be those particles up to 100 μm in diameter with the mean diameter being 40 to 50 μm.

Sand is defined as particles greater than 100 μm in diameter. Desert sand flux declines approximately exponentially with height above the surface. For the surface roughness expected at the POCE site, 90 percent of the sand flux will be within 25 cm (10 in.) of the surface. The design shall withstand a sand flux which averages 0.3 gm/cm^2-sec within that region at velocities up to (TBD) meters/second.

The frequency of storm occurrence and duration to be considered will depend on the site selected. For example, in the Southwestern desert area a major storm frequency of four or less per year with a maximum duration of

36 hours are to be assumed. Minor storms of nine per year and a maximum duration of 6 hours are to be assumed.

The effect of dust devils shall also be considered in the design. The maximum core diameter and tangential velocities to be considered are 70m and 30 m/sec, respectively. The maximum vertical velocity to be considered is 15 m/sec.

Subsystem components shall be protected from the electrostatic charging and discharging associated with sand and dust storms. This shall include grounding the silvered surface on the reflector to prevent attraction of charged dust particles.

3.2.6.3.6 Rain, Hail, and Snow. Storms of the following types and intensities:

Rain: Average storm intensity of (TBD) cm/hour (TBD in/hr) for (TBD) hours with peak periods of (TBD) cm/hour (TBD in/hr) lasting (TBD) minutes. Three to five storms per year.

Hail: Mean particle diameter of 5 to 10 mm (0.20 to 0.39 in.), extreme diameter of 25 mm (1 in.). Fall velocity of 20 m/sec (65.6 ft/sec). Hail stone compressive strength of 1.03 MN/m^2 (150 psi) for 25 mm stone; 5.07 MN/m^2 (735 psi) for stones less than 10 mm in diameter. Storm intensity of (TBD) particles per square meter per minute lasting 10 to 20 minutes. Frequency of occurrence--one in 5 to 6 years.

Snow: (TBD)

3.2.6.3.7 Lightning. The subsystem shall be designed to withstand a lightning threat that has a current pulse of 140,000 amperes with a 1.5-microsecond rise time decaying to 50 percent in 40 microseconds. A continuing current of 200 to 400 amperes will follow the main stroke and last for 160 to 300 milliseconds. Up to 10 restrokes can occur with 30,000 to 70,000 amperes peak current each. Total charge transfer of the primary stroke and the restrokes events can reach 200 coulombs. Design criteria of "A Ground Lightning Environment for Engineering Usage", Stanford Research Institute Project No. 1834 shall be used.

3.2.6.3.8 Earthquake. The collector subsystem shall be designed to withstand, without structural damage or yielding, the earthquake environment described in Table 1 and Figure 4. The environment is given in terms of response spectra and ground motion histories for soft rock or firm sediment. If the collector subsystem is located on competent rock, the above environment may be reduced by 33 percent. If the subsystem is located on soft sediment, the above environments shall be increased by 50 percent. The response spectra or ground motion histories shall be used as input to the analytical model of the soil and collector heliostat assembly in both vertical and horizontal directions to assess earthquake-induced loads.

Table 1
EARTHQUAKE HORIZONTAL GROUND MOTION HISTORIES

Location	Year	Component	Scale Factor
El Centro	1940	NS	1.0
El Centro	1934	EW	1.4
Olympia	1949	N10W	1.4
Taft	1952	S69E	1.7

Each ground motion history is to be multiplied by the indicated scale factor.

3.2.7 Transportability. Collector subsystem components shall be designed for transportability within applicable Federal and state regulations by highway and railroad carriers utilizing standard transport vehicles and materials handling equipment. The components, in their packaged condition, shall be capable of withstanding the climatic conditions and shock and vibration environments defined in paragraph 3.2.6.2. Whenever feasible, components shall be segmented and packaged to sizes that are transportable under normal commercial transportation limitations in accordance with (a) below. Subsystem components that exceed normal transportation limits (see (b) below) shall be transportable with the use of special routes, clearances, and permits.

(a) Transportability Limits for Normal Conditions (Permits Not Required)

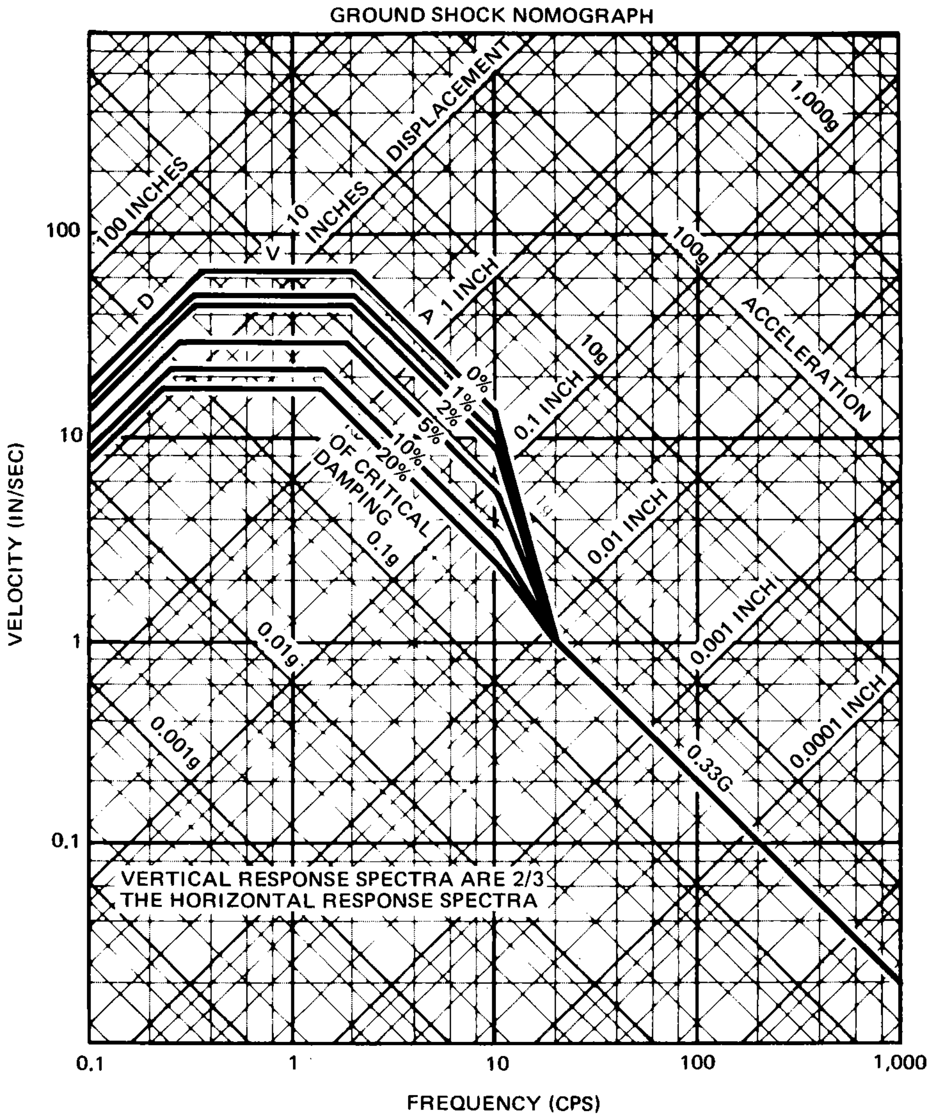

Figure 4. Earthquake Horizontal Response Spectra

	Truck	Rail
Height:	13 ft 6 in above road	16 ft 0 in
Width:	8 ft 0 in	10 ft 6 in
Length:	55 ft 0 in - Eastern States 60 ft 0 in - Western States	60 ft 6 in
Gross Wt:	73,280 lb; 18,000 lb/axle	200,000 lb

(b) Transportability Limits for Special Conditions

	Truck	Rail
Height:	14 ft 6 in above road	16 ft 0 in above rail

Width:	12 ft 0 in	12 ft 0 in
Length:	70 ft 0 in	80 ft 6 in
Gross Wt:	100,000 lb with sufficient axles to distribute weight over highway not to exceed 18,000 lb/axle.	400,000 lb

3.3 Design and Construction. Commercial design and construction standards relevant to the intended use of the component or structure in question shall be employed. Where applicable, the "Uniform Building Code (1973 ed.)", the American Institute of Steel Construction "Manual of Steel Construction (7th ed.)", and the American Concrete Institute "Building Code Requirements for Reinforced Concrete" shall be used. The ASCE paper No. 3269, "Wind Forces on Structures" (ASCE Transactions, Vol 126, Part II, 1961), shall be used during design when determining loading due to winds. For electrical components, the National Electric Code (ANSI C1), the National Electrical Manufacturers Association (NEMA), and MIL-STD-454 standards for electronic equipment shall be used. The electronic equipment shall be grounded in conformance with the MIL-E-4158 specifications. The heliostat and sensor pedestals shall be installed within 1° of vertical and shall not deviate from that alignment (exclusive of seismic effects) at rates exceeding 0.2°/year and 0.1°/year, respectively.

3.3.1 Materials, Processes, and Parts. To the maximum extent possible, standard materials, processes, and off-the-shelf components shall be used. Wherever possible, commercial specifications shall be employed.

The glass to be used for mirror panels shall meet the requirements of specifications DD-G-451C type I and DD-M-00411b (GSA-FSS). The reflective surface of the heliostat shall be vapor-deposited silver.

Dissimilar materials as defined by MIL-STD-889 shall not be used in direct contact (i.e., suitable protection shall be provided to avoid galvanic corrosion).

3.3.2 Electrical Transients. The subsystem operation shall not be adversely affected by external or internal power line transients caused by normal switching, fault clearing, or lightning. Switching transients and fault clearing functions will require less than six cycles of the fundamental frequency (100 milliseconds) and shall be limited to 1.7 P.U. voltage (1.7 per unit or 170 percent).

Components of the subsystem shall be shielded from the lightning threat specified in paragraph 3.2.6.3.7. Shielding shall protect the electrical components from both the bound charge and induced current threats. Lightning arresters shall be installed which will limit the resultant line voltage to 5 P.U. on a line to ground basis during the time interval of peak current as defined in paragraph 3.2.6.3.7. The air terminal design and installation shall be in accordance with NFPA Bulletin No. 78 (ANSI C5.1).

3.3.3 Electromagnetic Radiation. The collector subsystem shall be designed to minimize susceptibility to electromagnetic interference and to minimize the generation of conducted or radiated interference. The design criteria contained in the following Air Force design handbooks shall be used to ensure electromagnetic compatibility: Design Handbook on Electromagnetic Compatibility (AFSC DH1-4), Checklist of General Design Criteria (AFSC DH1-X), and Instrumentation Grounding and Noise Minimization Handbook (AFRPL-TR-65-1).

3.3.4 Nameplate and Product Marking. All deliverable end items shall be labeled with a permanent nameplate listing, as a minimum, manufacturer name, part number, change letter, serial number, and date of manufacture.

All access doors to replaceable/repairable items shall be labeled to show equipment installed in that area, and any safety precautions or special considerations to be observed during servicing.

3.3.5 Workmanship. The level of workmanship shall conform to practices defined in the codes, standards, and specifications applicable to the selected site and the using utility. Where specific skill levels or certifications are required, current certification status shall be maintained with evidences available for examination. Where skill levels or details of workmanship are not specified, the work shall be accomplished in accordance with the level of quality currently in use in the construction, fabrication, and assembly of commercial power plants. All work shall be finished in a manner such that it presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a generally uniform appearance.

3.3.6 Interchangeability. Major components, circuit cards, and other items with a common function shall be provided with standard tolerances and connector locations to permit interchange for servicing. Components that have similar appearance but different functions shall incorporate protection against inadvertent erroneous installation through the use of such devices as keying, connector size, or attachment geometry. All heliostats shall be interchangeable regardless of position in the heliostat array.

3.3.7 Safety. The collector subsystem shall be designed to minimize safety hazards to operating and service personnel, the public, and equipment. Electrical components shall be insulated and grounded. All parts or components with elevated temperatures shall be insulated against contact with or exposure to personnel. Any moving elements shall be shielded to avoid entanglements and safety override controls/interlocks shall be provided for servicing. All pertinent OSHA rules and regulations shall be observed.

3.3.8 Human Engineering. The collector subsystem shall be designed to facilitate manual operation, adjustment, and maintenance as needed. Human engineering studies shall be performed to determine the optimum allocation of functions to personnel or automatic control. Particular human engineering attention should be applied in the collector subsystem to electrical/electronic packaging to ensure rapid repair/replacement, the provision of adequate lighting for night maintenance, the placarding of hazardous work areas, and equipment for item removal and handling. MIL-STD-1472, Human Engineering Design Criteria, shall be used as a guide in designing equipment.

3.4 Documentation

3.4.1 Characteristics and Performance. Equipment functions, normal operating characteristics, limiting conditions, test data, and performance curves, where applicable, shall be provided.

3.4.2 Instructions. Operation and maintenance instructions shall be prepared for assembly, installation, alignment, adjustment, checking, lubrication, and maintenance of the collector subsystem. All instructions shall include references to applicable subsystem engineering data and guides to troubleshooting instruments and controls. All phases of collector subsystem operation shall be addressed including startup, routine and normal operation, on-line and off-line maintenance, shutdown, contingency operation, and emergency conditions.

3.4.3 Construction. Engineering and assembly drawings shall be provided to show the equipment construction, including assembly and disassembly procedures. Engineering data, wiring diagrams, and parts lists shall be provided.

3.5 Logistics. The elements required to support the collector subsystem are:

Support and test equipment

Technical publications

Personnel and training

Facilities

Spares, repair parts and consumables

Transportation, handling and packaging

Data file

Field service

The requirements for the elements shall be established as a result of a support requirements analysis to be prepared by the contractor. The results of the analysis shall be documented in accordance with the contract.

3.5.1 Maintenance. Maintenance activities are categorized as follows:

Level 1, On-line maintenance

Level 2, Off-line on-site maintenance

Level 3, Off-line off-site maintenance

Level 1, On-Line Maintenance: The following scheduled and unscheduled maintenance activities shall be identified for the collector subsystem.

Task	Frequency
Visual inspection	Daily
Remove and replace	(TBD)
Repair in place	(TBD)
Adjust	(TBD)
Align	(TBD)
Calibrate	(TBD)

Task	Frequency
Lubricate	(TBD)
Paint	(TBD)
Transporting	(TBD)

Level 2, Off-Line On-Site Maintenance: The following maintenance activities shall be identified in the maintenance plan. Frequencies shall be (TBD).

Fault verification

Fault isolation to a removable item

Remove and replace a faulty item

Verify acceptable repaired item

Repair designated subtiered items

Servicing

Lubrication

Visual inspection

Transporting

Level 3, Off-Line Off-Site Maintenance: Level 3 maintenance activities are those to be performed at the equipment supplier's facility. Frequencies and turnaround times shall be (TBD).

Maintenance Plan: A maintenance plan shall be prepared by the contractor which identifies scheduled and unscheduled maintenance requirements. The maintenance plan shall reflect the results of the support requirements analysis and shall specify the following as appropriate.

Use of multi-purpose test equipment

Items to be repaired

Items to be replaced

Maintenance and repair cycles

Use of operational support equipment for maintenance

Level, frequency, and location of maintenance action

Facilities, equipment, and tools

3.5.2 Supply. The selection and positioning of spares, repair parts and consumables shall be in accordance with the levels of repair determined by the support requirements analysis, and shall use the following criteria:

Protection Level: Items shall be packaged in accordance with the requirements of section 5.0.

Demand Rate: The mean-time-between-maintenance-actions provided by the maintainability analyses shall be the departure point for spares determinations. The quantities and mix shall be such that there is a (TBD) percent probability of a part being available on demand.

Pipeline: Pipeline quantities shall be determined on the basis of system location demand rate and repair cycle times. Resupply methods, distribution and location of system stocks shall be determined after site selection.

Procurement and Release for Production: Long lead time supply items shall be procured or released early enough to be on-site 30 days prior to initial operation. Other items shall be procured or released lead-time away so as to minimize obsolescence due to design changes, except for those items for which significant cost savings can be achieved through acquisition concurrent with production.

Minimum/Maximum Levels: Minimum and maximum quantities of spares and repair parts to be stocked shall initially be determined by use of predicted failure rates. These levels are to be adjusted as actual usage rates are established.

3.5.3 Facilities and Facility Equipment. To be determined after site selection.

3.6 Personnel and Training

3.6.1 Personnel. The pilot plant is to be installed, checked out, and tested as a proof-of-concept experiment by contractor personnel; then taken over and operated as a commercial power plant by utility personnel. Operation and maintenance personnel requirements shall be satisfied by recruitment from the established utility labor pool. Unique aspects of the collector subsystem dictate a need for training existing utility people but do not establish a need for new skills or trades. The types and numbers of utility personnel requiring training, along with the unique tasks, are as follows:

Type	No.	Unique Task
TBD	TBD	Reflector repair and handling
		Heliostat removal and replacement
		Heliostat alignment
		Heliostat handling and transporting

Heliostat component repair and servicing

Sensor removal and replacement

Field controller maintenance

Safety requirements

Emergency operations

(Others TBD)

3.6.2 Training. The contractor shall prepare and conduct a training program for contractor personnel as necessary for performance of the POCE. The contractor shall conduct a training program for utility personnel in accordance with contractual requirements.

3.7 Precedence. The order of precedence of collector subsystem requirements and characteristics shall be as follows:

(a) Performance (including scalability to commercial power levels)

(b) Capability to withstand natural environmental conditions

(c) Cost

Specific characteristic and requirement precedence shall be established based on system cost effectiveness sensitivity analyses. This specification has precedence over documents referenced herein. The contractor shall notify the procuring activity of each instance of conflicting, or apparently conflicting, requirements within this specification or between this specification and a referenced document.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Tests. All tests shall be performed by the contractor. These tests may be witnessed by ERDA or its representatives or the witnessing may be waived. In either case, substantive evidence of hardware compliance with all test requirements is required.

4.1.2 General Test Requirements. Tests shall be conducted in accordance with a test plan to be prepared by the contractor and approved by ERDA. Specific required tests are identified in subsection 4.2. Tests shall be classified in the test plan as:

(a) Development tests for the purpose of determining the design,

(b) Acceptance tests for the purpose of verifying conformance to design and determining acceptability of product for further operations or for delivery, or

(c) Qualification tests for the purpose of verifying adequacy of design and method of production to yield a product conforming to specified requirements.

Acceptance tests and qualification tests shall be defined for verifications as indicated in subsection 4.3, Table 2. The test of the collector subsystem in conjunction with another subsystem is regarded as a system test and shall be as specified in the System Requirements Specification.

4.1.3 Previous Tests. Maximum use shall be made of test data available from the subsystem research experiments and hardware tests already completed. Where conformance to this specification can be established at less cost by analysis of such data, tests shall not be repeated.

4.2 Specific Test Requirements. Specific required tests are defined herein. Additional tests shall be defined by the contractor in the course of design and development where necessary to properly validate the performance and design integrity of the collector subsystem.

4.2.1 Subsystem Performance Tests. [This paragraph will define tests for evaluation of the collector subsystem as fully assembled in order to assure compatibility before attempting system tests.]

4.2.2 Assembly and Subassembly Performance Tests. [Definition to be completed in Phase 1 to include but not be limited to the following.]

Heliostat (basic performance and response)

Reflective surface (mirror reflectance, "focusing")

Sensor positioning

Field controller (continuity, isolation, performance)

4.2.3 Environmental Tests. [Definition to be completed in Phase 1.]

4.2.4 Materials and Processes Control Tests. [Definition to be completed in Phase 1 to include but not be limited to the following.]

Glass

Coatings

Adhesives

Vapor-deposited metal

Welding

4.2.5 Life Tests and Analyses. One set of each major subassembly shall be subjected to extended life testing as follows. [Methods TBD.]

4.2.5.1 Mean Time Before Failure/Replacement. Sufficient data shall be gathered from the above life tests and also from component suppliers in order to estimate the MTBF and MTBR for the given design configuration.

4.2.6 Engineering Critical Component Qualification Tests. Components for which reliability data are not available shall be subjected to sufficient qualification testing to estimate their impact on overall device MTBF.

4.3 Verification of Conformance. Verification that the requirements of sections 3 and 5 of this specification are fulfilled shall be performed by the contractor by the methods specified in Table 2. The methods of verification are defined as follows:

(a) Inspection - examination and measurement of product.

(b) Analysis - examination of the design and associated data, which may include relevant test information.

(c) Similarity - demonstration or acceptable evidence of the performance of sufficiently similar product to permit conformance to be inferred.

(d) Test - functional operation or exposure under specified conditions to evaluate product performance.

(e) Demonstration - exhibition of the product or service in its intended modes and conditions.

4.3.1 Hardware Acceptance for POCE. The contractor shall provide a system by which conformance of hardware to the design will be verified prior to initiation of subsystem level tests. This verification of conformance shall include proof-by-assembly and the examination of records as elements of inspection. A record shall be made of each inspection or test performed and of the verification. In addition, evidence shall be maintained of satisfactory accomplishment of inspections and tests required by codes and standards that apply to the collector subsystem.

Table 2

COLLECTOR SUBSYSTEM REQUIREMENT VERIFICATION MATRIX

Verification Methods	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test (including life tests and critical component qualification)
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.1 Collector Subsystem Definition	2,4	A	
3.1.1 Collector Subsystem Diagram	N/A	N/A	
3.1.2 Interface Definition	N/A	N/A	
3.1.2.1 Physical Site	2	N/A	
3.1.2.2 Receiver Subsystem	2,4	A	

Table 2

COLLECTOR SUBSYSTEM REQUIREMENT
VERIFICATION MATRIX (Continued)

Verification

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

Test Categories

A. Acceptance Test
B. Qualification Test (including life tests and critical component qualification)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.1.2.3 Master Control	2,4	A	
3.1.2.4 Electrical Power Generation Subsystem	1,4	A	
3.1.2.5 Internal Interfaces	N/A	N/A	
3.2 Characteristics	N/A	N/A	
3.2.1 Performance	4	A	
3.2.2 Physical Characteristics	1,2	N/A	
3.2.3 Reliability	2	N/A	
3.2.4 Maintainability	2	N/A	
3.2.5 Availability	2	N/A	
3.2.6 Environmental Conditions	N/A	N/A	

Table 2

COLLECTOR SUBSYSTEM REQUIREMENT VERIFICATION MATRIX (Continued)

Verification		Test Categories	
1.	Inspection	A.	Acceptance Test
2.	Analysis	B.	Qualification Test (including life tests and critical component qualification)
3.	Similarity		
4.	Test		
5.	Demonstration		

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.2.6.1 General	2	N/A	
3.2.6.2 Transportation and Handling	N/A	N/A	
3.2.6.2.1 Temperature	N/A	N/A	
3.2.6.2.2 Humidity	N/A	N/A	
3.2.6.2.3 Vibration	2,4	A	
3.2.6.2.4 Shock	N/A	N/A	
3.2.6.2.5 Other Conditions	N/A	N/A	
3.2.6.3 Operational	2,3,4	B	Make maximum use of data from tests of SRE hardware
3.2.6.3.1 Temperature	N/A	N/A	Apply in 3.2.6.3
3.2.6.3.2 Humidity	N/A	N/A	Apply in 3.2.6.3

Table 2

COLLECTOR SUBSYSTEM REQUIREMENT VERIFICATION MATRIX (Continued)

Verification

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

Test Categories

A. Acceptance Test
B. Qualification Test (including life tests and critical component qualification)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.2.6.3.3 Wind	2,3		Make maximum use of data from tests of SRE hardware
3.2.6.3.4 Wind-Induced Vibration	2,4	B	
3.2.6.3.5 Sand and Dust	1,2,3	N/A	
3.2.6.3.6 Rain, Hail, and Snow	2	N/A	
3.2.6.3.7 Lightning	2	N/A	
3.2.6.3.8 Earthquake	2	N/A	
3.2.7 Transportability	2,4	B	
3.3 Design and Construction	1,2	N/A	
3.3.1 Materials, Processes, and Parts	1,2	N/A	Test requirements as in subordinate specifications

Table 2

COLLECTOR SUBSYSTEM REQUIREMENT VERIFICATION MATRIX (Continued)

Verification	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test (including life tests and critical component qualification)
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.3.2 Electrical Transients	1, 2, 4		
3.3.3 Electromagnetic Radiation	2, 4	B	
3.3.4 Nameplates and Product Marking	1		
3.3.5 Workmanship	1		
3.3.6 Interchangeability	2		
3.3.7 Safety	1, 2		
3.3.8 Human Engineering	1, 2		
3.4 Documentation	N/A	N/A	
3.4.1 Characteristics and Performance	1, 2	N/A	

Table 2

COLLECTOR SUBSYSTEM REQUIREMENT VERIFICATION MATRIX (Continued)

Verification	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test (including life tests and critical component qualification)
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.4.2 Instructions	1,2	N/A	
3.4.3 Construction	1,2	N/A	
3.5 Logistics	2	N/A	
3.5.1 Maintenance	2	N/A	
3.5.2 Supply	2	N/A	
3.5.3 Facilities and Facility Equipment	TBD	TBD	To be determined after site selection
3.6 Training	N/A	N/A	
3.6.1 Personnel	2	N/A	
3.6.1 Training	2	N/A	
3.7 Precedence	2	N/A	

Table 2

COLLECTOR SUBSYSTEM REQUIREMENT
VERIFICATION MATRIX (Continued)

Verification

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

Test Categories

A. Acceptance Test
B. Qualification Test (including life tests and critical component qualification)

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
4.2.5 Life Tests and Analyses	4	B	
4.2.5.1 Mean Time Before Failure/Replacement	2	N/A	
5.1 General	1,2	N/A	
5.2 Preservation and Packaging	1,2	N/A	

5.0 PREPARATION FOR DELIVERY

5.1 General. Packaging for collector subsystem components shall provide adequate protection during shipment by common carrier from supplier to the first receiving activity for immediate use or temporary storage.

5.2 Preservation and Packaging. Subsystem components that may be harmed when exposed to the normal transportation and handling environments (paragraph 3.2.6) shall be protected by inert environments, barrier materials, or equivalent techniques.

5.3 Packing. Shipping containers and their cushioning devices shall ensure protection of collector subsystem components when exposed to the shock and vibrations loads defined in paragraph 3.2.6. Containers shall meet, as a minimum, the requirements in the following regulations as applicable to the mode of transportation utilized.

(a) National Motor Freight Classification (Highway Transportation)

(b) Uniform Freight Classification (Railroad Transportation)

(c) CAB Tariff 96 and 169 (Air Transportation)

(d) R. M. Graziano's Tariff 29 (For Dangerous Articles Surface)

(e) CAB Tariff 82 (For Dangerous Articles Air)

5.4 Handling and Transportability. Containers with gross weights exceeding 60 pounds shall have skids and other provisions for handling by standard materials handling equipment. When feasible, container sizes and configurations shall be compatible with efficient utilization of transport vehicles.

5.5 Marking. Unless otherwise specified, container marking shall be standard commercial practice.

APPENDIX 2 POCE Receiver Subsystem

RECEIVER SUBSYSTEM
REQUIREMENTS SPECIFICATION

APRIL 1975

VOLUME 2
PART 1
APPENDIX 2

CONTENTS

CONTENTS (Continued)

1.0 SCOPE

This specification establishes the performance, design, and test requirements for the POCE receiver subsystem.

2.0 APPLICABLE DOCUMENTS

The equipment, materials, design, and construction of the receiver subsystem shall comply with all Federal, state, local, and user standards, regulations, codes, laws, and ordinances which are currently applicable for the selected site and using utility. These shall include but not be limited to the government and non-government documents itemized below. If there is an overlap in or conflict between the requirements of these documents and the applicable Federal, state, county, or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent shall take precedence.

The following documents of the issue in effect on the date of request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 <u>Government Documents</u>

2.1.1 <u>Specifications</u>

Regulations of the Occupational Safety and Health Administration (OSHA)

Regulations of the California Occupational Safety and Health Administration CAL/OSH - if required

2.1.2 <u>Other Publications</u>

National Motor Freight Classification 100B - Classes and Rules Apply on Motor Freight Traffic

Uniform Freight Classification 11 - Railroad Traffic Ratings Rules and Regulations

CAB Tariff 96 - Official Air Transport Rules Tariff

CAB Tariff 169 - Official Air Transport Local Commodity Tariff

R. H. Graziano's Tariff 29 - Hazardous Materials Regulations of the Department of Transportation

CAB Tariff 82 - Official Air Transport Restricted Articles Tariff

2.2 Non-Government Documents

2.2.1 Standards

American National Standards Institute, B31.1 Power Piping

Manual of Steel Construction, 7th Edition, 1974, American Institute of Steel Construction

Building Code Requirements for Reinforced Concrete, ACI 318-71, American Concrete Institute

Uniform Building Code - 1973 Edition, Vol 1 by International Conference of Building Officals

American Society of Mechanical Engineers, Boiler and Pressure Vessel Code:

Section 1, Rules for Construction of Power Boilers

Section 2, Material Specifications

Section 5, Nondestructive Examination

Section 8, Unfired Pressure Vessels

Section 9, Welding and Brazing Qualifications

National Electric Code, NFPA 70-1971 (ANSI C1-1971)

3.0 REQUIREMENTS

3.1 Receiver Subsystem Definition. The receiver for the POCE shall provide a means of transferring redirected radiant solar flux energy from an array of heliostats into steam (1) for generating electrical power with a conventional turbine-generator, (2) for converting to stored thermal energy in the thermal storage subsystem, and (3) for generating electrical power with a conventional turbine-generator using surplus thermal energy recovered from stored thermal energy in the thermal storage subsystem. The water/steam shall be capable of operating in a standard steam cycle. The receiver subsystem shall consist of:

(a) The receiver unit (absorber (boiler/superheater), header, drums, valves, controls and instrumentation per ASME code, and support structure),

(b) The riser piping from the ground to the receiver,

(c) The downcomer piping from the receiver to the ground,

(d) The receiver pump(s) and control devices necessary to control the fluid flow, temperature, and pressure to the receiver unit and within the receiver unit,

(e) The required insulation and thermal protection to control thermal energy losses and provide personnel protection,

(f) The tower structure necessary to elevate and support the receiver.

The POCE receiver subsystem shall have the capability of operating at a capacity of 34.3 MWth net at 2 P.M. local sun time on a clear day at winter solstice and 42.3 MWth at noon local sun time on a clear day at summer solstice. The receiver shall be capable of withstanding a peak flux of 0.3 MW/m^2 without degradation in structural integrity or performance as specified herein. The receiver subsystem design shall be capable of scaling to a larger commercial central receiver power generating system ranging in size from 100 MWe to 300 MWe. The receiver shall be controlled by the master control within the pilot plant; however, the receiver shall also be capable of monitoring its own operation and shall be capable of adjusting its own operation for time variant insolation in order to supply rated steam conditions to the turbine-generator, and to preclude failures that would cause extensive equipment damage or be hazardous to personnel.

3.1.1 <u>Receiver Subsystem Diagram</u>. Figure 1 shows the receiver and its interfaces with the other subsystems and receiver elements. Figure 2 and 3 present the functional elements of the receiver and the receiver unit, respectively, and define their internal interfaces.

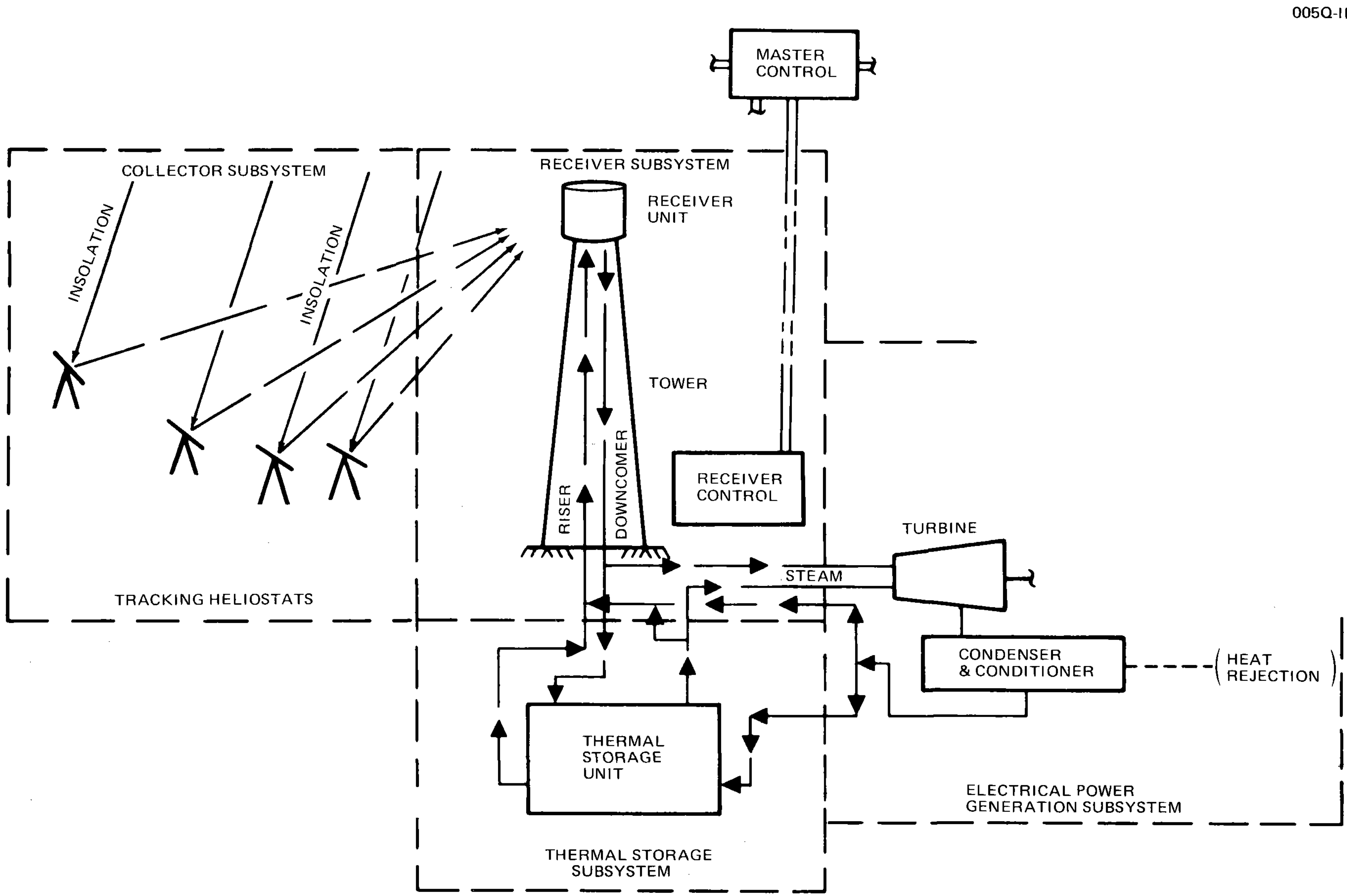

Figure 1. Receiver Subsystem Major Interfaces

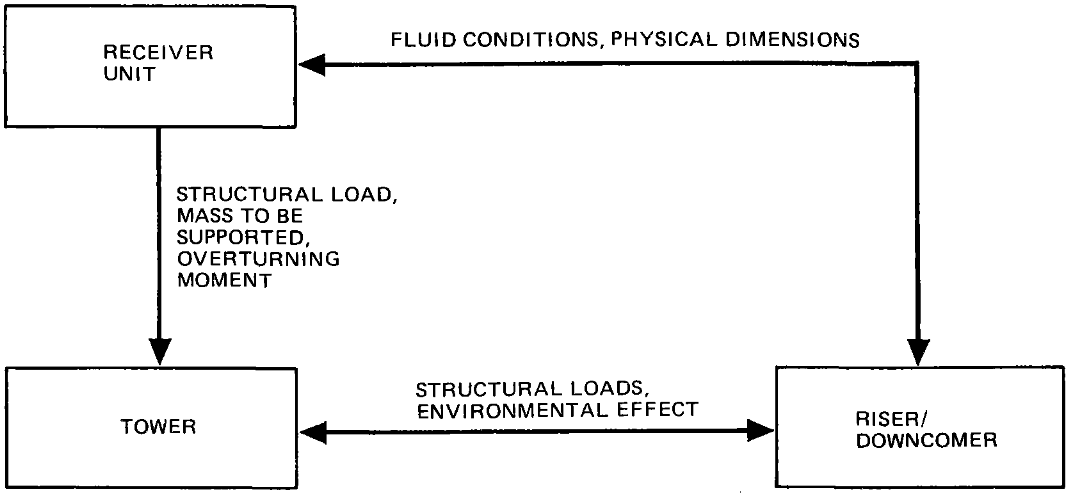

Figure 2. Interfaces Within Receiver Subsystem

3.1.2 Interface Definition. The physical and functional interfaces between the receiver subsystem and other subsystems are as follows.

3.1.2.1 Receiver/Collector Subsystem. The receiver shall have dimensions which will permit it to intercept 99 percent of a maximum sized image of 6.6 m by 17 m (21.6 ft by 56 ft) from a heliostat. The receiver shall be designed to generate steam for the specified steam cycle when exposed to a programmable radiant energy flux from a 360° array of heliostats of the collector subsystem. The receiver shall have a minimum absorptivity of 0.90.

3.1.2.2 Receiver/Thermal Storage Subsystem. Piping, connections, and mounting fixtures shall be provided at the tower base to match those of the thermal storage subsystem.

(a) Superheated steam header/steam downcomer. The receiver subsystem shall be designed to provide for the physical connection with, and delivery of steam to the thermal storage subsystem at a maximum flowrate of 17.3 kg/sec (38 lb/sec), static pressure of 10.4 MN/m^2 (1,500 psia), and temperature of 475 degrees C (890 degrees F).

(b) Feedwater return. The receiver subsystem shall be designed to provide the physical connection with, and receipt of water from the thermal storage subsystem to the feedwater riser at a static pressure of at least 11.4 MN/m^2 (1,650 psia), maximum flowrate of 17.3 kg/sec (38 lb/sec) and at a temperature of 205 degrees C (400 degrees F).

3.1.2.3 Receiver/Electrical Power Generation Subsystem. Piping, connections, and mounting fixtures shall be provided to match those of the electrical power generation subsystem.

(a) Superheated steam header/turbine high pressure line. The receiver subsystem shall be designed to connect to the superheated

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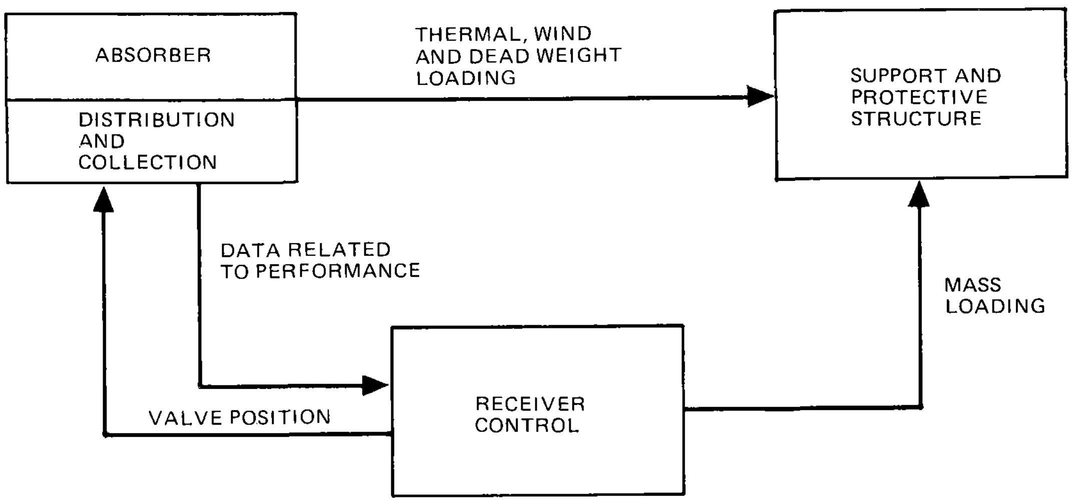

Figure 3. Interfaces Within Receiver Unit

steam header/turbine high-pressure line and deliver steam at a maximum flowrate of 17.3 kg/sec (18 lb/sec), statis pressure 10.4 MN/m^2 (1,500 psia), and a temperature of 475 degrees C (890 degrees F).

(b) Feedwater header/water riser. The receiver subsystem shall be designed to receive feedwater return from the electric power generation subsystem at a static pressure of 11.4 MN/m^2 (1,650 psia), a maximum flowrate of 17.3 kg/sec (38 lb/sec), and a temperature range of 205 to 260 degrees C (400 to 500 degrees F).

3.1.2.4 Receiver/Master Control. The receiver controls shall be responsive to standard control signals (per power industry practice) from the pilot plant master control. The receiver internal controls shall also employ standard control signals and shall adhere to standard power industry practice.

3.1.2.5 Receiver Major Component Interfaces. Principal interfaces within the receiver subsystem include:

(a) Receiver Unit/Riser/Downcomer. The receiver unit shall be physically connected to the riser/downcomer through the distribution and collection subassembly. The water header shall be designed to receive water from the riser at a static pressure of at least 11.4 MN/m^2 (1,650 psia). The steam header shall be designed to connect to the downcomer which will carry the rated capacity at a maximum flow velocity of 7.2 m/sec (23 fps), and a maximum pressure of 10.4 MN/m^2 (1,500 pisa).

(b) Receiver Unit/Tower. The receiver unit shall be rigidly attached through its support structure to the tower top providing for the absorption of all static, environmental, and self-induced loads.

(c) Riser/Downcomer/Tower. The riser/downcomer shall be rigidly attached to the tower at the top and through intermediate supports providing for absorption of all environmental and thermally induced loads.

3.1.3 Major Components List. The receiver subsystem is comprised of three major assemblies; the receiver unit, the riser/downcomer, and the tower.

3.1.3.1 Receiver Unit. The receiver unit shall be comprised of the following major components.

(a) Absorber

Absorber tubes and surface coating

Orifices

Backup structure

(b) Distribution and Collection

Inlet and exit manifolds (headers)

Pressure relief check and shutoff valves

Main supply lines

Throttling flow control valve

(c) Receiver Support Structure

Main structural members

Tower interface

Support members for functional components

(d) Receiver Controls

All instrumentation (temperature, pressure flowrate)

Signal conversion equipment

Analog-to-digital converters

Digital-to-analog converters

Central processing unit

Software

3.1.3.2 Riser/Downcomer. The water riser and steam downcomer shall be comprised of the following major components:

Piping

Structural supports to tower

Insulation

3.1.3.3 Tower. The tower shall be comprised of the following major components:

Structure

Elevators

Heat shield

Crane

3.2 Characteristics

3.2.1 Performance. The POCE receiver shall have a steam generating capacity sufficient to produce up to 42.3 MWth. It shall have the capability of absorbing a peak heat flux of 0.3 MW/m^2 (0.18 Btu/in^2-sec). The receiver design shall provide for maximum technology transferability to a 300 MWth to 900 MWth receiver for a commercial power plant.

Specific characteristics of the receiver subsystem shall be as follows:

(a) Maximum skin temperature or average wall temperature (whichever governs) of the receiver unit shall be consistent with practice as specified in Section I of the ASME Boiler and Pressure Vessel Code. The life of the receiver shall be 10,000 cycles when calculated in accordance with ASME Boiler and Pressure Vessel Code (Section I) practice.

(b) The pressure differential between the superheat header and the feedwater header shall be between 0.55 and 0.83 MN/m^2 (80 to 120 psia).

(c) The effective solar absorptance of the absorber surface shall be at least 0.9 at operating temperature.

(d) The total emittance of the receiver surface shall be as small as practical consistent with maintaining the specified solar absorptance.

(e) The controls (including instrumentation) shall respond to transient and emergency conditions to provide for self-monitoring of receiver performance and to adjust flow in individual receiver parts to obtain proper performance and to avoid adverse effects on receiver components. Additionally, the controls shall monitor fluid conditions within the receiver such that the master control can be continuously apprised of the receiver conditions and performance characteristics. All instrumentation and controls wiring shall be installed per NEMA standards.

(f) Startup shall be accomplished following a signal of anticipated sunrise from the master control. Following this signal, the receiver controls shall perform sufficient checks to ensure that it can operate in a manner consistent with safety regulations as specified in (TBD). Upon sunrise the receiver shall regulate its own operation to ensure peak efficiency during all modes of operation.

(g) The receiver shall be capable of being operated in a degraded mode (e.g., with an inoperative section or module) in a useful manner such that it can be used to charge the thermal storage subsystem if the amount and/or condition of the steam produced is not compatible with the power generation subsystem.

(h) The designed life expectancy of the receiver and its component parts shall be 30 years and/or 10,000 cycles provided maintenance is provided as specified in paragraph 3.2.4.

3.2.2 Physical Characteristics. The receiver unit shall have a maximum mass (dry) less than 100,000 kg (200,000 lb). The maximum wet mass shall be 103,000 kg (225,000 lb). The receiver unit shall have a maximum vertical dimension less than 25 m (76 ft) and a maximum projected horizontal dimension less than 9 m (28 ft). The receiver unit shall be of such a design that it can be readily erected on and removed from the tower in pieces. The maximum mass of the pieces shall be (TBD). The receiver unit shall be designed to provide reasonable access for maintenance from permanent or temporary work platforms.

The riser and downcomer pipelines shall be carried on the outside of the tower structure from the receiver to interfaces with the electrical power generation and the thermal storage subsystems. The vertical riser and downcomer shall be mounted on the outer surface of the tower to facilitate installation, maintenance, and repair. They shall be mounted in continuous vertical runs down the tower with all expansion being accommodated in single bends at the base of the tower. The vertical sections shall be supported by standard counterweighted pipe hangers which permit free expansion.

The downcomer shall be constructed of ASTM Standard A335, P11 pipe with an internal diameter of approximately 0.31 m (12 in). The riser shall be constructed of ASTM Standard A106, Grade B scheduled pipe with an inside diameter of approximately 0.091 m (3.6 in). All joints shall be of a welded construction. The pipes shall be insulated with calcium silicate insulation conforming to ASTM Standard C533. Aluminum jacketing shall be employed on any areas exposed to the weather.

Redundant boost pumps shall be located upstream of the riser inlet. Each pump shall be capable of increasing the feedwater pressure from 2.85 MN/m^2 (410 psia) to 12.6 MN/m^2 (1,820 psia) at a maximum flowrate of 14 kg/sec (110,000 lb/hr) and a peak power consumption of 184 kW (248 HP).

The receiver support structure shall be designed to carry the receiver unit at the top of the 95 m (312 ft) high tower structure plus approximately 44,000 kg (20,000 lb) of downcomer and riser pipelines.

The tower structure shall be a tapering reinforced concrete cylinder, the inner diameter ranging from 20 ft at the base to 12 ft at the top; the shell thickness from base to top shall vary from 3 to 1 ft.

The tower structure shall be designed to withstand lateral forces caused by seismic activities as specified in paragraph 3.2.6 without failing. Steel components shall be designed such that yielding will not occur and concrete shall be designed to withstand failure in shear or compression. Dynamically, the tower shall be analyzed for resonance characteristics, pendulum effects, vibration and whip action under seismic conditions.

Two combined freight and passenger elevators shall be provided for operation and maintenance purposes. One elevator shall operate inside the tower structure for access purposes within the inner core of the receiver. The other elevator shall operate along the outside of the tower shell.

Cantilevered and trussed supports from the tower shall carry the rails and elevator cab, and shall be designed to withstand winds and seismic lateral loading as specified in paragraph 3.2.6. A caged safety ladder for emergency purposes shall be installed in the interior of the tower structure for use by personnel when the elevators are inoperative.

The exterior elevator is intended to be used to service the exterior portion of the receiver. Hinged or foldout platform sections shall extend outward at the bottom of the receiver to interface with the top elevator station.

Suitable embedments shall be installed in the upper 50 to 70 ft length of the tower for the purpose of supporting an annular heat shield to protect the concrete tower from errant heliostat reflections. This heat shield shall also protect the exterior elevator components and personnel.

A crane consisting of mast and jib shall be mounted to the top of the tower for erecting the receiver core section. The crane shall be designed to be remounted on the top of the erected receiver core following installation in order to install the remaining receiver components. The jib portion of the crane shall extend beyond the completed receiver space envelope so that the parts can be hoisted from grade to the top of the receiver. The crane shall be designed such that by simple dismantling or folding, it can be stored within the receiver confines during operation of the pilot plant to protect it during heliostat misalignments. The crane shall be capable of reactivation as required for maintenance of the receiver.

3.2.3 Reliability. High reliability shall be achieved in the receiver subsystem design by providing adequate operating margins, maximizing the use of proven standard parts, and using conservative design practices such that the reliability performance shall not degrade the capability to achieve the availability specified in paragraph 3.2.5 when operated in the environments specified in paragraph 3.2.6.

Single-point failures that disable the automatic mode of system operation shall be eliminated wherever practical. In cases where it is impossible to eliminate such failure modes, suitable devices shall be used to detect and warn of the occurrence of a failure. As a minimum, redundancies for the heat transfer fluid supply pumps shall be incorporated in the design.

3.2.4 Maintainability. The receiver subsystem shall be designed such that required service can be accomplished by personnel of normal skills, with a minimum of nonstandard tools or special equipment. The receiver subsystem shall be designed to provide malfunction indication and fault isolation information data required by the master control concerning critical components (TBD). Critical components are those components that, because of failure risk, downtime or effect on the overall POCE performance, materially affect the capability to achieve the system availability requirements. Items which do not have a redundant mode of operation shall incorporate maximum capability for on-line repair or replacement. These items might include, for example, temperature and pressure sensors and actuators for valves.

The receiver subsystem shall be designed such that potential maintenance points can be easily reached, components such as electronic modules readily replaced, and elements subject to wear or damage easily serviced or replaced. Preventive maintenance shall be such as to limit downtime to 1 day per month.

3.2.5 Availability. The receiver subsystem shall operate in accordance with the paragraph 3.2.1 performance requirements 94.6 percent of its scheduled operating time based on reliability and maintainability exclusive of insolation conditions. Determinations of availability shall use as a time reference a period of one year.

3.2.6 Environmental Conditions

3.2.6.1 General. The conditions described in the following paragraphs are representative of the transportation and operating site environments to be encountered by the receiver subsystem. For design purposes safety margins shall be used commensurate with availability and performance requirements to ensure operation in accordance with paragraph 3.2.1 during or after exposure to these conditions.

3.2.6.2 Transportation and Handling. The following conditions occurring separately or in combination may be encountered by packaged equipment during handling and transportation.

3.2.6.2.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.6.2.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.6.2.3 Transportation Vibration and Shock. Vibration and shock as encountered during transport. Conditions are as follows:

VIBRATION

Transportation Mode	Continuous Excitations (Steady-State) in g's	Discrete Impulse (Transient) in g's	Predominant Frequency Range
Highway	0.06	1.5	2 to 200 Hz
Rail	0.05	1.5	2 to 200 Hz
Air (Jet Aircraft)	0.05	1.5	2 to 500 Hz

SHOCK (g's)
(Normal Load Limits)

Transport Media	Longitudinal	Lateral	Vertical	Average Pulse Time msec
Air	2.0	1.5	2.0	11-40
Highway	2.0	1.5	3.0	11-40
Rail (Rolling)(1)	3.0	0.75	3.0	11-40
Cushion Car (Humping)	3.0	2.0	3.0	11-40

(1) Shock loads are for rail cars equipped with standard draft gears.

All critical (frangible) components of the collector subsystem shall be designed or packaged such that the conditions described above do not induce a dynamic environmental condition which exceeds the structural capability of the component. These conditions reflect careful handling and firmly constrained (tied down) transporting via common carrier.

All components shall be designed to withstand handling/hoisting inertial loads up to 2 g's considering number, location, and type of hoisting points.

3.2.6.2.4 Handling Shock. Handling shocks may result from drops of packaged equipment. Corresponding acceleration peaks may be of the order of 7 g's vertical and 4 g's horizontal with a (TBD) wave profile and a duration of 10 to 50 milliseconds.

3.2.6.2.5 Other Conditions. The equipment may encounter other conditions during transportation and handling including wind, rain, snow, ice, hail, and blowing sand and dust. These are not expected to exceed the operational conditions of paragraph 3.2.6.3.

3.2.6.3 Operational. The following conditions occurring separately or in combination may be encountered by the receiver during the pilot plant 30-year operational life. Unless specified otherwise the receiver shall be designed to perform in accordance with paragraph 3.2.1 during and after exposure to these conditions.

3.2.6.3.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.6.3.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.6.3.3 Wind. Sustained surface winds up to 8.9 m/sec (20 mph) for a period of (TBD) hours with gust RMS velocities up to 11.6 m/sec (25.9 mph). With degraded performance, the subsystem shall continue to operate in sustained surface winds up to 13.8 m/sec (30.9 mph) for (TBD) hours with gust RMS velocities up to 17.9 m/sec (40 mph). While nonoperational, the receiver subsystem shall not be damaged by surface winds of 35.7 m/sec (79.9 mph) for periods up to (TBD) hours with gust RMS velocities to 46.4 m/sec (103.8 mph).

The receiver unit shall operate without degradation in efficiency in steady wind with a profile developed using a 1/7 power law with a base velocity of 8.9 m/sec (20 mph) at 10 m (32.8 ft) height (see Figure 4). In addition, a gust factor of 1.3 shall be applied to this profile to determine unsteady wind forces. The receiver unit shall survive, without permanent deformation or structural degradation, winds with a profile as described above using a base velocity of 35.7 m/sec (79.9 mph) at 10 m (32.8 ft) height. A gust factor of 1.3 shall be applied to this profile to determine unsteady wind forces.

These are derived from 35.7 m/sec base, 50-year fastest mile (Reference ASCE Paper 3269, Vol. 126). Maximum steady winds with gusts during operation are to be considered throughout a complete daylight operational period. Practices recommended in the ASCE Paper 3269, Vol. 126 and the Uniform Building Code, 1973, Vol. 1 shall be employed in designing the receiver subsystem for winds.

3.2.6.3.4 Vibration (Wind-Induced). The natural wind environment to which the receiver subsystem will be periodically exposed induces vibratory response. Based on the wind environments specified in paragraph 3.2.6.3.3, the attendant fluctuating loads on the exposed surfaces are as follows:

	Frequence of Resonances	Fatigue Equivalent Wind Velocity	Modal Force	Duration (at resonance)
Elevated Receiver	0 to 40 Hz	14.9 m/sec (48.9 ft/sec)	530 kg (1,165 lb)	2.1×10^7 sec
Total Tower	0 to 40 Hz	14.9 m/sec (48.9 ft/sec)	4,727 kg (10,400 lb)	2.1×10^7 sec

To preclude fatigue due to these fluctuating loads, the structure shall be designed such that stresses are below the endurance limits for this loading.

3.2.6.3.5 Sand and Dust. The subsystem shall not evidence operational degradation or component destruction following exposure to sand and dust storms.

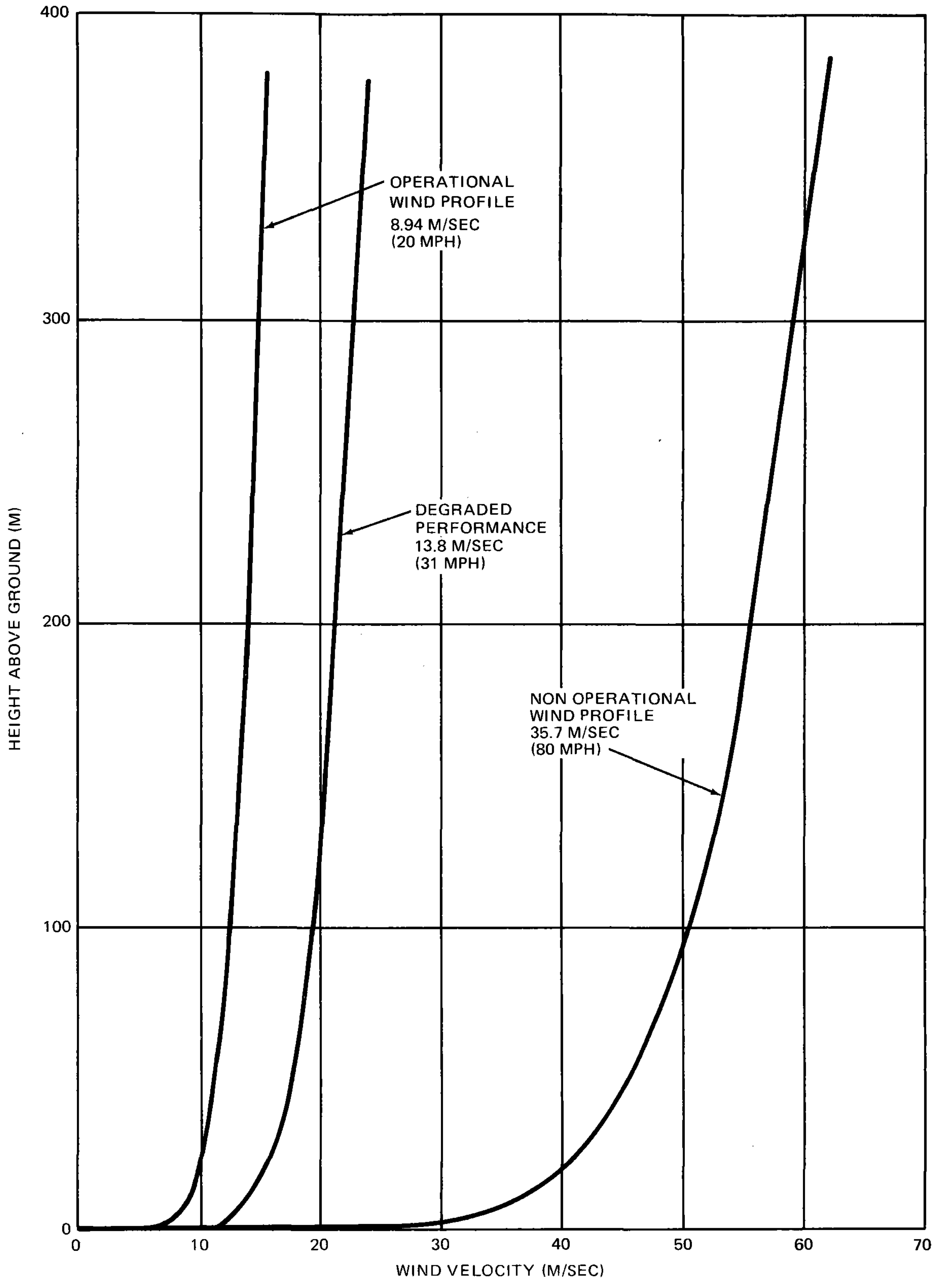

Figure 4. Wind Profiles for Receiver Subsystem

The design shall withstand dust fluxes of 10^{-4} g/cm^2-sec at velocities up to (TBD) meters/second. Dust is defined to be those particles up to 100 μm in diameter with the mean diameter being 40 to 50 μm.

Sand is defined as particles greater than 100 μm in diameter. Desert sand flux declines approximately exponentially with height above the surface. For the surface roughness expected at the POCE site, 90 percent of the sand flux will be within 25 cm (10 in.) of the surface. The design shall withstand a sand flux which averages 0.3 g/cm^2-sec within that region at velocities up to (TBD) meters/second.

The frequency of storm occurrence and duration to be considered will depend on the site selected. For example, in the Southwestern desert area a major storm frequency of four or less per year with a maximum duration of 36 hours is to be assumed. Nine minor storms per year with maximum durations of 6 hours are to be assumed.

The effect of dust devils shall also be considered in the design. The maximum core diameter and tangential velocities to be considered are 70 m (230 ft) and 30 m/sec (98 ft/sec), respectively. The maximum vertical velocity to be considered is 15 m/sec (49 ft/sec).

Subsystem components shall be protected from the electrostatic charging and discharging associated with sand and dust storms.

3.2.6.3.6 Rain, Hail, and Snow. Storms of the following types and intensities:

Rain: Average storm intensity of (TBD) cm/hour (TBD in/hr) for (TBD) hours with peak periods of (TBD) cm/hour (TBD in/hr) lasting (TBD) minutes. Three to five storms per year.

Hail: Mean particle diameter of 5 to 10 mm (0.20 to 0.39 in.), extreme maximum diameter of 25 mm (1 in.). Fall velocity of 20 m/sec (65.6 ft/sec). Hail stone compressive strenght of 1.03 MN/m^2 (150 psi) for 25 mm stone; 5.07 MN/m^2 (735 psi) for stones less than 10 mm in diameter. Storm intensity of (TBD) particles per square meter per minute lasting 10 to 20 minutes. Frequency of occurrence -- one in 5 to 6 years.

Snow: (TBD)

3.2.6.3.7 Lightning. The subsystem shall be designed to withstand a lightning threat that has a current pulse of 140,000 amperes with a 1.5 microsecond rise time decaying to 50 percent in 40 microseconds. A continuing current of 200 to 400 amperes will follow the main stroke and last for 160 to 300 milliseconds. Up to 10 restrokes can occur with 30,000 to 70,000 amperes peak current each. Total charge transfer of the primary stroke and the restrokes events can reach 200 coulombs.

The receiver subsystem shall be protected by a 90° cone of protection per NFPA 78. Elements used in this design will also provide a part of the lightning protection for the collector subsystem.

3.2.6.3.8 Earthquake. The receiver subsystem shall be designed to withstand, without structural damage or yielding, the earthquake environment described in Table 1 and Figure 5. The environment is given in terms of response spectra and ground motion histories for soft rock or firm sediment. If the receiver subsystem is located on competent rock, the above environment may be reduced by 33 percent. If the receiver subsystem is located on soft sediment, the above environments shall be increased by 50 percent. In addition, the receiver subsystem shall withstand without catastrophic failure, the earthquake environment described above but increased by 100 percent.

The response spectra or ground motion histories shall be used as input to the analytical model of the soil and assembly in both vertical and horizontal directions to assess earthquake-induced loads.

3.2.7 Transportability. Receiver subsystem components shall be designed for transportability within applicable Federal and state regulations by highway and railroad carriers utilizing standard transport vehicles and materials handling equipment. The components, in their packaged condition, shall be capable of withstanding the climatic conditions and shock and vibration environments defined in paragraph 3.2.6.2. Whenever feasible, components shall be segmented and packaged to sizes that are transportable under normal commercial transportation limitations (see (a) below). Subsystem components that exceed normal transportation limits (see (b) below) shall be transportable with the use of special routes, clearances, and permits.

Table 1

EARTHQUAKE HORIZONTAL GROUND MOTION HISTORIES

Location	Year	Component	Scale Factor
El Centro	1940	NS	1.0
El Centro	1934	EW	1.4
Olympia	1949	N10W	1.4
Taft	1952	S69E	1.7

Each ground motion history is to be multiplied by the indicated scale factor.

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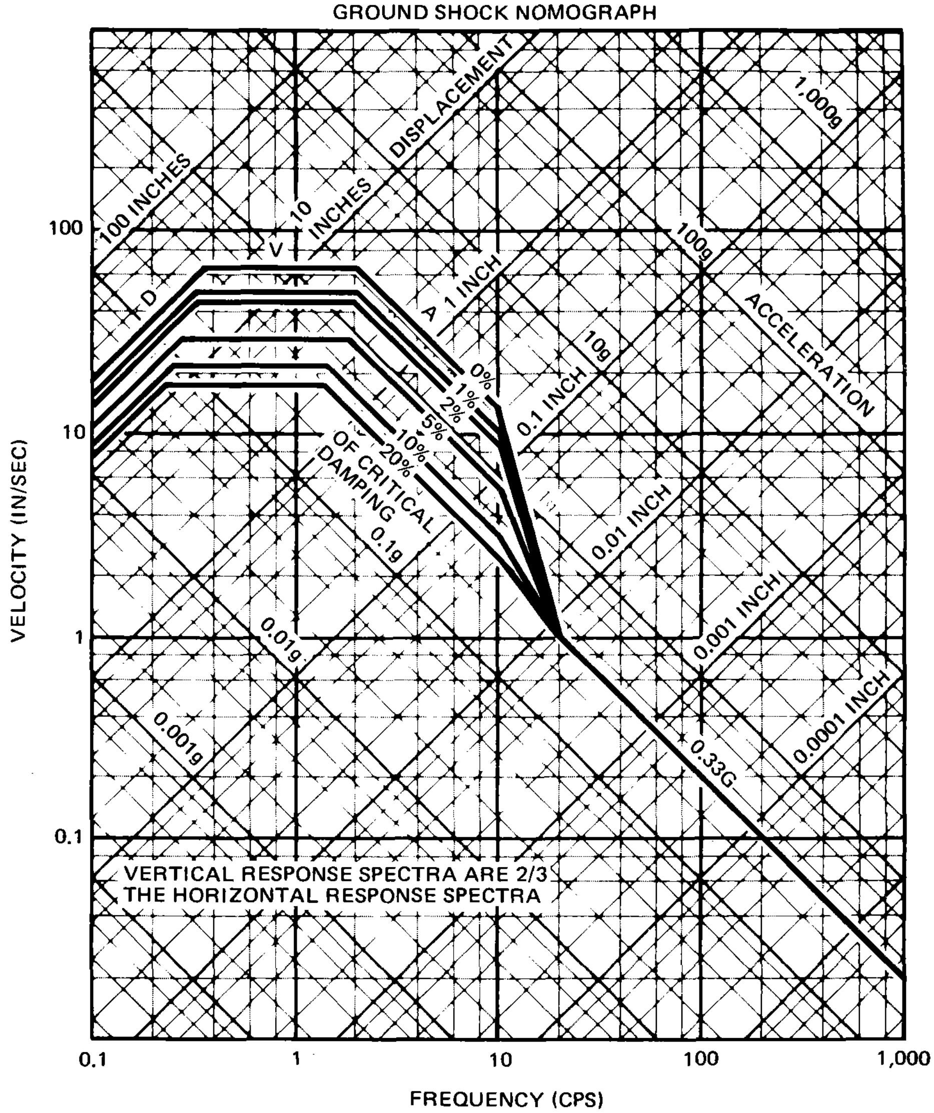

Figure 5. Earthquake Horizontal Response Spectra

(a) Transportability Limits for Normal Conditions (Permits Not Required)

	Truck	Rail
Height:	13 ft 6 in above road	16 ft 0 in
Width:	8 ft 0 in	10 ft 6 in
Length:	55 ft 0 in - Eastern States 60 ft 0 in - Western States	60 ft 6 in
Gross Wt:	73,280 lb; 18,000 lb/axle	200,000 lb

(b) Transportability Limits for Special Conditions

	Truck	Rail
Height:	14 ft 6 in above road	16 ft 0 in above rail
Width:	12 ft 0 in	12 ft 0 in
Length:	70 ft 0 in	80 ft 6 in
Gross Wt:	100,000 lb with sufficient axles to distribute weight over highway not to exceed 18,000 lb/axle.	400,000 lb

3.3 Design and Construction. The receiver shall be designed and constructed in accordance with the ASME Boiler and Pressure Vessel Code, Section 1, II, V, and IX. Piping shall be provided as specified in ANSI B31.1. The tower structure and associated facilities shall be designed and constructed in accordance with the best engineering practices. The standards of the American Institute of Steel Construction, American Concrete Institute, and Uniform Building Code shall be employed.

3.3.1 Materials, Processes, and Parts. The receiver unit and piping shall be fabricated from materials as specified in the ASME Boiler and Pressure Vessel Code, Sections I, II and ANSI B31.1. Materials shall be suitable for the service conditions specified in paragraph 3.2.6. Except where otherwise specified, all structural materials and fabricated steel used in items of equipment shall conform to the Standards of the American Institute of Steel Construction, American Concrete Institute, and Uniform Building Code as applicable. Except where essential, the use of exotic or costly materials is to be avoided. All elements of the receiver unit except for absorber tubing shall be constructed from standard and/or commercial parts.

3.3.2 Electrical Transients. The subsystem operation shall not be adversely affected by external or internal power line transients caused by normal switching, fault clearing, or lightning. Switching transients and fault clearing functions will require less than six cycles of the fundamental frequency (100 milliseconds) and shall be limited to 1.7 P.U. voltage (1.7 per unit or 170 percent). Lightning arresters shall be installed which will limit the resultant line voltage to 5 P.U. on a line to ground basis during the time interval of peak current as defined in paragraph 3.2.6.3.6. Components of the subsystem shall be shielded from the lightning threat specified in paragraph 3.2.6.3.6. Shielding shall protect the electrical components from both the bound charge and induced current threats.

3.3.3 Electromagnetic Radiation. The receiver subsystem shall be designed to minimize susceptibility to electromagnetic interference and to minimize the generation of conducted or radiated interference. The design criteria contained in the following Air Force design handbooks shall be used to assure electromagnetic compatibility: Design Handbook on Electromagnetic Compatibility (AFSC DH1-4), Checklist of General Design Criteria (AFSC DH1-X), and Instrumentation Grounding and Noise Minimization Handbook (AFRPL-TR-65-1).

3.3.4 Nameplates and Product Marking. All deliverable items shall be labeled with a permanent nameplate listing, as a minimum, manufacturer name, part number, change letter, serial number, and date of manufacture.

All access doors to replaceable/repairable items shall be labeled to show equipment installed in that area, and any safety precautions or special considerations to be observed during servicing.

3.3.5 Workmanship. The level of workmanship shall conform to practices defined in the codes, standards, and specifications applicable to the selected site and the using utility. Where specific skill levels or certifications are required, current certification status shall be maintained with evidences available for examination. Where skill levels or details of workmanship are not specified, the work shall be accomplished in accordance with the level of quality currently in use in the construction, fabrication, and assembly of commercial power plants. All work shall be finished in a manner such that it presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a generally uniform appearance.

3.3.6 Interchangeability. Major components, circuit cards, and other items with a common function shall be provided with standard tolerances and connector locations to permit interchange for servicing. Components that have similar appearance but different functions shall incorporate protection against inadvertent erroneous installation through the use of such devices as keying, connector size, or attachment geometry.

3.3.7 Safety. The receiver shall be designed to minimize safety hazards to operating and service personnel, the public, and equipment. Electrical components shall be insulated and grounded. Any moving elements shall be shielded to avoid entanglements and safety override controls/interlocks shall be provided for servicing. Insulation shall be provided on all parts or components with elevated temperatures exposed to personnel access required for routine inspections, servicing, repair, and maintenance procedures. All pertinent OSHA rules and regulations shall be observed. The use of toxic materials is to be avoided. The tower structure and associated facilities shall be designed and constructed to assure safe and reasonable access by personnel and the required tools, equipment, parts and materials to perform the necessary inspections, servicing, repair and maintenance procedures.

3.3.8 Human Engineering. All receiver controls and mechanical details shall facilitate manual operation, adjustment and maintenance. MIL-STD-1472, Human Engineering Design Criteria, shall be used as a guide in designing equipment layouts, controls, displays, placards, illumination, access ways, and similar design considerations.

3.4 Documentation

3.4.1 Characteristics and Performance. Equipment functions, normal operating characteristics, limiting conditions, test data, and performance curves, where applicable, shall be provided.

3.4.2 Instructions. Instructions shall cover assembly, installation, alignment, adjustment, checking, lubrication, and maintenance. Operating instructions shall be included for startup, routine and normal operation, regulation and control, shutdown, and emergency conditions. A guide to troubleshooting instruments and controls shall be provided.

3.4.3 Construction. Engineering and assembly drawings shall be provided to show the equipment construction, including assembly and disassembly procedures. Engineering data, wiring diagrams, and parts lists shall be provided.

3.5 Logistics. The elements required to support the receiver subsystem are:

Support and test equipment

Technical publications

Personnel and training

Facilities

Spares, repair parts and consumables

Transportation, handling and packaging

Data file

Field service

The requirements for the elements shall be established as a result of a support requirements analysis to be prepared by the contractor. The results of the analysis shall be documented in accordance with the contract.

3.5.1 Maintenance. Maintenance activities are categorized as follows:

Level 1, On-line maintenance

Level 2, Off-line on-site maintenance

Level 3, Off-line off-site maintenance

Level 1, On-Line Maintenance: The following scheduled and unscheduled maintenance activities shall be identified for the receiver subsystem.

Task	Frequency
Visual inspection	Daily
Remove and replace	(TBD)
Repair in place	(TBD)
Adjust	(TBD)
Clean	(TBD)
Paint	(TBD)

Level 2, Off-Line On-Site Maintenance: The following maintenance activities shall be identified in the maintenance plan. Frequencies shall be (TBD).

Fault verification

Fault isolation to a removable item

Remove and replace a faulty item

Verify acceptable repaired item

Repair designated subtiered items

Servicing

Lubrication

Visual inspection

Level 3, Off-Line Off-Site Maintenance: Level 3 maintenance activities are those to be performed at the equipment supplier's facility. Frequencies and turnaround times shall be (TBD).

Maintenance Plan: A maintenance plan shall be prepared by the contractor which identifies scheduled and unscheduled maintenance requirements. The maintenance plan shall reflect the results of the support requirements analyses and shall specify the following as appropriate.

Use of milti-purpose test equipment

Items to be repaired

Items to be replaced

Maintenance and repair cycles

Use of operational support equipment for maintenance

Level, frequency, and location of maintenance action

Facilities, equipment, and tools

3.5.2 Supply. The selection and positioning of spares, repair parts, and consumables shall be in accordance with the levels of repair determined by the support requirements analysis, and shall use the following criteria:

Protection Level: Items shall be packaged in accordance with the requirements of section 5.0.

Demand Rate: The mean-time-between-maintenance-actions provided by the maintainability analyses shall be the departure point for spares determinations. The quantities and mix shall be such that there is a (TBD) percent probability of a part being available on demand.

Pipeline: Pipeline quantities shall be determined on the basis of system location, demand rate and repair cycle times. Resupply methods, distribution, and location of system stocks shall be determined after site selection.

Procurement and Release for Production: Long-lead-time supply items shall be procured or released early enough to be on-site 30 days prior to initial operation. Other items shall be procured or released lead-time away so as to minimize obsolescence due to design changes, except for those items for which significant cost savings can be achieved through acquisition concurrent with production.

Minimum/Maximum Levels: Minimum and maximum quantities of spares and repair parts to be stocked shall initially be determined by use of predicted failure rates. These levels are to be adjusted as actual usage rates are established.

3.5.3 Facilities and Facility Equipment. To be determined after site selection.

3.6 Personnel and Training

3.6.1 Personnel. The pilot plant is to be installed, checked out, and tested as a proof-of-concept experiment by contractor personnel; then taken over and operated as a commercial power plant by utility personnel. Operation and maintenance personnel requirements shall be satisfied by recruitment from the established utility labor pool. Unique aspects of the receiver subsystem dictate a need for training existing utility people but do not establish a need for new skills or trades. The types and numbers of utility personnel requiring training, along with the unique tasks, are as follows:

Type	No.	Unique Task
TBD	TBD	Receiver component repair and servicing
		Absorber panel removal and replacement
		Sensor removal and replacement
		Control, stop/check, and relief valve removal and replacement
		Receiver control operation and maintenance
		Special maintenance equipment operation
		Safety requirements
		Emergency operations
		Others (TBD)

3.6.2 Training. The contractor shall prepare and conduct a training program for contractor personnel as necessary for performance of the POCE. The contractor shall conduct a training program for utility personnel in accordance with contractual requirements.

3.7 Precedence. The order of precedence of receiver subsystem requirements and characteristics shall be as follows:

(a) Performance (including scalability to commercial power levels)

(b) Safety

(c) Lifetime

(d) Cost

(e) Weight and size

Specific characteristic and requirement precedence shall be established based on system cost effectiveness sensitivity analyses. This specification has precedence over documents referenced herein. The contractor shall notify the procuring activity of each instance of conflicting, or apparently conflicting, requirements within this specification or between this specification and a referenced document.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Tests. All tests shall be performed by the contractor. These tests may be witnessed by ERDA or its representatives or the witnessing may be waived. In either case, substantive evidence of hardware compliance with all test requirements is required.

4.1.2 General Test Requirements. Tests shall be conducted in accordance with a test plan to be prepared by the contractor and approved by ERDA. Specific required tests are identified in subsection 4.2. Tests shall be classified in the test plan as:

(a) Development tests for the purposes of determining the design,

(b) Acceptance tests for the purpose of verifying conformance to design and determining acceptability of product for further operations or for delivery, or

(c) Qualification tests for the purpose of verifying adequacy of design and method of production to yield a product conforming to specified requirements.

Acceptance tests and qualification tests shall be defined for verifications as indicated in subsection 4.3, Table 2. The test of the receiver subsystem in conjunction with another subsystem is regarded as a system test and shall be as specified in the System Requirements Specification.

4.1.3 Previous Tests. Maximum use shall be made of test data available from the subsystem experiments and hardware tests already completed. Where conformance to this specification can be established at less cost by analysis of such data, tests shall not be repeated.

4.2 Specific Test Requirements. Specific required tests are defined herein. Additional tests shall be defined by the contractor in the course of design and development where necessary to properly validate the performance and design integrity of the receiver subsystem.

4.2.1 Subsystem Performance Tests. Performance of the receiver subsystem shall be measured to verify compliance with thermal performance requirements, hydraulic pressure and requirements, and ability of the receiver to maintain its performance under time variant operating conditions. (This portion will be expanded in Phase I to define tests for evaluation of the receiver subsystem as fully assembled in order to assure compatibility before attempting system tests. The following is one category of such subsystem performance tests.)

4.2.1.1 Subsystem Integrity. The integrity of the complete subsystem when installed shall be verified by subjecting it to hydrostatic pressure testing, cold flow, and hot flow checkouts. These checkouts shall be controlled by the receiver control.

4.2.2 Assembly and Subassembly Performance Tests. (Definition to be completed in Phase 1 to include but not be limited to the following.)

4.2.2.1 Absorber Mechanical and Structural Integrity. Mechanical and structural integrity of the absorber shall be verified by subjecting the device to a simulated wind load of 20 m/sec (64 fps) at simulated operating conditions.

4.2.2.2 Receiver Control Performance. Performance of the receiver control shall be verified subsequent to receiver subsystem installation by subjecting the control to functional checkouts using software supplied by the contractor. This software shall be compatible with the receiver control with no hardware changes.

4.2.2.3 Structure Integrity. Structural integrity of the receiver unit support structure shall be verified by inspection as specified in sections (TBD) of the Uniform Building Code and Sections (TBD) of the standards of the American Institute of Steel Construction.

4.2.2.4 Tower Integrity. Structural integrity of the tower shall be verified by inspection as specified in the Uniform Building Code and the standards of The American Institute of Steel Construction.

4.2.2.5 Riser/Downcomer Integrity. The integrity of the riser/downcomer shall be verified by subjecting it to hydrostatic pressure tests at an equivalent pressure in an unheated condition relative to the conditions set forth in paragraph 3.1.2.

4.2.2.6 Absorber Performance. Prior to installation of the absorber, the ability of the absorber design to meet the performance requirements of paragraph 3.2.1 shall have been demonstrated.

4.2.3 Environmental Tests. (Definition to be completed in Phase I.)

4.2.4 Materials and Processes Control Tests. (Definition to be completed in Phase I.)

4.2.5 Life Tests and Analysis. One set of each major subassembly shall be subjected to accelerated or extended life testing and/or analysis where data from component suppliers are not sufficient to estimate MTBF and MTBR for the given design configuration. This shall include durability of the absorber sunlight receiving surfaces, absorber tube structural integrity, burn-in of all electronics, valve functional characteristics, and structural integrity of the receiver unit.

4.2.5.1 Mean Time Before Failure/Replacement. Sufficient data shall be gathered from the above life tests and also from component suppliers in order to estimate the MTBF and MTBR for the given design configuration.

4.2.6 Engineering Critical Component Qualification Tests. Components for which reliability data are not available shall be subjected to sufficient qualification testing to estimate their impact on overall device MTBF.

4.3 Verification of Conformance. Verification that the requirements of sections 3 and 5 of this specification are fulfilled shall be performed by the contractor by the methods specified in Table 2. The methods of verification are defined as follows:

(a) Inspection - examination and measurement of product.

(b) Analysis - examination of the design and associated data, which may include relevant test information.

(c) Similarity - demonstration or acceptable evidence of the performance of sufficiently similar product to permit conformance to be inferred.

(d) Test - functional operation or exposure under specified conditions to evaluate product performance.

(e) Demonstration - exhibition of the product or service in its intended modes and conditions.

4.3.1 Hardware Acceptance for POCE. The contractor shall provide a system by which conformance of hardware to the design will be verified prior to initiation of subsystem level tests. This verification of conformance

Table 2

RECEIVER SUBSYSTEM REQUIREMENT VERIFICATION MATRIX

Verification Methods	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test including life tests and critical component qualification
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable."

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.1 Receiver Subsystem Definition	1,2,4	A	
3.1.1 Receiver Subsystem Diagram	N/A	N/A	
3.1.2 Interface Definition	N/A	N/A	
3.1.2.1 Receiver/Collector Interface	2.4	B	
3.1.2.2 Receiver/Thermal Storage Interface	1.4	A	
3.1.2.3 Receiver/El. Power Gen. Interface	1,2,4	A	
3.1.2.4 Receiver/Master Control Interface	2.4	A	Master control inputs are simulated for subsystem tests.
3.1.2.5 Receiver Major Components	1,2,3,4	A,B	Tower structure environmental tests are classed as qualifications. Make maximum use of SRE test data.

Table 2

RECEIVER SUBSYSTEM REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test including life tests and critical component qualification
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable."

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.1.3 Major Components List	N/A	N/A	
3.1.3.1 Receiver Unit	1,2	N/A	
3.1.3.2 Riser	1,2	N/A	
3.1.3.3 Downcomer	1,2	N/A	
3.1.3.4 Tower	1,2	N/A	
3.2 Characteristics	N/A	N/A	
3.2.1 Performance	2,4	A	Master control inputs are simulated for subsystem tests.
3.2.2 Physical Characteristics	1,2,5	N/A	Demonstration may be in conjunction with operational tests at system level.
3.2.3 Reliability	2	N/A	
3.2.4 Maintainability	2	N/A	

Table 2

RECEIVER SUBSYSTEM REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test including life tests and critical component qualification.
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable."

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.2.5 Availability	2	N/A	
3.2.6 Environmental Conditions	N/A	N/A	
3.2.6.1 General	2	N/A	
3.2.6.2 Transportation and Handling	N/A	N/A	
3.2.6.2.1 Temperature	N/A	N/A	See entry for 3.2.6.1
3.2.6.2.2 Humidity	N/A	N/A	See entry for 3.2.6.1
3.2.6.2.3 Vibration	4	B	
3.2.6.2.4 Shock	N/A	N/A	See entry for 3.2.6.1
3.2.6.2.5 Other Conditions	N/A	N/A	See entry for 3.2.6.1
3.2.6.3 Operational	2, 3, 4	B	Make maximum use of SRE test data.

Table 2

RECEIVER SUBSYSTEM REQUIREMENT
VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test including life tests and critical component qualification.
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable."

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.2.6.3.1 Thermal	N/A	N/A	See entry for 3.2.6.3
3.2.6.3.2 Humidity	N/A	N/A	See entry for 3.2.6.3
3.2.6.3.3 Wind	2,3,4	B	Make maximum use of SRE test data.
3.2.6.3.4 Sand and Dust	2,3,4	B	Make maximum use of SRE test data.
3.2.6.3.5 Rain, Hail and Snow	N/A	N/A	See entry for 3.2.6.3
3.2.6.3.6 Lightning	1,2	N/A	
3.2.6.3.7 Earthquake	2	N/A	
3.2.7 Transportability	2,5	N/A	
3.3 Design and Construction	1,2,4	A	
3.3.1 Materials, Processes, and Parts	1,2	N/A	Test requirements are in applicable item or process specification

Table 2

RECEIVER SUBSYSTEM REQUIREMENT
VERIFICATION MATRIX (Continued)

Verification Methods		Test Categories	
1.	Inspection	A.	Acceptance Test
2.	Analysis	B.	Qualification Test including life tests and critical component qualification.
3.	Similarity		
4.	Test		
5.	Demonstration		

N/A denotes "not applicable."

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.3.2 Electrical Transients	2,4	B	Necessary test inputs may be simulated.
3.3.3 Electromagnetic Radiation	2.4	B	
3.3.4 Nameplates and Product Marking	1	N/A	
3.3.5 Workmanship	1	N/A	
3.3.6 Interchangeability	1,2	N/A	
3.3.7 Safety	1,2	N/A	
3.3.8 Human Engineering	2	N/A	
3.4 Documentation	N/A	N/A	
3.4.1 Characteristics and Performance	1	N/A	
3.4.2 Instructions	1,2	N/A	

Table 2

RECEIVER SUBSYSTEM REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test including life tests and critical component qualification.
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable."

Requirement (paragraph)	Verification Method	Test Category	Remarks
3.4.3 Construction	1,2	N/A	
3.5 Logistics	2	N/A	
3.5.1 Maintenance	2	N/A	
3.5.2 Supply	2	N/A	
3.5.3 Facilities and Facilities Equipment	TBD	TBD	To be determined after site selection.
3.6.1 Personnel	2	N/A	
3.6.2 Training	2	N/A	
5.1 General	1,2	N/A	
5.2 Preservation and Packaging	1	N/A	
5.3 Packing	1,2	N/A	

Table 2

RECEIVER SUBSYSTEM REQUIREMENT
VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test including life tests and critical component qualification.
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable."

Requirement (paragraph)	Verification Method	Test Category	Remarks
5.4 Handling and Transportability	1,2	N/A	
5.5 Marking	1	N/A	

shall include proof-by-assembly and the examination of records as elements of inspection. A record shall be made of each inspection or test performed and of the verification. In addition, evidence shall be maintained of satisfactory accomplishment of inspections and tests required by codes and standards that apply to the collector subsystem.

5.0 PREPARATION FOR DELIVERY

5.1 General. Packaging for receiver subsystem components shall provide adequate protection during shipment by common carrier from supplier to the first receiving activity for immediate use or temporary storage.

5.2 Preservation and Packaging. Subsystem components that may be harmed when exposed to the normal transportation and handling environments of paragraph 3.2.6 shall be protected by inert environments, barrier materials, or equivalent techniques.

5.3 Packing. Shipping containers and their cushioning devices shall ensure protection of receiver subsystem components when exposed to the shock and vibrations loads defined in paragraph 3.2.6. Containers shall meet, as a minimum, the requirements in the following regulations as applicable to the mode of transportation utilized.

(a)	National Motor Freight Classification	(Highway Transportation)
(b)	Uniform Freight Classification	(Railroad Transportation)
(c)	CAB Tariff 96 and 169	(Air Transportation)
(d)	R. M. Graziano's Tariff 29	(For Dangerous Articles Surface)
(e)	CAB Tariff 82	(For Dangerous Articles Air)

5.4 Handling and Transportability. Containers with gross weights exceeding 60 pounds shall have skids and other provisions for handling by standard materials handling equipment. When feasible, container sizes and configurations shall be compatible with efficient utilization of transport vehicles.

5.5 Marking. Unless otherwise specified, container marking shall be standard commercial practice.

APPENDIX 3 POCE Thermal Storage Subsystem

THERMAL STORAGE SUBSYSTEM
REQUIREMENTS SPECIFICATION

VOLUME 2
PART 1
APPENDIX 3

CONTENTS

CONTENTS (Continued)

1.0 SCOPE

This specification establishes the performance, design, and test requirements for the thermal storage subsystem.

2.0 APPLICABLE DOCUMENTS

The equipment, materials, design, and construction of the thermal storage subsystem shall comply with all Federal, state, local, and user standards, regulations, codes, laws, and ordinances which are currently applicable for the selected site and using utility. These shall include but not be limited to the government and non-government documents itemized below. If there is an overlap in or conflict between the requirements of these documents and the applicable Federal, state, county, or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent shall take precedence.

The following documents of the issue in effect on the date of request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Government Documents

2.1.1 Specifications

Regulations of the Occupational Safety and Health Administration (OSHA)

Regulations of the California Occupational Safety and Health Administration CAL/OSHA - if required

2.1.2 Other Publications

National Motor Freight Classification 100B - Classes and Rules Apply on Motor Freight Traffic

Uniform Freight Classification 11 - Railroad Traffic Ratings Rules and Regulations

CAB Tariff 96 - Official Air Transport Rules Tariff

CAB Tariff 169 - Official Air Transport Local Commodity Tariff

R. H. Graziano's Tariff 29 - Hazardous Materials Regulations of the Department of Transportation

CAB Tariff 82 - Official Air Transport Restricted Articles Tariff

2.2 Non-Government Documents

2.2.1 Standards

Manual of Steel Construction, 7th Edition, 1974, American Institute of Steel Construction

Building Code Requirements for Reinforced Concrete, ACI 318-71, American Concrete Institute

American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section 8, Unfired Pressure Vessels

American National Standards Institute, B31.1, Power Piping

National Electric Code, NFPA 70-1971 (ANSI C1-1971)

3.0 REQUIREMENTS

3.1 Thermal Storage Subsystem Definition. The thermal storage subsystem for the POCE shall provide a means of transferring to stored thermal energy a portion of the thermal output from the receiver subsystem and subsequently transferring stored thermal energy to steam in a form suitable for generating electrical power with a conventional turbine-generator. The water/steam shall be capable of operating at a standard steam cycle. The thermal storage subsystem shall consist of:

(a) The superheat steam piping, valves, fittings, and connections to the downcomer piping from the receiver subsystem to the inlet heat exchangers.

(b) The desuperheater to reduce the temperature of the receiver outlet steam to a level satisfactory for heating the heat transfer fluid.

(c) The thermal storage heater, valves, fittings, and piping required to transfer the thermal energy from the steam into the heat transfer fluid and then into the complete thermal storage media.

(d) The thermal storage unit, including materials, containers, structures, internal piping, insulation, and an ullage maintenance unit required for the actual storage of thermal energy.

(e) The steam generator, valves, fittings, and connections to the high-pressure steam supply for the electrical power generation subsystem.

(f) The auxiliary feedwater heater, valves, fittings and connections to the receiver feedwater return for heating feedwater to the receiver.

(g) The fluid maintenance unit, valves, and connections in the fluid circulation loops to provide refurbishment and makeup of the heat transfer fluid.

(h) The pumps, instrumentation and controls required to regulate and direct the steam and fluid flows, temperatures and pressures as appropriate to provide full flexibility of the thermal storage subsystem.

3.1.1 Thermal Storage Subsystem Diagram. The thermal storage subsystem relationship to and interfaces with the overall plant are shown in Figure 1. The subsystem functional schematic diagram is given in Figure 2, showing all major components and their interrelationships.

3.1.2 Interface Definition. The interfaces between the thermal storage subsystem and other POCE subsystems are illustrated in Figure 1 and between major components of the thermal storage subsystem in Figure 2.

3.1.2.1 Thermal Storage Subsystem/Receiver Subsystem. Piping, connections, and mounting fixtures shall be provided at the tower base to match those of the receiver subsystem at the exit of the receiver output bypass valve. The thermal storage subsystem shall be designed to accept steam (1) at a pressure of 10.0 MN/m^2 (1,450 psia), (2) at a temperature of 477 degrees C (890 degrees F), and (3) with thermal energy at rates up to the maximum deliverable from the receiver subsystem (42.3 MWth). The subsystem shall be capable of accepting steam flowrates varying from 10 to 100 percent of nominal (nominal 18.8 kg/sec (41.6 lb/sec)) and at rates of flowrate change up to (TBD) percent/minute. Piping, connections, and mounting fixtures shall be provided at the tower base to match those of the receiver subsystem feedwater return at the inlet to the tower feedwater pump. The thermal

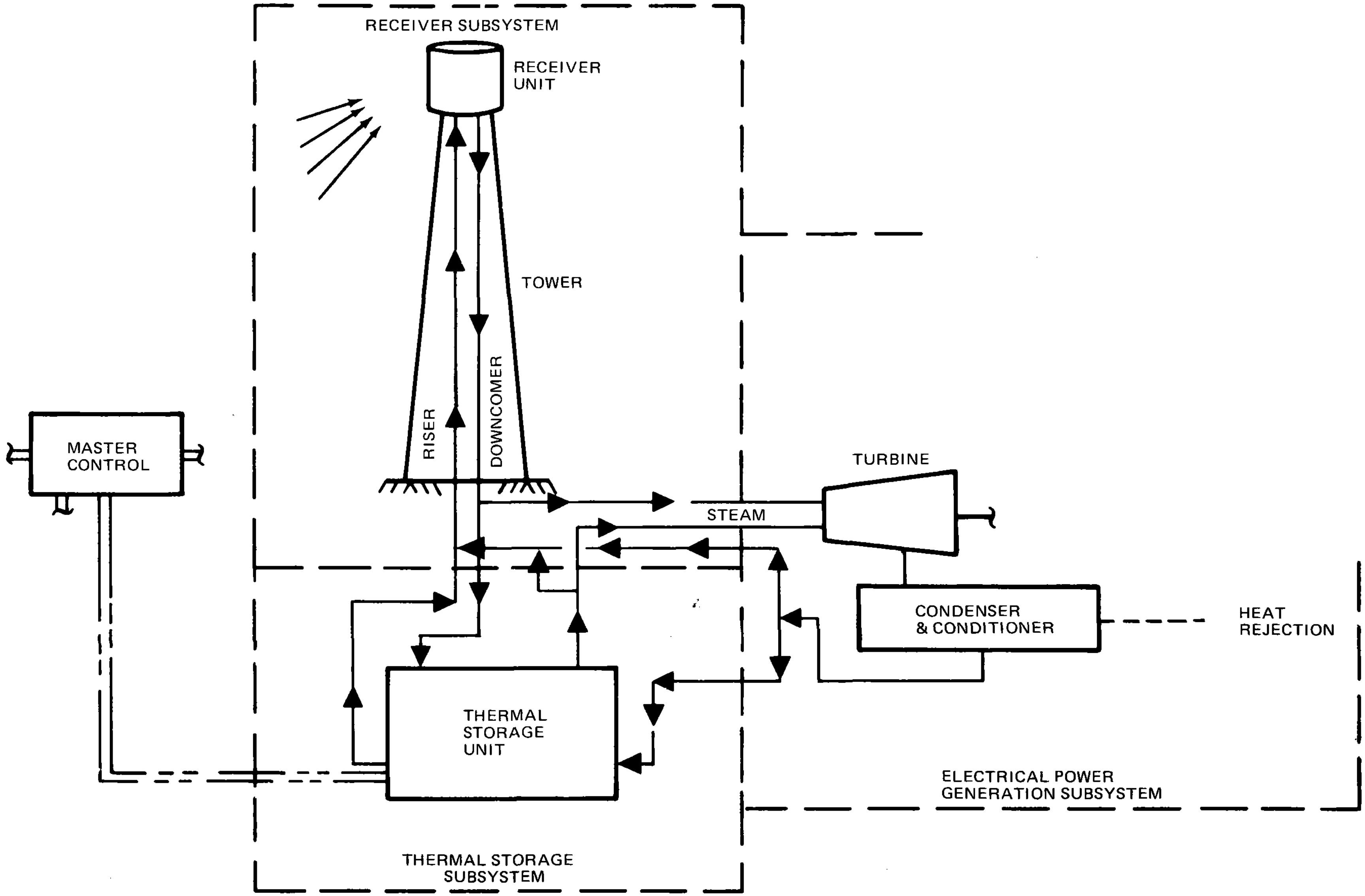

Figure 1. Thermal Storage Subsystem Major Interfaces

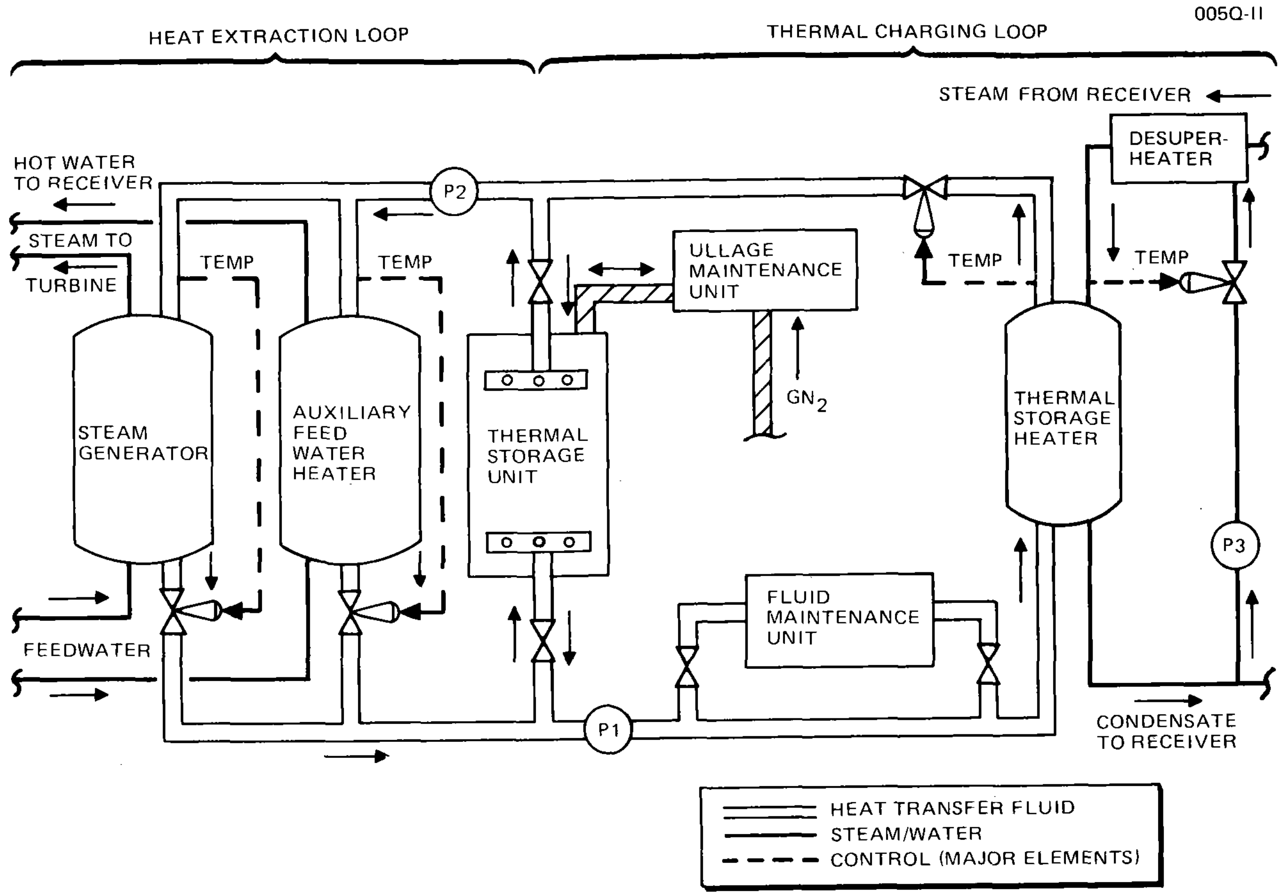

Figure 2. Schematic of POCE Thermal Storage Subsystem

storage subsystem shall return water at a temperature of 246 degrees C (475 degrees F) and pressure of 10.0 MN/m^2 (1,450 psia) with flowrates corresponding to the incoming steam accepted from the receiver subsystem.

3.1.2.2 Thermal Storage Subsystem/Electrical Power Generation Subystem. Piping, connections, and mounting fixtures shall be provided to match those of the electrical power generation subsystem at the entrance of the turbine inlet steam manifold valve. Steam shall be supplied by the thermal storage subsystem at a temperature of 274 degrees C (525 degrees F) and a pressure of 2.8 MN/m^2 (400 psia), with a nominal flowrate of 13.8 kg/sec (30.3 lb/sec) and a flowrate range capability of 10 to 100 percent of nominal.

Piping, connections, and mounting fixtures shall be provided to match those at valves in the turbine condensate boost pump discharge line. The water to the thermal storage subsystem shall be at a temperature of 105 degrees C

(220 degrees F) and pressure of 2.8 MN/m^2 (410 psia), with flowrates in the range of 9.8 to 14 kg/sec (21.6 to 30.9 lb/sec).

3.1.2.3 Thermal Storage Subsystem/Master Control. The subsystem controls shall be responsive to standard control signals (per power industry practices) from the master control. There shall be three pairs of major control commands: (1) start/stop energy storage, (2) start/stop alternate steam generation from stored energy, and (3) start/stop alternate feedwater heating. In addition to these major commands from the master control, the interface shall provide for throttling controls imposed by the master control based on the subsystem status measurements sent to master control and based also on variations in steam and water flowrates imposed on the subsystem by the interfacing subsystems (with the flowrate variations also controlled by the master control). The subsystem control shall respond to such flowrate modulations by metering heat transfer fluid flows and subsystem functions. The master control shall ensure that the thermal storage subsystem is controlled properly over the total range of operating modes and operating conditions.

3.1.2.4 Thermal Storage Subsystem Major Component Interfaces. Principal interfaces within the thermal storage subsystem include:

(a) Major Process Components. Each of the seven major process components (thermal storage unit, thermal storage heater, desuperheater, thermal storage heater, thermal storage unit, fluid maintenance unit, ullage maintenace unit, auxiliary feedwater heater, and steam generator plus the two fluid circulation pumps and the condensate pump are shown in Figure 2 and listed in paragraph 3.1.3. These components shall be physically and functionally compatible. Piping and connections, which form the only physical interfaces, shall be provided to physically integrate these components, as shown in Figure 2.

(b) Major Process Components/Controls. Provisions shall be made for connection of control valves, controls, and control lines for the functions shown in Figure 2. Control lines shall be of (TBD) type and connected in (details TBD). Provisions shall be made for connection of (TBD) instrumentation sensors and instrumentation lines to the process components. Sensors shall be of (TBD) type and connected in (details TBD).

3.1.3 Major Component List. The major components comprising the thermal storage subsystem shall be:

(a) Thermal storage unit (including rock, heat transfer fluid, containers, structures, internal piping, insulation)

(b) Thermal storage heater

(c) Desuperheater

(d) Steam generator

(e) Auxiliary feedwater heater

(f) Ullage maintenance unit

(g) Fluid maintenance unit

(h) Subsystem control

3.2 Characteristics

3.2.1 Performance. The thermal storage subsystem shall perform in accordance with the requirements of the following paragraphs.

The total subsystem life expectancy shall be 30 years, with maintainability as specified in paragraph 3.2.4. The instrumentation and control response times shall be adequate to ensure stable, flexible, safe operation in all normal and emergency operating modes.

3.2.1.1 Thermal Storage Unit. The thermal storage unit shall have an extractable thermal storage capacity of not less than 195 MWth-hr, with thermal charging rates from 4 MWth to 42.3 MWth and energy extraction rates from 3 MWth to 32.5 MWth. It shall be capable of operating in the energy extraction mode at 32.5 MWth for 6 hours, and at lower rates for longer times up to 24 hours. It shall be capable of operation at a heat transfer fluid temperature of at least 302 degrees C (575 degrees F). The unit shall have a hold time of 24 hours based on a maximum allowable thermal loss of 2 percent of extractable capacity in 24 hours. The extraction capability (percent of stored energy which can be extracted at 32.5 MWth with a temperature degradation of less than 8.3 degrees C (15 degrees F)) shall be at least 85 percent.

3.2.1.2 Thermal Storage Heater. The thermal storage heater shall accept steam from the desuperheater at 10.0 MN/m^2 (1,450 psia) and 343 degrees C (650 degrees F), and at flowrates varying from 10 to 100 percent of nominal (nominal is 23.2 kg/sec (51.1 lb/sec)), and at rates of flowrate change up to 4 percent/second. The heater shall be capable of completely condensing the steam under these conditions, and shall be capable of heating the heat transfer fluid to at least 302 degrees C (575 degrees F) under maximum steam flow conditions, based on entering heat transfer fluid at 218 degrees C (425 degrees F). The heater shall be designed for safe operation at the maximum pressures which can be experienced during operation: 12.4 MN/m^2 (1,800 psia) on the steam side and 0.33 MN/m^2 (47.5 psia) on the fluid side. The heater shall be designed to ensure that the maximum film temperature of the fluid does not exceed 344 degrees C (650 degrees F).

3.2.1.3 Desuperheater. The desuperheater shall accept steam from the receiver subsystem at a pressure of 10.0 MN/m^2 (1,450 psia), a temperature of 477 degrees C (890 degrees F), at flowrates varying from 10 to 100 percent of nominal (nominal 18.8 kg/sec (41.6 lb/sec)), and at rates of flowrate change up to 4 percent/second. The desuperheater (together with the condensate return and associated controls) shall be capable of controlling the output steam to within ± (TBD) degrees C over a range of temperature settings from (TBD) to (TBD). It shall be designed for safe operation at the maximum pressure of 12.4 MN/m^2 (1,800 psi) and temperature of 510 degrees C (950 degrees F).

3.2.1.4 Steam Generator. The steam generator shall be capable of producing steam at a temperature of 274 degrees C (525 degrees F) and a pressure of 2.8 MN/m^2 (400 psia), with a nominal flowrate of 13.8 kg/sec (30.3 lb/sec) and a flowrate range capability of 10 to 100 percent of nominal. These performance figures are predicated on having available feedwater at a temperature of 104 degrees C (220 degrees F) and pressure of 2.8 MN/m^2 (410 psia) at the necessary flowrates. The steam generator shall be designed for safe operation at the maximum pressures and temperatures which can be experienced during operation: (TBD) MN/m^2 on the steam side, (TBD) MN/m^2 on the fluid side, and temperatures of 302 degrees C (575 degrees F).

3.2.1.5 Auxiliary Feedwater Heater. The heater shall be capable of heating water to at least 246 degrees C (475 degrees F), with a nominal flowrate of 14 kg/sec and a flowrate range capability of 10 to 100 percent of nominal. These performance figures are predicated on having available inlet water at a temperature of at least 104 degrees C (220 degrees F) and a pressure of (TBD) MN/m^2 at the necessary flowrates. The heater shall be designed for safe operation at the maximum pressures and temperatures which can be experienced during operation: (TBD) MN/m^2 on the water side, (TBD) MN/m^2 on the fluid side, and a temperature of 302 degrees C (575 degrees F).

3.2.1.6 Thermal Charging Loop Pump. The hot heat transfer fluid pump in the thermal charging loop (pump P1 in Figure 2) shall be a centrifugal, high-temperature pump capable of pumping up to 173 kg/sec (382 lb/sec) heat transfer fluid over a head of 0.23 MN/m^2 (33 psi), with a minimum pressure at the pump suction flange of (TBD) MN/m^2. The pump shall be capable of this performance and safe operation at temperatures up to 316 degrees C (600 degrees F).

3.2.1.7 Energy Extraction Loop Pump. The hot heat transfer fluid pump in the energy extraction loop (pump P2 in Figure 2) shall be a centrifugal, high-temperature pump capable of pumping up to 140 kg/sec (310 lb/sec) of heat transfer fluid over a head of 0.23 MN/m^2 (33 psi), with a minimum pressure at the pump suction flange of (TBD) MN/m^2. The pump shall be capable of this performance and safe operation at temperatures up to 316 degrees C (600 degrees F).

3.2.1.8 Ullage Maintenance Unit. The ullage maintenance unit for the thermal storage unit shall be designed to fulfill two main functions: (1) to maintain at all times an inert atmosphere in the ullage (gas) space of the thermal storage unit, and (2) to maintain a controlled pressure range in the ullage, with provisions for venting steam during the initial startup. The inert gas shall be nitrogen. The ullage pressure shall be maintained within the range (TBD) MN/m^2.

3.2.1.9 Fluid Maintenance Unit. The fluid maintenance unit shall be designed to clean the heat transfer fluid, both during initial startup with an unseasoned rock bed and during normal operations. The unit shall remove solid particles down to a size of (TBD) μm and also provide processing of the fluid to remove decomposition products as necessary to prevent degradation of the fluid side heat transfer surfaces and to avoid significant changes in fluid flow properties. The unit shall be capable of operation in either batch or continuous modes, with a capacity of (TBD) kg/sec (TBD lb/sec) of heat transfer fluid.

3.2.2 Physical Characteristics. Specific size, shape, and configuration constraints shall be governed by the power plant layout and design to facilitate efficient and safe operation and maintenance. The thermal storage subsystem shall be designed to provide safe and reasonable ingress, egress and access for inspection, maintenance and repair of the structure, steam lines, utilities, instrumentation, and controls consistent with the availability requirements of paragraph 3.2.5. The thermal storage subsystem shall be so configured and located within the POCE as to minimize adverse effects on the other subsystems. All of the above shall be consistent with cost considerations. The required ground area shall be (TBD) by (TBD). The maximum height of any subsystem components shall be (TBD) meters with unrestricted access overhead.

3.2.3 Reliability. High reliability shall be achieved in the subsystem design by providing adequate operating margins and using proven standard parts and conservative design practices such that the reliability performance shall not degrade the capability to achieve the availability specified in paragraph 3.2.5 when operated in the environments specified in paragraph 3.2.6.

Single-point failures that disable the automatic mode of system operation shall be eliminated wherever practical. In cases where it is impossible to eliminate such failure modes, suitable devices shall be used to detect and warn of the occurrence of a failure. As a minimum, redundancies for the heat transfer fluid supply pumps shall be incorporated in the design.

3.2.4 Maintainability. The thermal storage subsystem shall be designed such that required service can be accomplished by personnel of normal skills, with a minimum of nonstandard tools or special equipment. The subsystem shall be designed to provide malfunction indication and fault isolation information data required by the master control concerning critical components (TBD). Critical components are those components that, because of failure risk, downtime or effect on the overall POCE performance, materially affect the capability to achieve the system availability requirements. Items which do not have a redundant mode of operation shall incorporate maximum capability for on-line repair or replacement. These items might include, for example, temperature and pressure sensors and actuators for valves. The subsystem shall be designed such that potential maintenance points can be easily reached, components such as electronic modules can be readily replaced, and elements subject to wear or damage can be easily serviced or replaced.

The mean and maximum downtime of the entire subsystem shall not exceed (TBD). Modular construction shall be employed for the (TBD) components in order to simplify maintainability, decrease subsystem downtime, and increase operating flexibility.

3.2.5 Availability. The thermal storage subsystem shall operate in accordance with paragraph 3.2.1 performance requirements 99.5 percent of its scheduled operating time based on reliability and maintainability exclusive of insolation conditions. Determinations of availability shall use a period of one year as a time reference.

3.2.6 Environmental Conditions

3.2.6.1 General. The conditions described in the following paragraphs are representative of the transportation and operating site environments to be encountered by the thermal storage subsystem. For design purposes safety margins shall be used commensurate with availability and performance requirements to ensure operation in accordance with paragraph 3.2.1 during or after exposure to these conditions.

3.2.6.2 Transportation and Handling. The following conditions occurring separately or in combination may be encountered by packaged equipment during handling and transportation.

3.2.6.2.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.6.2.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.6.2.3 Transportation Vibration and Shock. Vibration and shock as encountered during transport. Conditions are as follows:

VIBRATION

Transportation Mode	Continuous Excitations (Steady-State) in g's	Discrete Impulse (Transient) in g's	Predominant Frequency Range
Highway	0.06	1.5	2 to 200 Hz
Rail	0.05	1.5	2 to 200 Hz
Air (Jet Aircraft)	0.05	1.5	2 to 500 Hz

SHOCK (g's)
(Normal Load Limits)

Transport Media	Longitudinal	Lateral	Vertical	Average Pulse Time msec
Air	2.0	1.5	2.0	11-40
Highway	2.0	1.5	3.0	11-40
Rail (Rolling) (1)	3.0	0.75	3.0	11-40
Cushion Car (Humping)	3.0	2.0	3.0	11-40

(1) Shock loads are for rail cars equipped with standard draft gears.

All critical (frangible) components of the thermal storage subsystem shall be designed or packaged such that the conditions described above do not induce a dynamic environmental condition which exceeds the structural capability of the component. These conditions reflect careful handling and firmly constrained (tied down) transporting via common carrier.

All components shall be designed to withstand handling/hoisting inertial loads considering number, location, and type of hoisting points.

3.2.6.2.4 Handling Shock. Handling shocks may result from drops of packaged equipment. Corresponding acceleration peaks may be of the order of 7 g's vertical with 4 g's horizontal with a (TBD) wave profile and a duration of 10 to 50 milliseconds.

3.2.6.2.5 Other Conditions. The equipment may encounter other conditions during transportation and handling including wind, rain, snow, ice, hail, and blowing sand and dust. These are not expected to exceed the operational conditions of paragraph 3.2.6.3.

3.2.6.3 Operational. The following conditions occuring separately or in combination may be encountered by the thermal storage subsystem during the pilot plant 30-year operational life. Unless specificed otherwise, the thermal storage subsystem shall be designed to perform in accordance with paragraph 3.2.1 during and after exposure to these conditions.

3.2.6.3.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.6.3.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.6.3.3 Wind. Sustained winds up to 8.9 m/sec (20 mph) for a period of (TBD) hours with gust RMS velocities up to 11.6 m/sec (25.9 mph). While non-operational, the thermal storage subsystem shall not be damaged by sustained winds of 35.7 m/sec (79.9 mph) for periods up to (TBD) hours with gust RMS velocities to 46.4 m/sec (103.8 mph). These are derived from 35.7 m/sec (79.9 mph) base. 50-year fastest mile (Reference ASCE Paper 3269, Volume 126). Maximum steady winds with gusts during operation are to be considered throughout a complete daylight operational period. Practices recommended in the ASCE Paper 3269, Volume 126 and the Uniform Building Code, 1973, Volume 1 shall be employed in designing thermal storage subsystem elements for winds.

3.2.6.3.4 Sand and Dust. The thermal storage subsystem shall not evidence operational degradation or component destruction following exposure to sand and dust storms. The design shall withstand dust fluxes of 10^{-4} g/cm^2-sec at velocities up to (TBD) meters/second. Dust is defined to be those particles up to 100 μm in diameter with the mean diameter being 40 to 50 μm.

Sand is defined as particles greater than 100 μm in diameter. Desert sand flux declines approximately exponentially with height above the surface. For the surface roughness expected at the POCE site, 90 percent of the sand flux will be within 25 cm of the surface. The design shall withstand a sand flux which averages 0.3 g/cm^2-sec within that region at velocities up to (TBD) meters/second.

The frequency of storm occurrence and duration to be considered will depend on the site selected. For example, in the Southwestern desert area a major storm frequency of four or less per year with a maximum duration of 36 hours is to be assumed. Nine minor storms per year with maximum durations of 6 hours are to be assumed.

The effect of dust devils shall also be considered in the design. The maximum core diameter and tangential velocities to be considered are 70 m and 30 m/sec, respectively. The maximum vertical velocity to be considered is 15 m/sec.

Subsystem components shall be protected from the electrostatic charging and discharging associated with sand and dust storms.

3.2.6.3.5 Rain, Hail, and Snow. Storms of the following types and intensities:

Rain: Average storm intensity of (TBD) cm/hour (TBD in/hr) for (TBD) hours with peak periods of (TBD) cm/hour (TBD in/hr) lasting (TBD) minutes. Three to five storms per year.

Hail: Mean particle diameter of 5 to 10 mm (0.20 to 0.39 in.), extreme maximum diameter of 25 mm (1 in.). Fall velocity of 20 m/sec (65.6 ft/sec). Hail stone compressive strength of 1.3 MN/m^2 (150 psi) for 25 mm stone; 5.07 MN/m^2 (735 psi) for stones less than 10 mm in diameter. Storm intensity of (TBD) particles per square meter per minute lasting 10 to 20 minutes. Frequency of occurrence -- one in 5 to 6 years.

Snow: (TBD)

3.2.6.3.6 Lightning. A lightning threat that has a current pulse of 140,000 amperes with a 1.5-microsecond rise time decaying to 50 percent in 40 microseconds. A continuing current of 200 to 400 amperes will follow the main stroke and last for 160 to 300 milliseconds. Up to 10 restrokes can occur with 30,000 to 70,000 amperes peak current each. Total charge transfer of the primary stroke and the restrokes events can reach 200 coulombs.

3.2.6.3.7 Earthquake. The thermal storage subsystem shall be designed to withstand, without structural damage or yielding, the earthquake environment described in Table 1 and Figure 3. The environment is given in terms of response spectra and ground motion histories for soft rock or firm sediment. If the thermal storage subsystem is located on competent rock, the above environment may be reduced by 33 percent. If the subsystem is located on soft sediment, the above environments shall be increased by 50 percent. The response spectra or ground motion histories shall be used as input to the analytical model of the soil and the thermal storage subsystem in both vertical and horizontal directions to assess earthquake-induced loads.

Table 1

EARTHQUAKE HORIZONTAL GROUND MOTION HISTORIES

Location	Year	Component	Scale Factor
El Centro	1940	NS	1.0
El Centro	1934	EW	1.4
Olympia	1949	N10W	1.4
Taft	1952	S69E	1.7

Each ground motion history is to be multiplied by the indicated scale factor.

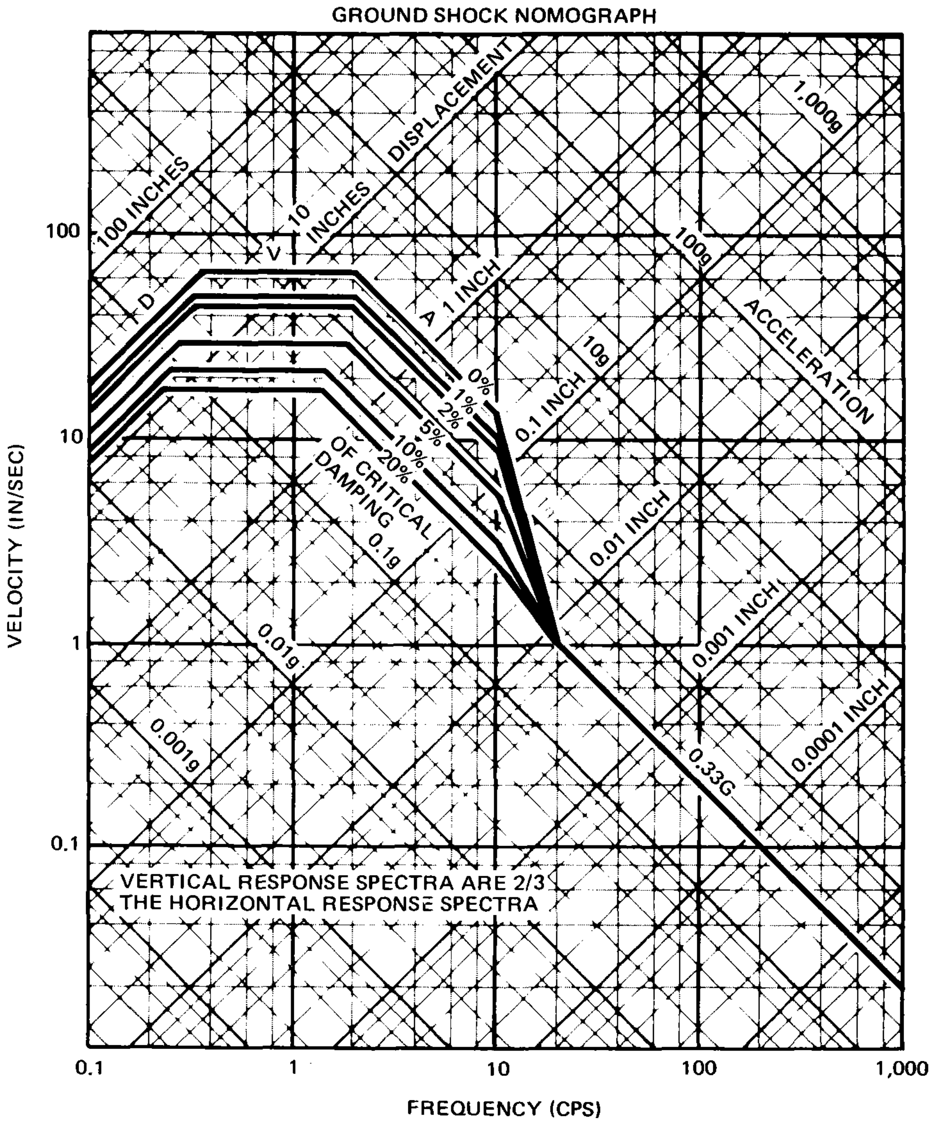

Figure 3. Earthquake Horizontal Response Spectra

3.2.7 Transportability. Thermal storage subsystem components shall be designed for transportability within applicable Federal and state regulations by highway and railroad carriers utilizing standard transport vehicles and materials handling equipment. The components, in their packaged condition, shall be capable of withstanding the climatic conditions and shock and vibration environments defined in paragraph 3.2.6.2. Whenever feasible, components shall be segmented and packaged to sizes that are transportable under normal commercial transportation limitations (see (a) below). Subsystem components that exceed normal transportation limits (see (b) below) shall be transportable with the use of special routes, clearances, and permits, or the necessary parts for field assembly shall be transportable within these limits.

(a) Transportability Limits for Normal Conditions (Permits Not Required)

	Truck	Rail
Height:	13 ft 6 in above road	16 ft 0 in
Width:	8 ft 0 in	10 ft 6 in
Length:	55 ft 0 in - Eastern States 60 ft 0 in - Western States	60 ft 6 in
Gross Wt:	73,280 lb; 18,000 lb/axle	200,000 lb

(b) Transportability Limits for Special Conditions

	Truck	Rail
Height:	14 ft 6 in above road	16 ft 0 in above rail
Width:	12 ft 0 in	12 ft 0 in
Length:	70 ft 0 in	80 ft 6 in
Gross Wt:	100,000 lb with sufficient axles to distribute weight over highway not to exceed 18,000 lb/axle.	400,000 lb

3.3 Design and Construction. Thermal storage subsystem vessels and heat exchangers shall be designed, fabricated, and inspected to conform to the ASME Code for Unfired Pressure Vessels and the applicable API and TEMA standards. Piping shall be designed, fabricated, and inspected in accordance with the American National Standard Code for Pressure Piping.

3.3.1 Materials, Processes, and Parts. Materials of construction throughout shall be selected to ensure compatibility with the process fluids at the maximum operating conditions. The thermal storage subsystem components shall be fabricated from materials as specified in the applicable codes. Special attention shall be directed to prevent unnecessary use of costly materials.

No toxic or exotic materials shall be used. Wherever possible, standard and commercial parts shall be used. Specifically, the following shall be commercial parts:

Heat transfer fluid pumps

Water pumps

Steam generator

Auxiliary feedwater heater

Valves and controls

(others TBD)

3.3.2 Electrical Transients. The subsystem operation shall not be adversely affected by external or internal power line transients caused by normal switching, fault clearing, or lightning. Switching transients and fault clearing functions will require less than six cycles of the fundamental frequency (100 milliseconds) and shall be limited to 1.7 P.U. voltage (1.7 per unit or 170 percent). Lightning arresters shall be installed which will limit the resultant line voltage to 5 P.U. on a line to ground basis during the time interval of peak current.

Components of the thermal storage subsystem shall be shielded from the lightning threat specified in paragraph 3.2.6.3.6. Shielding shall protect the electrical components from both the bound charge and induced current threats.

3.3.3 Electromagnetic Radiation. The thermal storage subsystem shall be designed to minimize susceptibility to electromagnetic interference and to minimize the generation of conducted or radiated interference. The design criteria contained in the following Air Force design handbooks shall be used to assure electromagnetic compatibility: Design Handbook on Electromagnetic Compatibility (AFSC DH1-4), Checklist of General Design Criteria (AFSC DH1-X), and Instrumentation Grounding and Noise Minimization Handbook (AFRPL-TR-65-1).

3.3.4 Nameplate and Product Marking. All deliverable end items shall be labeled with a permanent nameplate listing, as a minimum, manufacturer name, part number, change letter, serial number and date of manufacture.

All access doors to replaceable/repairable items shall be labeled to show equipment installed in that area, and any safety precautions or special considerations to be observed during servicing.

3.3.5 Workmanship. The level of workmanship shall conform to practices defined in the codes, standards, and specifications applicable to the selected site and the using utility. Where specific skill levels or certifications are required, current certification status shall be maintained with evidences available for examination. Where skill levels or details of workmanship are not specified, the work shall be accomplished in accordance with the level of quality currently in use in the construction, fabrication, and assembly of commercial power plants. All work shall be finished in a manner such that it presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a generally uniform appearance.

3.3.6 Interchangeability. Major components, circuit cards, and other items with a common function shall be provided with standard tolerances and connector locations to permit interchange for servicing. Components that have similar appearance but different functions shall incorporate protection against inadvertent erroneous installation through the use of such devices as keying, connector size, or attachment geometry.

3.3.7 Safety. The thermal storage subsystem shall be designed to minimize safety hazards to operating and service personnel, the public, and the equipment. Electrical components shall be insulated and grounded. All parts or components with elevated temperatures shall be insulated against contact with or exposure to personnel. Any moving elements shall be shielded to avoid entanglements and safety override controls/interlocks shall be provided for servicing. Isolation valves shall be provided on all major assemblies and on all interface utility lines to permit isolation and shutdown of assemblies and segments of the subsystem. Piping shall be designed, fabricated, and inspected in accordance with the American National Standard Code for Pressure Piping, Section 31.3, and shall be of welded construction wherever practical. Concrete and/or earth berms and dikes shall be provided to contain the maximum quantity of heat transfer fluid which can be emptied from all above-grade sections of the subsystem. The storage tank, heat exchangers, and piping shall be visually inspected and leak-checked after assembly but before insulation is installed. Safety showers and eyewashes shall be provided. Ladders, handrails, and platforms shall meet OSHA standards. Fire protection equipment shall be provided.

3.3.8 Human Engineering. The thermal storage subsystem shall be largely indentured to the receiver and the electrical power generation subsystems. Therefore, almost all of the normal operating functions of the thermal storage subsystem will be handled automatically, with minimum allocation of function to personnel (at the subsystem level). Special attention shall be directed to the human engineering of any tasks or operations where the effects of human error would be particularly serious. All subsystem controls and mechanical details shall facilitate manual operation, adjustment, and maintenance. MIL-STD-1472, Human Engineering Design Criteria, shall be used as a guide in designing controls, placards, illumination, access for maintenance, and similar design considerations.

3.4 Documentation

3.4.1 Characteristics and Performance. Equipment functions, normal operating characteristics, limiting conditions, test data, and performance curves, where applicable, shall be provided.

3.4.2 Instructions. Instructions shall cover assembly, installation, alignment, adjustment, checking, lubrication, and maintenance. Operating instructions shall be included for startup, routine and normal operation, regulation and control, shutdown, and emergency conditions. A guide to troubleshooting instruments and controls shall be provided.

3.4.3 Construction. Engineering and assembly drawings shall be provided to show the equipment construction, including assembly and disassembly procedures. Engineering data, wiring diagrams, and parts lists shall be provided.

3.5 Logistics. The elements required to support the thermal storage subsystem are:

Support and test equipment

Technical publications

Personnel and training

Facilities

Spares, repair parts and consumables

Transportation, handling and packaging

Data file

Field service

The requirements for the elements shall be established as a result of a support requirements analysis to be prepared by the contractor. The results of the analysis shall be documented in accordance with the contract.

3.5.1 Maintenance. Maintenance activities are categorized as follows:

Level 1, On-line maintenance

Level 2, Off-line on-site maintenance

Level 3, Off-line off-site maintenance

Level 1, On-Line Maintenance: The following scheduled and unscheduled maintenance activities shall be identified for the subsystem in the maintenance plan.

Task	Frequency
Visual inspection	Daily
Remove and replace	(TBD)
Repair in place	(TBD)
Adjust	(TBD)
Clean	(TBD)
Calibrate	(TBD)
Lubricate	(TBD)
Paint	(TBD)

Level 2, Off-Line On-Site Maintenance: The following maintenance activities shall be identified in the maintenance plan. Frequencies shall be (TBD).

Fault verification

Fault isolation to a removable item

Remove and replace a faulty item

Verify acceptable repaired item

Repair designated subtiered items

Servicing

Lubrication

Visual inspection

Level 3, Off-Line Off-Site Maintenance: Level 3 maintenance activities are those to be performed at the equipment supplier's facility. Frequencies and turnaround times shall be (TBD).

Maintenance Plan: A maintenance plan shall be prepared by the contractor which identifies scheduled and unscheduled maintenance requirements. The maintenance plan shall reflect the results of the support requirements analyses and shall specify the following as appropriate.

Use of multi-purpose test equipment

Items to be repaired

Items to be replaced

Maintenance and repair cycles

Use of operational support equipment for maintenance

Level, frequency, and location of maintenance action

Facilities, equipment, and tools

3.5.2 Supply. The selection and positioning of spares, repair parts, and consumables shall be in accordance with the levels of repair determined by the supports requirements analysis, and shall use the following criteria:

Protection Level: Items shall be packaged in accordance with the requirements of section 5.0.

Demand Rate: The mean-time-between-maintenance-actions provided by the maintainability analyses shall be the departure point for spares determinations. The quantities and mix shall be such that there is a (TBD) percent probability of a part being available on demand.

Pipeline: Pipeline quantities shall be determined on the basis of system location demand rate and repair cycle times. Resupply methods, distribution, and location of system stocks shall be determined after site selection.

Procurement and Release for Production: Long lead time supply items shall be procured or released early enough to be on-site 30 days prior to initial operation. Other items shall be procured or released lead-time away so as to minimize obsolescence due to design changes, except for those items for which significant cost savings can be achieved through acquisition concurrent with production.

Minimum/Maximum Levels: Minimum and maximum quantities of spares and repair parts to be stocked shall initially be determined by use of predicted failure rates. These levels are to be adjusted as actual usage rates are established.

3.5.3 Facilities and Facility Equipment. To be determined after site selection.

3.6 Personnel and Training

3.6.1 Personnel. The pilot plant is to be installed, checked out, and tested as a proof-of-concept experiment by contractor personnel; then taken over and operated as a commercial power plant by utility personnel. Operation and maintenance personnel requirements shall be satisfied by recruitment from the established utility labor pool. Unique aspects of the thermal storage subsystem dictate a need for training existing utility people but do not establish a need for new skills or trades. The types and numbers of utility personnel requiring training, along with the unique tasks, are as follows:

Type	No.	Unique Task
TBD	TBD	Thermal storage heater component removal and replacement.
		Steam generator component removal and replacement.
		Auxiliary feedwater heater component removal and replacement.
		Desuperheater component removal and replacement.
		Storage medium replenishment
		Storage medium maintenance
		Heat transfer fluid replenishment

3.6.2 Training. The contractor shall prepare and conduct a training program for contractor personnel as necessary for performance of the POCE. The contractor shall conduct a training program for utility personnel in accordance with contractual requirements.

3.7 Precedence. The order of precedence of requirements of the thermal storage subsystem characteristics shall be as follows:

(a) Performance (including scalability to commercial power level)

(b) Safety

(c) Cost

Specific characteristics and requirement precedence shall be established based on system cost effectiveness sensitivity analyses. This specification has precedence over documents referenced herein. The contractor shall notify the procuring activity of each instance of conflicting, or apparently conflicting, requirements within this specification or between this specification and a referenced document.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Tests. All tests shall be performed by the contractor. These tests may be witnessed by ERDA or its representatives or the witnessing may be waived. In either case, substantive evidence of hardware compliance with all test requirements is required.

4.1.2 General Test Requirements. Tests shall be conducted in accordance with a test plan to be prepared by the contractor and approved by ERDA. Specific required tests are identified in subsection 4.2. Tests shall be classified in the test plan as:

(a) Development tests for the purpose of determining the design

(b) Acceptance tests for the purpose of verifying conformance to design, and determining acceptability of product for further operations or for delivery, or

(c) Qualification tests for the purpose of verifying adequacy of design and method of production to yield a product conforming to specified requirements.

Where performance of the thermal storage subsystem is to be evaluated in conjunction with another subsystem, the test is regarded as a system test and shall be as specified in the System Requirements Specification.

4.1.3 Previous Tests. Maximum use shall be made of test data available from the subsystem research experiments and hardware tests already completed. Where conformance to this specification can be established at less cost by analysis of such data, tests shall not be repeated.

4.2 Specific Test Requirements. Specific required tests are defined herein. Additional tests shall be defined by the contractor in the course of design and development where necessary to properly validate the performance and design integrity of the thermal storage subsystem. Acceptance tests shall be defined for the verification indicated as requiring such tests in subsection 4.3, Table 2.

4.2.1 Subsystem Performance Tests. This paragraph is to be completed in Phase 1 to define tests for evaluation of the thermal storage subsystem as fully assembled in order to assure compatibility before attempting system tests.

4.2.1.1 Subsystem Integrity. The integrity of the complete subsystem when installed shall be verified by subjecting it to hydrostatic pressure testing, cold flow and hot flow checkouts. These checkouts shall be controlled by the subsystem control.

4.2.2 Assembly and Subassembly Performance Tests. Definition to be completed in Phase 1 to include but not be limited to the following:

Charging loop flow control

Discharge loop flow control

Control equipment

4.2.3 Materials and Processes Control Tests. Definition to be completed in Phase 1.

4.2.4 Life Tests and Analyses. Major subassemblies shall be subjected to accelerated or extended life testing or analysis where data are not sufficient to estimate MTBF and MTBR for the given design configuration. The tank/rock bed thermocycle interaction test falls in this category, as does the stability test for heat transfer fluid. Consideration shall be given to the need for testing such components as seals, pumps, valves, and heat exchangers to establish maintenance and life characteristics.

4.2.4.1 Mean Time Before Failure/Replacement. Sufficient data shall be gathered from the above life tests and also from component suppliers to estimate the MTBF and MTBR for the given design configuration.

4.2.5 Engineering Critical Component Qualification Tests. Components for which reliability data are not available shall be subjected to sufficient accelerated or extended life testing to estimate their impact on overall device MTBF.

4.3 Verification of Conformance. Verification that the requirements of sections 3 and 5 of this specification are fulfilled shall be performed by the contractor by the methods specified in Table 2. The methods of verification are defined as follows:

(a) Inspection - examination and measurement of product.

Table 2

THERMAL STORAGE SUBSYSTEM REQUIREMENTS VERIFICATION MATRIX

Verification Method	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Acceptance Test B. Qualification Tests (including life tests and critical component qualification)

N/A denotes "not applicable"

Requirements (by paragraph)	Verification Method(s)	Test Category	Remarks
3.1 Thermal Storage Subsystem Definition	N/A	N/A	
3.1.1 Thermal Storage Subsystem Diagram	N/A	N/A	
3.1.2 Interface Definition	N/A	N/A	
3.1.2.1 TSS/Receiver Subsystem	1, 2, 4	A	
3.1.2.2 TSS/Electrical Power Generation Subsystem	1, 2, 4	A	
3.1.2.3 TSS/Master Control	2, 3, 4	A	Master control inputs may be simulated for subsystem tests.
3.1.2.4 TSS Major Components	1	N/A	
3.1.3 Major Component List	N/A	N/A	
3.2 Characteristics	N/A	N/A	

Table 2

THERMAL STORAGE SUBSYSTEM REQUIREMENTS
VERIFICATION MATRIX (Continued)

Requirements (by paragraph)	Verification Method(s)	Test Category	Remarks
3.2.1 Performance	2,4	A	
3.2.2 Physical Characteristics	1,2		
3.2.3 Reliability	2	N/A	Verify in design review.
3.2.4 Maintainability	2	N/A	Verify in design review.
3.2.5 Availability	2	N/A	Verify in design review.
3.2.6 Environmental Conditions	N/A	N/A	
3.2.6.1 General	2	N/A	
3.2.6.2 Transportation and Handling	N/A	N/A	
3.2.6.2.1 Temperature	N/A	N/A	See entry for 3.2.6.1
3.2.6.2.2 Humidity	N/A	N/A	See entry for 3.2.6.1
3.2.6.2.3 Vibration	2,3	N/A	
3.2.6.2.4 Shock	N/A	N/A	See entry for 3.2.6.1
3.2.6.2.5 Other Conditions	N/A	N/A	See entry for 3.2.6.1
3.2.6.3 Operational	2,3,4	B	Make maximum use of SRE test data

Table 2

THERMAL STORAGE SUBSYSTEM REQUIREMENTS VERIFICATION MATRIX (Continued)

Requirements (by paragraph)	Verification Method(s)	Test Category	Remarks
3.2.6.3.1 Temperature	N/A	N/A	See entry for 3.2.6.3
3.2.6.3.2 Humidity	N/A	N/A	See entry for 3.2.6.3
3.2.6.3.3 Wind	2,3,4	B	Make maximum use of SRE test data
3.2.6.3.4 Sand and Dust	2,3,4	B	Make maximum use of SRE test data
3.2.6.3.5 Rain, Hail and Snow	N/A	N/A	See entry for 3.2.6.3
3.2.6.3.6 Lightning	1,2	N/A	
3.2.6.3.7 Earthquake	2	N/A	
3.2.7 Transportability	2,5	N/A	
3.3 Design and Construction	1,2,4	N/A	
3.3.1 Materials, Process, and Parts	1,2	N/A	
3.3.2 Electrical Transients	1,2,3	N/A	
3.3.3 Electromagnetic Radiation	2,3	N/A	
3.3.4 Nameplate	1	N/A	

Table 2

THERMAL STORAGE SUBSYSTEM REQUIREMENTS
VERIFICATION MATRIX (Continued)

Requirements (by paragraph)	Verification Method(s)	Test Category	Remarks
3.3.5 Workmanship	1	N/A	
3.3.6 Interchangeability	1, 2, 5	N/A	
3.3.7 Safety	1, 2	N/A	
3.3.8 Human Engineering	2	N/A	
3.4 Documentation	N/A	N/A	
3.4.1 Characteristics and Performance	1, 2	N/A	
3.4.2 Instructions	1, 2	N/A	
3.4.3 Construction	1, 2	N/A	
3.5 Logistics	2	N/A	
3.5.1 Maintenance	2	N/A	
3.5.2 Supply	2	N/A	
3.5.3 Facilities and Facility Equipment	TBD	TBD	To be determined after site selection
3.6 Personnel and Training	N/A	N/A	

Table 2

THERMAL STORAGE SUBSYSTEM REQUIREMENTS VERIFICATION MATRIX (Continued)

Requirements (by paragraph)	Verification Method(s)	Test Category	Remarks
3.6.1 Personnel	2	N/A	
3.6.2 Training	2	N/A	
3.7 Major Component Characteristics	N/A	N/A	
3.7.1 Thermal Storage Unit	2,4	A	
3.7.2 Thermal Storage Heater	2,4	A	
3.7.3 Desuperheater	2,4	A	
3.7.4 Steam Generator	2,4	A	
3.7.5 Auxiliary Feedwater Heater	2,4	A	
3.7.6 Thermal Charging Loop Pump	1,2,4	A, B	
3.7.7 Energy Extraction Loop Pump	1,2,4	A, B	
3.7.8 Ullage Maintenance Unit	1,4,5	A	
3.7.9 Fluid Maintenance Unit	1,4,5	A	

Table 2

THERMAL STORAGE SUBSYSTEM REQUIREMENTS VERIFICATION MATRIX (Continued)

Requirements (by paragraph)	Verification Method(s)	Test Category	Remarks
3.8 Precedence	N/A	N/A	
5.0 Preparation for Delivery	N/A	N/A	
5.1 General	2, 5	N/A	
5.2 Preservation and Packaging	2, 5	N/A	
5.3 Packing	1, 2, 5	N/A	
5.4 Handling and Transportability	1, 2, 5	N/A	
5.5 Marking	1	N/A	

(b) Analysis - examination of the design and associated data, which may include relevant test information.

(c) Similarity - demonstration or acceptable evidence of the performance of sufficiently similar product to permit conformance to be inferred.

(d) Test - functional operation or exposure under specified conditions to evaluate product performance.

(e) Demonstration - exhibition of the product or service in its intended modes and conditions.

4.3.1 Hardware Acceptance for POCE. The contractor shall provide a system by which conformance of hardware to the approved design and any authorized changes thereto will be verified prior to initiation of subsystem level tests. This verification of conformance to design shall include proof-by-assembly and the examination of records as elements of inspection. A record shall be made of each inspection or test performed and of the verification. In addition, evidence shall be maintained of satisfactory accomplishment of inspections and tests required by codes and standards applicable to the thermal storage subsystem.

5.0 PREPARATION FOR DELIVERY

5.1 General. Packaging for thermal storage subsystem components shall provide adequate protection during shipment by common carrier from supplier to the first receiving activity for immediate use or temporary storage.

5.2 Preservation and Packaging. Subsystem components that may be harmed when exposed to the normal transportation and handling environments (paragraph 3.2.6) shall be protected by inert environments, barrier materials, or equivalent techniques.

5.3 Packing. Shipping containers and their cushioning devices shall ensure protection of thermal storage subsystem components when exposed to the shock and vibrations loads defined in paragraph 3.2.6. Containers shall meet, as a minimum, the requirements in the following regulations as applicable to the mode of transportation utilized.

(a) National Motor Freight Classification (Highway Transportation)

(b) Uniform Freight Classification (Railroad Transportation)

(c) CAB Tariff 96 and 169 (Air Transportation)

(d) R. M. Graziano's Tariff 29 (For Dangerous Articles Surface)

(e) CAB Tariff 82 (For Dangerous Articles Air)

5.4 Handling and Transportability. Containers with gross weights exceeding 60 pounds shall have skids and other provisions for handling by standard materials handling equipment. When feasible, container sizes and configurations shall be compatible with efficient utilization of transport vehicles.

5.5 Marking. Unless otherwise specified, container marking shall be standard commercial practice.

APPENDIX 4 POCE Electrical Power Generation Subsystem

ELECTRICAL POWER GENERATION SUBSYSTEM
REQUIREMENTS SPECIFICATION

APRIL 1975

Electrical Power Generation Subsystem design parameters are highly sensitive to the local meteorological conditions and water availability at the selected POCE site. The values provided in this specification reflect the subsystem requirements for a baseline with an assumed location in Inyokern, California. These values will be modified as appropriate following POCE site selection.

VOLUME 2
PART 1
APPENDIX 4

CONTENTS

CONTENTS (Continued)

1.0 SCOPE

This specification establishes the performance, design, and test requirements for the POCE (pilot plant) electrical power generation subsystem.

2.0 APPLICABLE DOCUMENTS

The equipment, materials, design, and construction of the electrical power generation subsystem shall comply with all Federal, state, local, and user standards, regulations, codes, laws, and ordinances which are currently applicable for the selected site and the using utility. These shall include but not be limited to the government and non-government documents itemized below. If there is an overlap in or conflict between the requirements of these documents and the applicable Federal, state, county, or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent shall take precedence.

The following documents of the issue in effect on the date of request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Government Documents

2.1.1 Specifications

Regulations of the Occupational Safety and Health Administration (OSHA)

Regulations of the California Occupational Safety and Health Administration (CAL/OSHA) - if required

2.1.2 Other Publications

National Motor Freight Classification 100B - Classes and Rules Apply on Motor Freight Traffic

Uniform Freight Classification 11 - Railroad Traffic Ratings Rules and Regulations

CAB Tariff 96 - Official Air Transport Rules Tariff

CAB Tariff 169 - Official Air Transport Local Commodity Tariff

R. H. Graziano's Tariff 29 - Hazardous Materials Regulations of the Department of Transportation

CAB Tariff 82 - Official Air Transport Restricted Articles Tariff

2.2 Non-Government Documents

2.2.1 Standards

American National Standards Institute - Piping Codes

Institute of Electrical and Electronic Engineers Code - Switchgear and Transformers

National Electrical Code - Wiring

National Electrical Manufacturers Association (NEMA) Standards - Motor, Starters

Instrument Society of America Standards

American Society for Testing Materials Standards

Uniform Building Code - 1973 Edition, Volume 1 by International Conference of Building Officials

American Society of Mechanical Engineers Pressure Vessel Codes including Unified Pressure Vessels

American Society of Mechanical Engineers Power Test Codes - Heat Exchanger, Turbines, etc.

American Society of Mechanical Engineers Performance Code (Turbine Efficiency, Heat Exchanger, Condenser Performance, Pump Performance)

Hydraulic Institute Standards - Pumps

Welding Code

National Electric Code, NFPA 70-1971 (ANSI C1-1971)

3.0 REQUIREMENTS

3.1 Electrical Power Generation Subsystem Definition. The electrical power generation subsystem for the POCE shall provide the means for transforming the thermal output of the receiver and/or thermal storage subsystems into 10 MWe net of 60 Hz electrical power at 13,200 volts. The output from the electrical power generation subsystem shall be regulated suitably for integration into existing electrical power system networks. The subsystem shall also provide for conditioning the steam as required to maintain proper system operation. The electrical power generation subsystem shall consist of:

(a) The high-pressure steam supply header, valves, and controls

(b) The steam turbine (prime mover)

(c) The electrical generator

(d) The low-pressure exhaust header, condenser, valves and controls

(e) The heat rejection unit, pumps, valves, and fittings

(f) Feedwater return piping, pumps, valves, heaters, and controls

(g) Water treatment equipment

(h) The controls required to (1) regulate the steam flow, temperature, as pressure as well as the 60 Hz electrical output voltage and amperage, as required, (2) vary the electrical load as necessary to maintain the required working fluid conditions.

(i) Subsystem power grid

(j) Plant auxiliaries

(k) Emergency power

(l) The electrical connections, cabling, metering, relaying, switching, and controls to the electrical power transmission network.

The electrical power generation subsystem design shall not require new development in scaling to a commercial power generation subsystem ranging in size from 100 to 300 MWe. The POCE subsystem tests shall be controlled by the master control in coordination with the control of the receiver, thermal storage, and collector subsystems.

3.1.1 Electrical Power Generation Subsystem Diagram. Figure 1 shows a schematic of the electrical power generation subsystem and its interfaces with other subsystems. Figure 2 shows the functional flows between the major elements of the electrical power generation subsystem, and between the electrical power generation subsystem and other interfacing subsystems.

3.1.2 Interface Definition. The physical and functional interfaces between the electrical power generation subsystem and the other subsystems or elements thereof are as follows.

3.1.2.1 Electrical Power Generation Subsystem/Receiver. Connections and mounting fixtures shall be provided to match those of the receiver subsystem. Power shall also be provided at (TBD) volts to operate receiver subsystem pumps, valves, and controls.

(a) Superheated Steam Header. The electrical power generation subsystem shall be designed to connect the superheated steam header with the receiver downcomer and accept superheated steam at the rated capacity of the receiver subsystem, including a design-point flowrate of 14 kg/sec (110,000 lb/hr), static pressure of 10 MN/m^2 (1,450 psia) and a temperature of 475 degrees C (890 degrees F).

(b) Feedwater Return. The electrical power generation subsystem shall be designed to connect the feedwater return header with the receiver riser and deliver condensate upstream of the alternate feedwater heater and main boost pump, at a design-point flowrate of 14 kg/sec, (110,000 lb/hr), static pressure of 2.85 MN/m^2 (410 psia) and a temperature of 205 degrees C (400 degrees F).

3.1.2.2 Electrical Power Generation Subsystem/Thermal Storage. Connections and mounting fixtures shall be provided to match those of the thermal storage subsystem. Auxiliary power shall also be provided at (TBD) volts to run thermal storage subsystem pumps, valves, and controls.

(a) Superheated Steam Header. The electrical power generation subsystem shall be designed to connect the superheated steam header with the thermal storage subsystem and receive the superheated steam at the rated delivery capacity of the thermal storage

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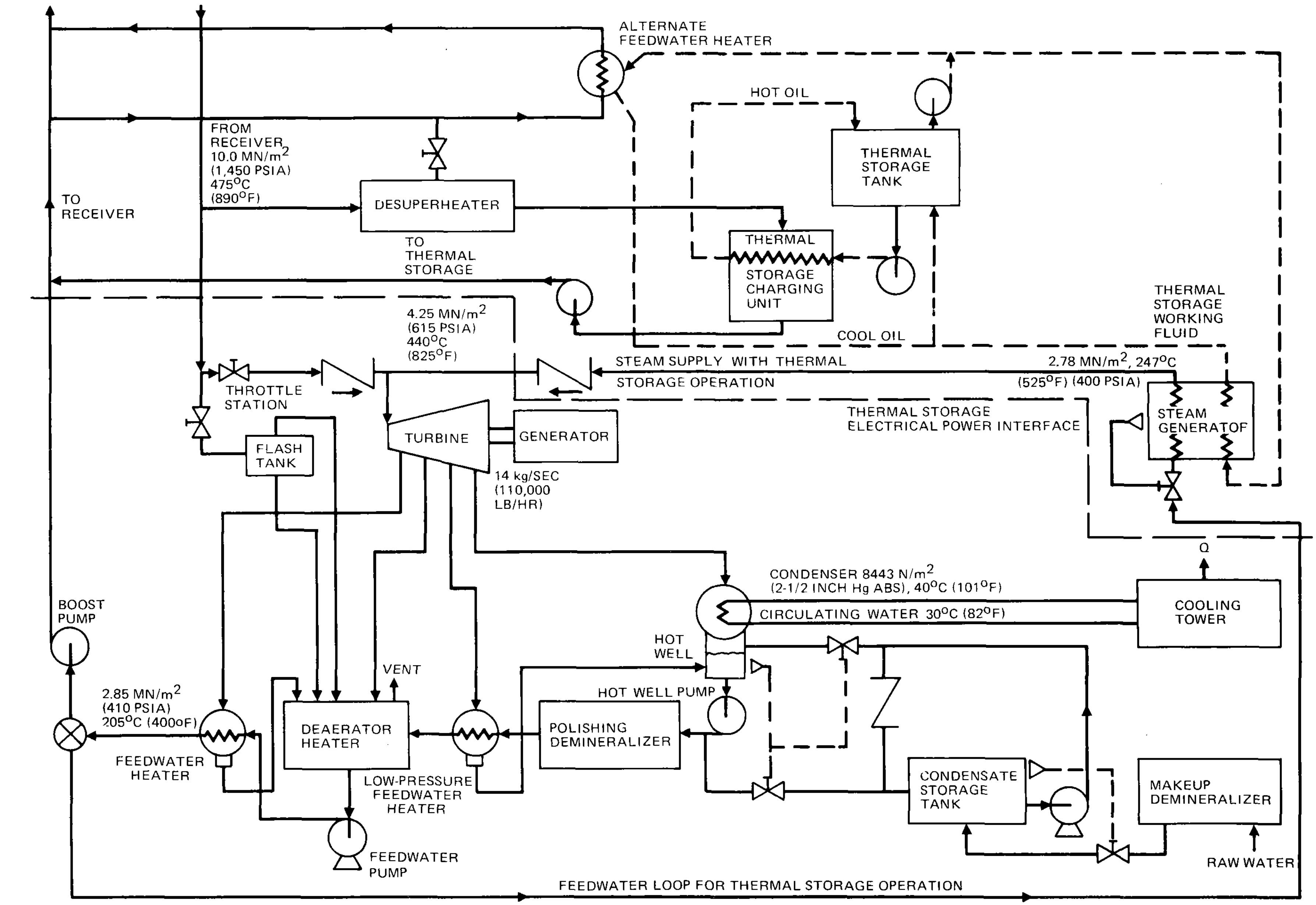


Figure 1. Plant Schematic

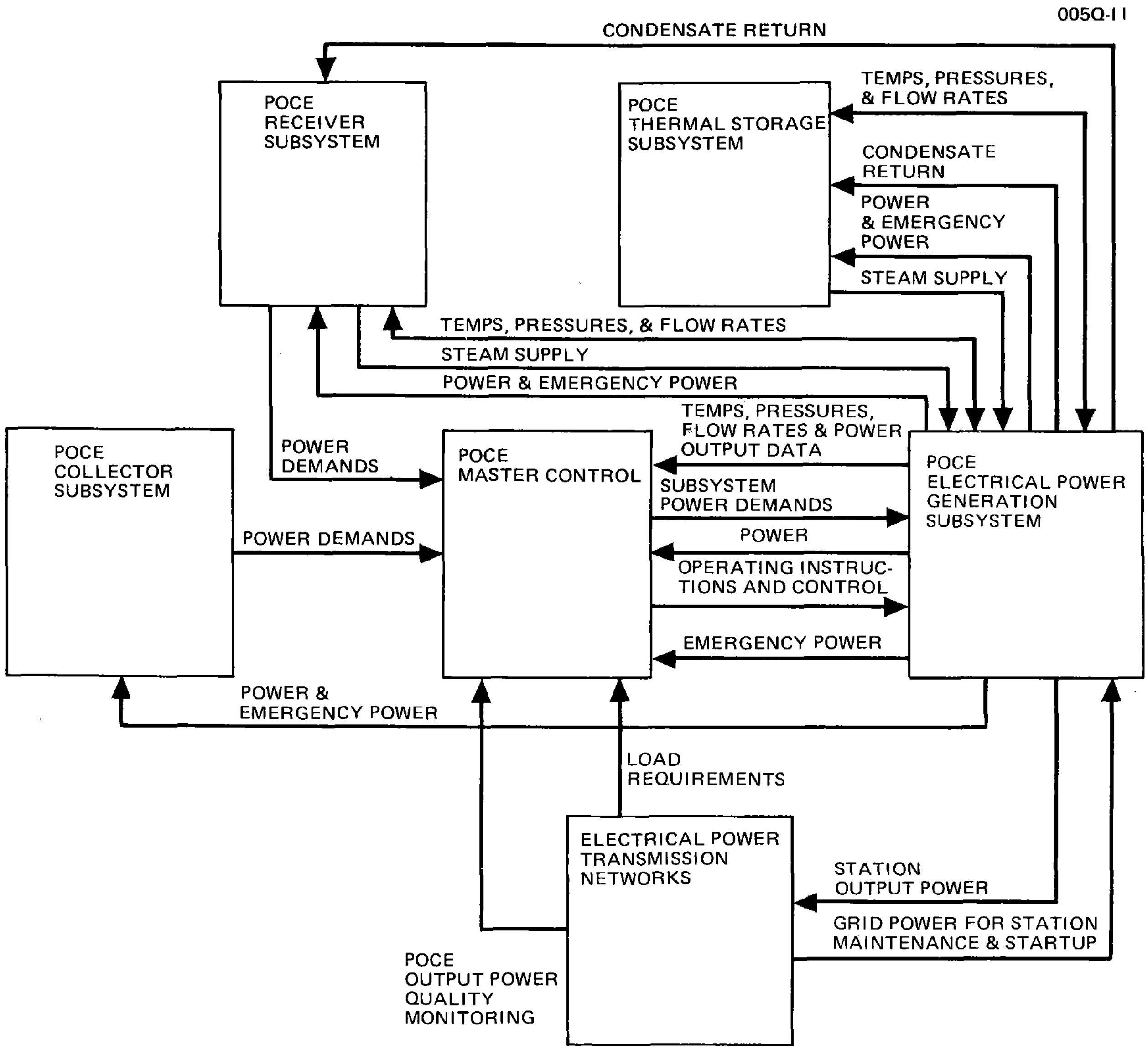


Figure 2. Functional Interfaces Between the Electrical Power Generation Subsystem and Other Operating Elements

subsystem during thermal storage discharge at a maximum flow rate of 12.9 kg/sec (101,000 lb/hr), static pressure of 2.8 MN/m^2 (400 psia), and a temperature of 275 degrees C (525 degrees F).

(b) Feedwater Return. The electric power generation subsystem shall be designed to connect the feedwater return header with the thermal storage subsystem and deliver condensate to the steam generator of the thermal storage subsystem during thermal storage discharge at a maximum flowrate of 12.9 kg/sec (101,000 lb/hr), static pressure of 2.85 MN/m^2 (410 psia) and a temperature of 105 degrees C (220 degrees F).

3.1.2.3 Electrical Power Generation Subsystem/Collector Subsystem. The electrical power generation subsystem shall include a power grid to deliver 3KVA electric power at 277 volt single phase to operate each heliostat during all POCE operating phases. The dimensions and details are (TBD).

3.1.2.4 Electrical Power Generation Subsystem/Master Control Unit. The electrical power generation subsystem controls shall be responsive to standard control signals (per power industry practice) from the POCE master control.

3.1.2.5 Electrical Power Generation Subsystem/Electrical Power Transmission Network. The electrical power generation subsystem shall be designed to connect to an electrical power transmission network and deliver 10 MWe net of regulated 60 Hz electrical power at 13,200 volts.

3.1.3 Major Component List. The electrical power generation subsystem shall be comprised of the following:

(a) Turbine

(b) Generator and excitation system

(c) Condenser

(d) Low-pressure feedwater heater

(e) Deaerator heater

(f) High-pressure heater

(g) Hot well pump(s)

(h) Feedwater pump(s)

(i) Water treatment equipment

(j) Plant power grid

(k) Cooling tower

(l) Circulating pumps

(m) Transformers

(n) Circuit breakers

(o) Electrical connections, cabling, metering, controls, and switch gear

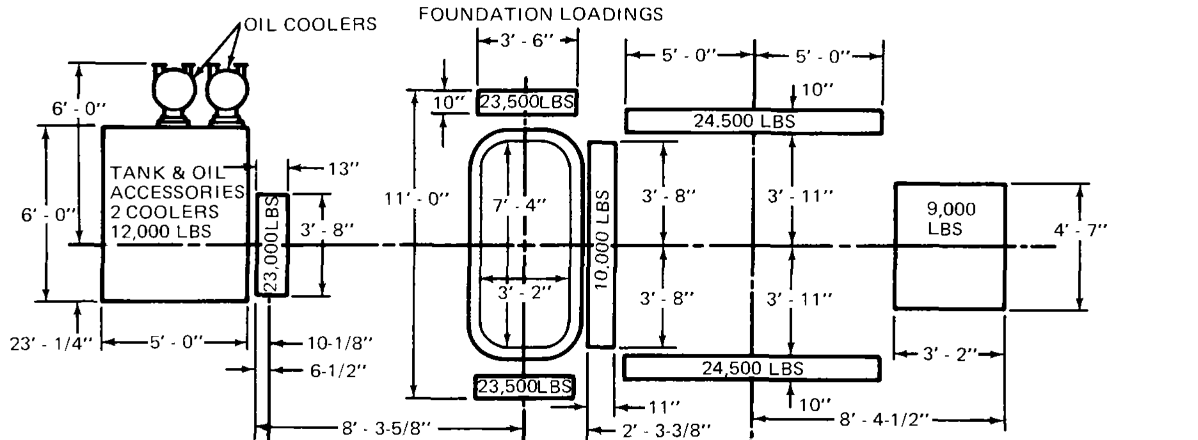
(p) Emergency power supply

3.2 Characteristics

3.2.1 Performance. The electrical power generation subsystem shall be designed to efficiently convert the available thermal energy into 60 Hz electrical power at 13,200 volts which is synchronized with the electrical network. A net electrical power output of 10 MW shall be available when a stream flow rate of 14 kg/sec (110,000 lb/hr) at a temperature of 441 degrees C (825 degrees F) and pressure of 4.25 MN/m^2 (615 psia) is supplied at the turbine inlet. These steam conditions shall be developed at the outlet of the turbine inlet steam conditioning and regulation equipment. A net electrical output of 7 MW shall be available when the turbine is powered by steam from the thermal storage subsystem at conditions defined in paragraph 3.1.2.2(a). During the 10 MW net electric design point operation, 21 ±3 percent of the turbine inlet steam flow is extracted for feedwater heating. The feedwater temperature shall be elevated to a maximum of 205 degrees C (400 degrees F) while a maximum of 25 MWth (85,000,000 Btu/hr) heat shall be rejected to the condenser. During deferred operational periods, sufficient steam shall be extracted to raise the feedwater temperature to 105 degrees C (220 degrees F) entering the steam generator. The water treatment facility shall be capable of providing makeup feedwater at a maximum flowrate of 3.6×10^{-4} m^3/sec (5.7 gpm), with dissolved solids being reduced to 20 to 50 PPB and the pH being maintained at 9.5. Heat rejection loop circulating water shall be treated with sulfuric acid, phosphate, and chlorine to prevent the formation of algae and scaling deposits while maintaining the pH at 7. Instrumentation and subsystem control equipment shall be compatible with the master control and satisfy all interface specifications identified in Appendix 5.

3.2.2 Physical Characteristics. Sizes, shapes, dimensions, and weights of a representative 10 MWe turbine-generator combination are depicted in Figure 3. The cooling tower shall be a two cell configuration of a redwood or fir construction with nominal dimensions of 12m long x 17m wide x 10m high (40 x 55 x 32 ft). The entire subsystem shall be designed to provide

WEIGHTS	LBS
NET WEIGHT	153,000
SHIPPING WEIGHT	168,000
HEAVIEST PART BEFORE ASSEMBLY-TURBINE	70,000
HEAVIEST PART AFTER ASSEMBLY-TURBINE UH	24,500



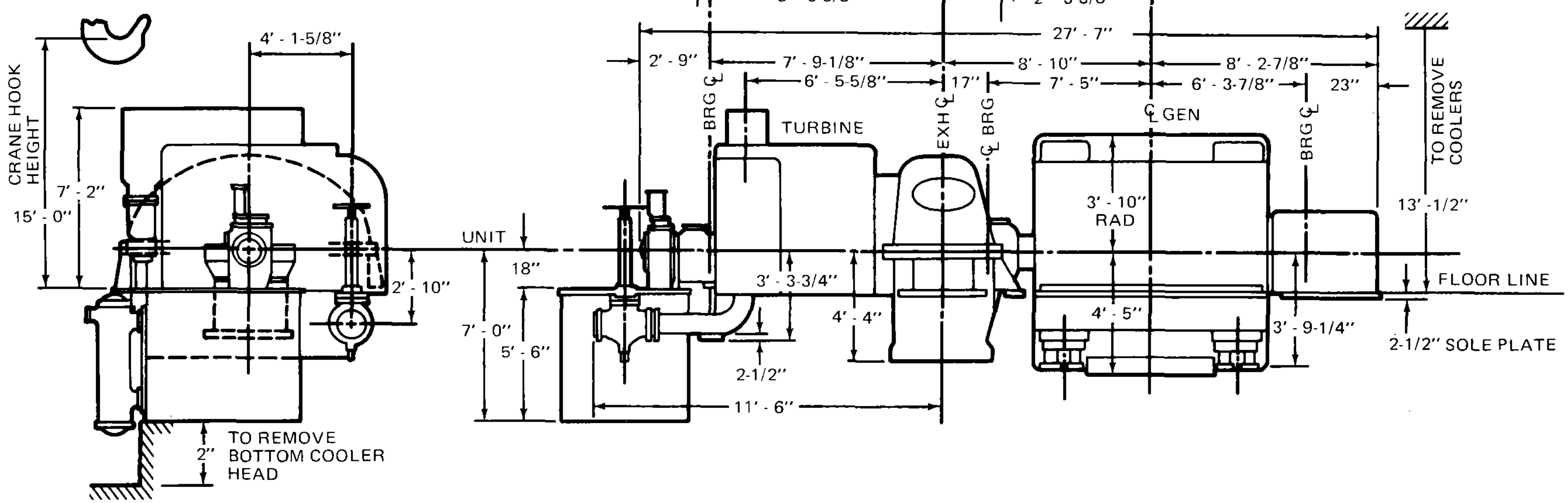


Figure 3. Representative 10 MW Turbine-Generator Physical Characteristics

safe ingress, egress, and access for proper inspection, maintenance, and repair of the structure, fluid flow lines, utilities, instrumentation and controls for each element or component. The elements or components of the subsystem shall be so configured and located within or relative to other portions of the solar thermal power plant as to minimize adverse effects on the other subsystems.

3.2.3 Reliability. High reliability shall be achieved in the electrical power generation subsystem design by providing adequate operating margins, maximizing the use of proven standard parts, and using conservative design practices such that the reliability performance shall not degrade the capability to achieve the availability specified in paragraph 3.2.5 when operated in the environments specified in paragraph 3.2.6.

Single-point failures that result in the loss of capability to generate electrical power or maintain synchronization with the electrical power transmission network shall be eliminated wherever practical. In cases where it is impossible to eliminate such failure modes, suitable devices shall be used to detect and warn of the occurrence of a failure.

3.2.4 Maintainability. The electrical power generation subsystem shall be designed such that required services can be accomplished by personnel of normal skills, with a minimum of nonstandard tools or special equipment.

The electrical power generation subsystem shall be designed to provide malfunction indication and fault isolation information data required by the master control concerning critical components (TBD). Critical components are those components that, because of failure risk, downtime, or effect on the overall POCE performance, materially affect the capability to achieve the system availability requirements.

Items which do not have a redundant mode of operation shall incorporate maximum capability for on-line repair or replacement. These items might include, for example, temperature and pressure sensors, and actuators for valves.

The electrical power generation subsystem shall be designed such that potential maintenance points can be easily reached, components such as electronic modules readily replaced, valves marked for visual indication of position, and elements subject to wear or damage such as pumps, valves, and gears, easily serviced or replaced.

3.2.5 Availability. The electrical power generation subsystem shall operate in accordance with paragraph 3.2.1 performance requirements 99.5 percent of its scheduled operating time based on reliability and maintainability exclusive of insolation conditions. Determinations of availability shall use as a time reference a period of one year.

3.2.6 Environmental Conditions

3.2.6.1 General. The conditions described in the following paragraphs are representative of the transportation and operating site environments to be encountered by the electrical power generation subsystem. Safety margins or protective devices shall be used commensurate with availability and performance requirements to ensure operation in accordance with paragraph 3.2.1 during or after exposure to these conditions.

3.2.6.2 Transportation and Handling. The following conditions occurring separately or in combination may be encountered by packaged equipment during handling and transportation.

3.2.6.2.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.6.2.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.6.2.3 Transportation Vibration and Shock. Vibration and shock as encountered during transport. Conditions are as follows:

VIBRATION

Transportation Mode	Continuous Excitations (Steady-State) in g's	Discrete Impulse (Transient) in g's	Predominant Frequency Range
Highway	0.06	1.5	2 to 200 Hz
Rail	0.05	1.5	2 to 200 Hz
Air (Jet Aircraft)	0.05	1.5	2 to 500 Hz

SHOCK (g's)
(Normal Load Limits)

Transport Media	Longitudinal	Lateral	Vertical	Average Pulse Time msec
Air	2.0	1.5	2.0	11-40
Highway	2.0	1.5	3.0	11-40
Rail (Rolling) (1)	3.0	0.75	3.0	11-40
Cushion Car (Humping)	3.0	2.0	3.0	11-40

(1) Shock loads are for rail cars equipped with standard draft gears.

All critical (frangible) components of the electrical power generation subsystem shall be designed or packaged such that the conditions described above do not induce a dynamic environmental condition which exceeds the structural capability of the component. These conditions reflect careful handling and firmly constrained (tied down) transporting via common carrier.

All components shall be designed to withstand handling/hoisting inertial loads up to 2 g's considering number, location, and type of hoisting points.

3.2.6.2.4 Handling Shock. Handling shocks may result from drops of packaged equipment. Corresponding acceleration peaks may be of the order of 7 g's vertical and 4 g's horizontal with a (TBD) wave profile and a duration of 10 to 50 milliseconds.

3.2.6.2.5 Other Conditions. The equipment may encounter other conditions during transportation and handling including wind, rain, snow, ice, hail, and blowing sand and dust. These are not expected to exceed the operational conditions of paragraph 3.2.6.3.

3.2.6.3 Operational. The following conditions occurring separately or in combination may be encountered by the electrical power generation subsystem during the pilot plant 30-year operational life. Unless specified otherwise, the electrical power generation subsystem shall be designed to perform in accordance with paragraph 3.2.1 during and after exposure to these conditions.

3.2.6.3.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.6.3.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.6.3.3 Wind. Sustained surface winds up to 8.9 m/sec (20 mph) for a period of (TBD) hours with gust RMS velocities up to 11.6 m/sec (25.9 mph).

While nonoperational, the electrical power generation subsystem shall not be damaged by surface winds of 35.7 m/sec (79.9 mph) for periods up to (TBD) hours with gust RMS velocities to 46.4 m/sec (103.8 mph). These are derived from 35.7 m/sec (79.9 mph) base, 50-year fastest mile (Reference ASCE Paper 3269, Vol. 126). Maximum steady winds with gusts during operation are to be considered throughout a complete daylight operational period. Practices recommended in the ASCE Paper 3269, Vol. 126 and the Uniform Building Code, 1973, Vol. 1 shall be employed in designing the electrical power generation subsystem for winds.

3.2.6.3.4 Sand and Dust. The subsystem shall not evidence operational degradation or component destruction following exposure to sand and dust storms. The design shall withstand dust fluxes of 10^{-4} g/cm^2-sec at velocities up to (TBD) meters/second. Dust is defined to be those particles up to 100 μm in diameter with the mean diameter being 40 to 50 μm.

Sand is defined as particles greater than 100 μm in diameter. Desert sand flux declines approximately exponentially with height above the surface. For the surface roughness expected at the POCE site, 90 percent of the sand flux will be within 25cm (10 inches) of the surface. The design shall withstand a sand flux which averages 0.3 g/cm^2-sec within that region at velocities up to (TBD) m/sec.

The frequency of storm occurrence and duration to be considered will depend on the site selected. For example, in the Southwestern desert area a major storm frequency of four or less per year with a maximum duration of 36 hours is to be assumed. Nine minor storms per year with a maximum duration of 6 hours is to be assumed.

The effect of dust devils shall also be considered in the design. The maximum core diameter and tangential velocities to be considered are 70m (230 ft) and 30 m/sec (98 ft/sec) respectively. The maximum vertical velocity to be considered is 15 m/sec (49 ft/sec).

Subsystem components shall be protected from the electrostatic charging and discharging associated with sand and dust storms where appropriate.

3.2.6.3.5 <u>Rain, Hail, and Snow.</u> Storms of the following types and intensities:

Rain: Average storm intensity of (TBD) cm/hour (TBD in/hr) for (TBD) hours with peak periods of (TBD) cm/hour (TBD in/hr) lasting (TBD) minutes. Three to five storms per year.

Hail: Mean particle diameter of 5 to 10 mm (0.20 to 0.39 inches) extreme maximum diameter of 25 mm (1 inch). Fall velocity of 20 m/sec (65.6 ft/sec). Hail stone compressive strength of 1.03 MN/m^2 (150 psi) for 25 mm stone; 5.07 MN/m^2 (735 psi) for stones less than 10 mm (0.39 inches) in diameter. Storm intensity of (TBD) particles per square meter per minute lasting 10 to 20 minutes. Frequency of occurrence - one in 5 to 6 years.

Snow: (TBD)

3.2.6.3.6 Lightning. The subsystem shall be designed to withstand a lightning threat that has a current pulse of 140,000 amperes with a 1.5-microsecond rise time decaying to 50 percent in 40 microseconds. A continuing current of 200 to 400 amperes will follow the main stroke and last for 160 to 300 milliseconds. Up to 10 restrokes can occur with 30,000 to 70,000 amperes peak current each. Total charge transfer of the primary stroke and the restrokes can reach 200 coulombs.

3.2.6.3.7 Earthquake. The subsystem shall be designed to withstand, without structural damage or yielding, the earthquake environment described in Table 1 and Figure 4. The environment is given in terms of response spectra and ground motion histories for soft rock or firm sediment. If the subsystem is located on competent rock, the above environment may be reduced by 33 percent. If the subsystem is located on soft sediment, the above environment shall be increased by 50 percent. The response spectra or ground motion histories shall be used as input to the analytical model of the soil in both vertical and horizontal directions to assess earthquake-induced loads.

3.2.7 Transportability. Electrical power generation subsystem components shall be designed for transportability within applicable Federal and state regulations by highway and railroad carriers utilizing standard transport vehicles and materials handling equipment. The components, in their packaged condition, shall be capable of withstanding the climatic conditions and shock and vibration environments defined in paragraph 3.2.6.2.

Table 1

EARTHQUAKE HORIZONTAL GROUND MOTION HISTORIES

Location	Year	Component	Scale Factor
El Centro	1940	NS	1.0
El Centro	1934	EW	1.4
Olympia	1949	N10W	1.4
Taft	1952	S69E	1.7

Each ground motion history is to be multiplied by the indicated scale factor.

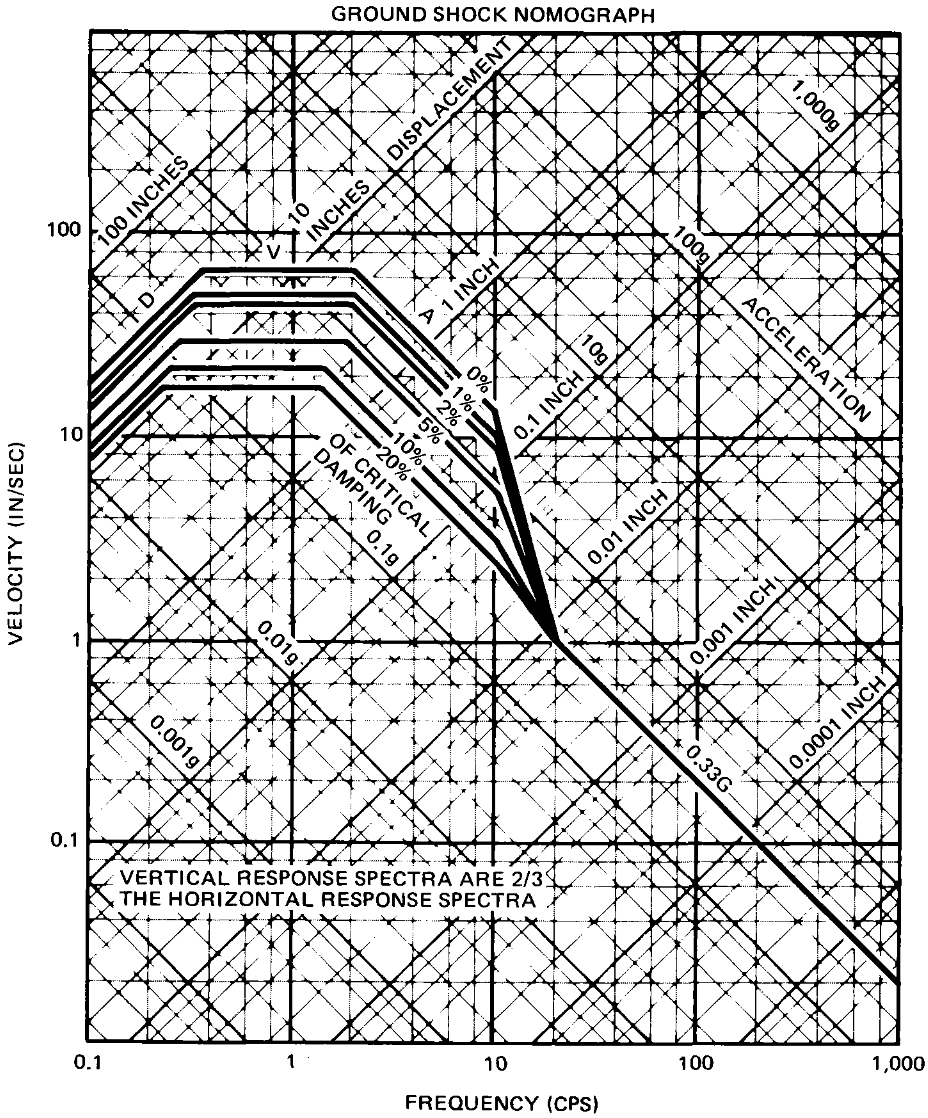


Figure 4. Earthquake Horizontal Response Spectra

Wherever feasible, components shall be segmented and packaged to sizes that are transportable under normal commercial transportation limitations (see (a) below). Subsystem components that exceed normal transportation limits (see (b) below) shall be transportable with the use of special routes, clearances, and permits.

(a) Transportability Limits for Normal Conditions (Permits Not Required)

	Truck	Rail
Height:	13 ft 6 in above road	16 ft 0 in

Width:	8 ft 0 in	10 ft 6 in
Length:	55 ft 0 in - Eastern States 60 ft 0 in - Western States	60 ft 6 in
Gross Weight:	73,280 lb; 18,000 lb/axle	200,000 lb

(b) Transportability Limits for Special Conditions

	Truck	Rail
Height:	14 ft 6 in above road	16 ft 0 in above rail
Width:	12 ft 0 in	12 ft 0 in
Length:	70 ft 0 in	80 ft 6 in

	Truck	Rail
Gross Weight:	100,000 lb with sufficient axles to distribute weight over highway not to exceed 18,000 lb/axle	400,000 lb

3.3 Design and Construction. Design and construction standards compatible with the end use shall be employed.

3.3.1 Materials, Processes, and Parts. To the maximum extent possible, standard materials and processes shall be employed. Highly stressed components and unusual materials shall be avoided. As far as practical, off-the-shelf components used in industry should be employed. Materials and components susceptible to environmental deterioration shall be protected with a suitable coating or protective layer.

3.3.2 Electrical Transients. The subsystem operation shall not be adversely affected by external or internal power line transients caused by normal switching, fault clearing, or lightning. Switching transients and fault clearing functions shall require less than six cycles of the fundamental frequency (100 milliseconds) and shall be limited to 1.7 P.U. voltage (1.7 per unit or 170 percent). Components of the electrical power generation subsystem shall be protected from the lightning threat specified in paragraph 3.2.6.3.6 by surge protection.

3.3.3 Nameplate and Product Marking. All deliverable end items shall be labeled with a permanent nameplate listing, as a minimum, manufacturer name, part number, change letter, serial number and date of manufacture.

All access doors to replaceable/repairable items shall be labeled to show equipment installed in that area, and any safety precautions or special servicing considerations to be observed during servicing.

3.3.4 Workmanship. The level of workmanship shall conform to practices defined in the codes, standards, and specifications applicable to the selected site and the using utility. Where specific skill levels or certifications are required, current certification status shall be maintained with evidences available for examination. Where skill levels or details of workmanship are not specified, the work shall be accomplished in accordance with the level of quality currently in use in the construction, fabrication, and assembly of commercial power plants. All work shall be finished in a manner such that it presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a generally uniform appearance.

3.3.5 Interchangeability. Major components and circuit cards and other items with a common function shall be produced with standard tolerances and connector locations to permit interchange for servicing. Components that have similar appearances but different functions shall incorporate protection against inadvertent, erroneous installation through the use of such devices as keying, connector size, or attachment geometry.

3.3.6 Safety. The electrical power generation subsystem shall be designed to minimize safety hazards to operating and service personnel, the public, and equipment. Electrical components shall be insulated and grounded. All parts or components with elevated temperatures shall be insulated against contact with or exposure to personnel. Any moving elements shall be shielded to avoid entanglements and safety override controls/interlocks shall be provided for servicing. All pertinent OSHA rules and regulations shall be observed.

3.4 Documentation

3.4.1 Characteristics and Performance. Equipment functions, normal operating characteristics, limiting conditions, test data, and performance curves, where applicable, shall be provided.

3.4.2 Instructions. Instructions shall cover assembly, installation, alignment, adjustment, checking, lubrication, and maintenance. Operating instructions shall be included for startup, routine and normal operation, regulation and control, shutdown, and emergency conditions. A guide to troubleshooting instruments and controls shall be provided.

3.4.3 Construction. Engineering and assembly drawings shall be provided to show the equipment construction, including assembly and disassembly procedures. Engineering data, wiring diagrams, and parts lists shall be provided.

3.5 Logistics. The elements required to support the electric power generation subsystem are:

Support and test equipment

Technical publications

Personnel and training

Facilities

Spares, repair parts and consumables

Transportation, handling and packaging

Data file

Field service

The requirements for the elements shall be established as a result of a support requirements analysis to be prepared by the contractor. The results of the analysis shall be documented in accordance with the contract.

3.5.1 Maintenance. Maintenance activities are categorized as follows:

Level 1, On-line maintenance

Level 2, Off-line on-site maintenance

Level 3, Off-line off-site maintenance

Level 1, On-Line Maintenance: The following scheduled and unscheduled maintenance activities shall be identified for the electrical power generation subsystem.

Task	Frequency
Visual inspection	Daily
Remove and replace	(TBD)
Repair in place	(TBD)
Adjust	(TBD)
Align	(TBD)
Calibrate	(TBD)
Lubricate	(TBD)
Paint	(TBD)
Transporting	(TBD)

Level 2, Off-Line On-Site Maintenance: The following maintenance activities shall be identified in the maintenance plan. Frequencies shall be (TBD).

Fault verification

Fault isolation to a removable item

Remove and replace a faulty item

Verify acceptable repaired item

Repair designated subtiered items

Servicing

Lubrication

Visual inspection

Transporting

Level 3, Off-Line Off-Site Maintenance: Level 3 maintenance activities are those to be performed at the equipment supplier's facility. Frequencies and turnaround times shall be (TBD).

Maintenance Plan: A maintenance plan shall be prepared by the contractor which identifies scheduled and unscheduled maintenance requirements. The maintenance plan shall reflect the results of the support requirements analysis and shall specify the following as appropriate.

Use of multi-purpose test equipment

Items to be repaired

Items to be replaced

Maintenance and repair cycles

Use of operational support equipment for maintenance

Level, frequency, and location of maintenance action

Facilities, equipment, and tools

3.5.2 Supply. The selection and positioning of spares, repair parts, and consumables shall be in accordance with the levels of repair as determined by the support requirements analysis, and shall use the following criteria:

Protection Level: Items shall be packaged in accordance with the requirements of section 5.0.

Demand Rate: The mean-time-between-maintenance-actions provided by the maintainability analyses shall be the departure point for spares determinations. The quantities and mix shall be such that there is a (TBD) percent probability of a part being available on demand.

Pipeline: Pipeline quantities shall be determined on system location demand rate and repair cycle times. Resupply methods, distribution and location of system stocks shall be determined after site selection.

Procurement and Release for Production: Long lead time items shall be procured or released early enough to be on-site 30 days prior to initial operation. Other items shall be procured or released lead-time away so as to minimize obsolescence due to design changes, except for those items for which significant cost savings can be achieved through acquisition concurrent with production.

Minimum/Maximum Levels: Minimum and maximum quantities of spares and repair parts to be stocked shall initially be determined by use of predicted failure rates. These levels are to be adjusted as actual usage rates are established.

3.5.3 Facilities and Facility Equipment. To be determined after site selection.

3.6 Personnel and Training

3.6.1 Personnel. The pilot plant is to be installed, checked out, and tested as a proof-of-concept experiment by contractor personnel; then taken over and operated as a commercial power plant by utility personnel. Operation and maintenance personnel requirements shall be satisfied by recruitment from the established utility labor pool. System interface aspects of the electrical power generation subsystem dictate a need for training existing utility people but do not establish a need for new skills or trades. The types and numbers of utility personnel requiring training, along with the unique tasks, are as follows:

Type	No.	Unique Task
TBD	TBD	System startup and shutdown
		Subsystem control maintenance
		Safety requirements
		Emergency operations
		(Others TBD)

3.6.2 Training. The contractor shall prepare and conduct a training program for contractor personnel as necessary for performance of the POCE. The contractor shall conduct a training program for utility personnel in accordance with contractual requirements.

3.7 Precedence. The order of precedence of electrical power generation subsystem requirements and characteristics shall be as follows:

(a) Performance (including scalability to commercial power levels)

(b) Flexibility

(c) Cost

Specific characteristic and requirement precedence shall be established based on system cost effectiveness sensitivity analyses. This specification has precedence over documents referenced herein. The contractor shall notify the procuring activity of each instance of conflicting, or apparently conflicting, requirements within this specification or between this specification and a referenced document.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Tests. All tests shall be performed by the contractor. These tests may be witnessed by ERDA or its representatives or the witnessing may be waived. In either case, substantive evidence of hardware compliance with all test requirements is required.

4.1.2 General Test Requirements. Tests shall be conducted in accordance with a test plan to be prepared by the contractor and approved by ERDA. Specific required tests are identified in subsection 4.2. Tests shall be classified in the test plan as:

(a) Development tests for the purposes of determining the design,

(b) Acceptance tests for the purpose of verifying conformance to design and determining acceptability of product for further operations or for delivery, or

(c) Qualification tests for the purpose of verifying adequacy of design and method of production to yield a product conforming to specified requirements.

Acceptance tests and qualification tests shall be defined for verifications as indicated in subsection 4.3, Table 2. The test of the electrical power generation subsystem in conjunction with another subsystem is regarded as a system test and shall be as specified in the System Requirements Specification.

4.1.3 Previous Tests and Data. Maximum use shall be made of data available from equipment supplier's and hardware tests already completed. Where conformance to this specification can be established at less cost by analysis of such data, tests shall not be required.

4.2 Specific Test Requirements. Specific required tests are defined herein. Additional tests shall be defined by the contractor in the course of design where necessary to properly validate the performance and design integrity of the electrical power generation subsystem.

4.2.1 Subsystem Performance Tests. [This portion will define tests for evaluation of the collector subsystem as fully assembled in order to assure compatibility before attempting system tests.]

4.2.2 Assembly and Subassembly Performance Tests. [Definition to be completed in Phase 1.]

4.2.3 Environmental Tests. [Definition to be completed in Phase 1.]

4.2.4 Materials and Processes Control Tests. [Definition to be completed in Phase 1.]

4.2.5 Life Tests and Analyses. One set of each major subassembly shall be subjected to extended life testing as follows. [Methods TBD.]

4.2.5.1 Mean Time Before Failure/Replacement. Sufficient data shall be gathered from the above life tests and also from component suppliers in order to estimate the MTBF and MTBR for the given design configuration.

4.2.6 Engineering Critical Component Qualification Tests. Components for which reliability data are not available shall be subjected to sufficient qualification testing to estimate their impact on overall device MTBF.

4.3 Verification of Conformance. Verification that the requirements of sections 3 and 5 of this specification are fulfilled shall be performed by the contractor by the methods specified in Table 2. The methods of verification are defined as follows:

(a) Inspection - examination and measurement of product.

(b) Analysis - examination of the design and associated data, which may include relevant test information.

(c) Similarity - demonstration or acceptable evidence of the performance of sufficiently similar product to permit conformance to be inferred.

(d) Test - functional operation or exposure under specified conditions to evaluate product performance.

(e) Demonstration - exhibition of the product or service in its intended modes and conditions.

4.3.1 Hardware Acceptance for POCE. The contractor shall provide a system by which conformance of hardware to the design will be verified prior to initiation of subsystem level tests. This verification of conformance shall include proof-by-assembly and the examination of records as elements of inspection. A record shall be made of each inspection or test performed and of the verfication. In addition, evidence shall be maintained of satisfactory accomplishment of inspections and tests required by codes and standards that apply to the electrical power generation subsystem.

5.0 PREPARATION FOR DELIVERY

5.1 General. Packaging for electrical power generation subsystem components shall provide adequate protection during shipment by common carrier from supplier to the first receiving activity for immediate use or temporary storage.

Table 2

ELECTRICAL POWER GENERATION - POCE
REQUIREMENT VERIFICATION MATRIX

Verification Methods

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

Test Categories

A. Acceptance Test
B. Qualification Test (includes life tests and critical component qualification)

N/A denotes "not applicable"

Requirement (Paragraph)	Verification Method	Test Category	Remarks
3.1 Electrical Power Generation Subsystem Definition	1,2	N/A	
3.1.1 Electrical Power Generation Subsystem Diagram	N/A	N/A	
3.1.2 Interface Definition	N/A	N/A	
3.1.2.1 Electrical Power Generation Subsystem/Receiver	1,2	N/A	
3.1.2.2 Electrical Power Generation Subsystem/Thermal Storage	1,2	N/A	
3.1.2.3 Electrical Power Generation Subsystem/Collector	2	N/A	
3.1.2.4 Electrical Power Generation Subsystem/Master Control Unit	2,4	A, B	
3.1.3 Major Component List	N/A	N/A	
3.2 Characteristics	N/A	N/A	

Table 2

ELECTRICAL POWER GENERATION - POCE
REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

Test Categories

A. Acceptance Test
B. Qualification Test (includes life tests and critical component qualification)

N/A denotes "not applicable"

Requirement (Paragraph)	Verification Method	Test Category	Remarks
3.2.1 Performance	1,2,4	A, B	
3.2.2 Physical Characteristics	1,2	N/A	
3.2.3 Reliability	2	N/A	
3.2.4 Maintainability	2	N/A	
3.2.5 Availability	2	N/A	
3.2.6 Environmental Conditions	N/A	N/A	
3.2.6.1 General	2	N/A	
3.2.6.2 Transportation and Handling	N/A	N/A	
3.2.6.2.1 Temperature	N/A	N/A	See entry for 3.2.6.1
3.2.6.2.2 Humidity	N/A	N/A	See entry for 3.2.6.1
3.2.6.2.3 Transportation Vibration and Shock	2,4	B	

Table 2

ELECTRICAL POWER GENERATION - POCE
REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

Test Categories

A. Acceptance Test
B. Qualification Test (includes life tests and critical component qualification)

N/A denotes "not applicable"

Requirement (Paragraph)	Verification Method	Test Category	Remarks
3.2.6.2.4 Handling Shock	N/A	N/A	See entry for 3.2.6.1
3.2.6.2.5 Other Conditions	N/A	N/A	See entry for 3.2.6.1
3.2.6.3 Operational	2,3,4	B	
3.2.6.3.1 Temperature	N/A	N/A	See entry for 3.2.6.3
3.2.6.3.2 Humidity	N/A	N/A	See entry for 3.2.6.3
3.2.6.3.3 Wind	2,3,4	B	Make maximum use of SRE test data
3.2.6.3.4 Sand and Dust	2,3,4	B	Make maximum use of SRE test data
3.2.6.3.5 Rain, Hail and Snow	N/A	N/A	See entry for 3.2.6.3
3.2.6.3.6 Lightning	2	N/A	

Table 2

ELECTRICAL POWER GENERATION - POCE
REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods	Test Categories
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Acceptance Test B. Qualification Test (includes life tests and critical component qualification)

N/A denotes "not applicable"

Requirement (Paragraph)	Verification Method	Test Category	Remarks
3.2.6.3.7 Earthquake	2	N/A	
3.2.7 Transportability	2.5	N/A	
3.3 Design and Construction	1,2,4	A	
3.3.1 Materials, Processes and Parts	1,2	N/A	
3.3.2 Electrical Transients	2,4	B	
3.3.3 Nameplate and Product Marking	1	N/A	
3.3.4 Workmanship	1	N/A	
3.3.5 Interchangeability	1,2	N/A	
3.3.6 Safety	1,2	N/A	
3.4 Documentation	N/A	N/A	

Table 2

ELECTRICAL POWER GENERATION - POCE
REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

Test Categories

A. Acceptance Test
B. Qualification Test (includes life tests and critical component qualification)

N/A denotes "not applicable"

Requirement (Paragraph)	Verification Method	Test Category	Remarks
3.4.1 Characteristics and Performance	1,2	N/A	
3.4.2 Instructions	1,2	N/A	
3.4.3 Construction	1,2	N/A	
3.5 Logistics	2	N/A	
3.5.1 Maintenance	2	N/A	
3.5.2 Supply	2	N/A	
3.5.3 Facilities and Facility Equipment	TBD	TBD	To be determined after site selection
3.6 Personnel and Training	N/A	N/A	
3.6.1 Personnel	2	N/A	
3.6.2 Training	2	N/A	

Table 2

ELECTRICAL POWER GENERATION - POCE
REQUIREMENT VERIFICATION MATRIX (Continued)

Verification Methods

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

Test Categories

A. Acceptance Test
B. Qualification Test (includes life tests and critical component qualification)

N/A denotes "not applicable"

Requirement (Paragraph)	Verification Method	Test Category	Remarks
3.7 Precedence	N/A	N/A	
5.0 Preparation for Delivery	N/A	N/A	
5.1 General	1,2	N/A	
5.2 Preservation and Packaging	1,2	N/A	
5.3 Packing	1,2	N/A	
5.4 Handling and Transportability	1,2	N/A	
5.5 Marking	1	N/A	

5.2 Preservation and Packaging. Subsystem components that may be harmed when exposed to the normal transportation and handling environments (paragraph 3.2.6) shall be protected by inert environments, barrier materials, or equivalent techniques.

5.3 Packing. Shipping containers and their cushioning devices shall ensure protection of electrical power generation subsystem components when exposed to the shock and vibrations loads defined in paragraph 3.2.6. Containers shall meet, as a minimum, the requirements in the following regulations as applicable to the mode of transportation utilized.

(a)	National Motor Freight Classification	(Highway Transportation)
(b)	Uniform Freight Classification	(Railroad Transportation)
(c)	CAB Tariff 96 and 169	(Air Transportation)
(d)	R. M. Graziano's Tariff 29	(For Dangerous Articles Surface)
(e)	CAB Tariff 82	(For Dangerous Articles Air)

5.4 Handling and Transportability. Containers with gross weights exceeding 60 pounds shall have skids and other provisions for handling by standard materials handling equipment. When feasible, container sizes and configurations shall be compatible with efficient utilization of transport vehicles.

5.5 Marking. Unless otherwise specified, container marking shall be standard commercial practice.

APPENDIX 5 POCE Master Control

MASTER CONTROL

REQUIREMENTS SPECIFICATION

APRIL 1975

This preliminary POCE master control specification presents a description of the conceptual performance and design requirements. Since these requirements are well within the state-of-the-art, no significant master control development problems are anticipated in Phase 2. Consequently, as indicated in Volume 4, the completion of this specification during Phase 1 will be subordinated to the completion of Appendixes 1, 2, 3, and 4.

VOLUME 2
PART 1
APPENDIX 5

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

1.0 SCOPE

This specification establishes the performance, design, and test requirements for the POCE master control.

2.0 APPLICABLE DOCUMENTS

The equipment, materials, design, and construction of the master control shall comply with all Federal, state, local, and user standards, regulations, codes, laws, and ordinances which are currently applicable for the selected site and using utility. These shall include but not be limited to the government and non-government documents itemized below. If there is an overlap in or conflict between the requirements of these documents and the applicable Federal, state, county, or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent shall take precedence.

The following documents of the issue in effect on the date of request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Government Documents

2.1.1 Specifications

Regulations of the Occupational Safety and Health Administration (OSHA).

Regulations of the California Occupational Safety and Health Administration CAL/OSHA - if required

MIL-H-46855, Human Engineering Requirements for Military Systems, Equipment and Facilities

2.1.2 Standards

MIL-STD-454, Standard Central Requirements for Electronic Equipment

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

MIL-STD-1472 Human Engineering Design Criteria for Military Systems, Equipment and Facilities

2.1.3 Other Publications

National Motor Freight Classification 100B - Classes and Rules Apply on Motor Freight Traffic

Uniform Freight Classification 11 - Railroad Traffic Ratings Rules and Regulations

CAB Tariff 96 - Official Air Transport Rules Tariff

CAB Tariff 169 - Official Air Transport Local Commodity Tariff

R. H. Graziano's Tariff 29 - Hazardous Materials Regulations of the Department of Transportation

CAB Tariff 82 - Official Air Transport Restricted Articles Tariff

Design Handbook on Electromagnetic Compatibility, AFSC DH 1-4

Instrumentation Grounding and Noise Minimization Handbook, AFRPL-TR-65-1

Checklist of General Design Criteria, AFSC DH 1-X

2.2 Non-Government Documents

2.2.1 Standards

National Electrical Manufacturers Association (NEMA) Standard
National Electric Code, NFPA 70-1971 (ANSI C1-1971)

3.0 REQUIREMENTS

3.1 Master Control Definition. The master control shall consist of the control and display equipment required to provide integrated overall control and integration of the POCE. The master control shall normally provide automatic control via software resident in the central computer but shall also have provisions for operator manual intervention.

The master control shall be capable of scaling to a larger commercial central receiver power generating system ranging in size from 100 to

300 MWe. In order to accomplish this, the master control shall have a modular design architecture utilizing standard building blocks that can be increased in quantity to handle the increased requirements of a larger plant.

3.1.1 Master Control Diagram. Figure 1 shows the functional interface between the various end items within the master control and the interfaces between the master control and the POCE subsystems.

3.1.2 Interface Definition. The physical and functional interface requirements between the master control and the subsystems are specified in the following paragraphs. The interface requirements defined in this section are those peculiar to each subsystem. General master control requirements are defined in paragraph 3.2.1.1. The master control physical interfaces with the various POCE subsystems are illustrated in Figure 1. The functional flow of information between the master control and the subsystems is shown in Figure 2.

3.1.2.1 Master Control/Collector Subsystem

3.1.2.1.1 Functional Interfaces. The master control shall be capable of performing the following control and checkout functions with respect to the collector subsystem.

(a) Provide each collector field controller with a sun acquisition azimuth and elevation command. This command will point the individual heliostats in that group to the accuracy required to acquire the sun within the 5° field of view of the tracking sensor.

(b) Provide a periodic update of the sun acquisition commands to allow the heliostats to track the sun within the 5° field of view during periods of cloud cover during the day.

(c) Command the total collector field to slew off the receiver in the event of a receiver malfunction or shutdown.

(d) Command the total collector field to a stowage position.

(e) Provide overall control and scheduling of the collector subsystem checkout.

005Q-II

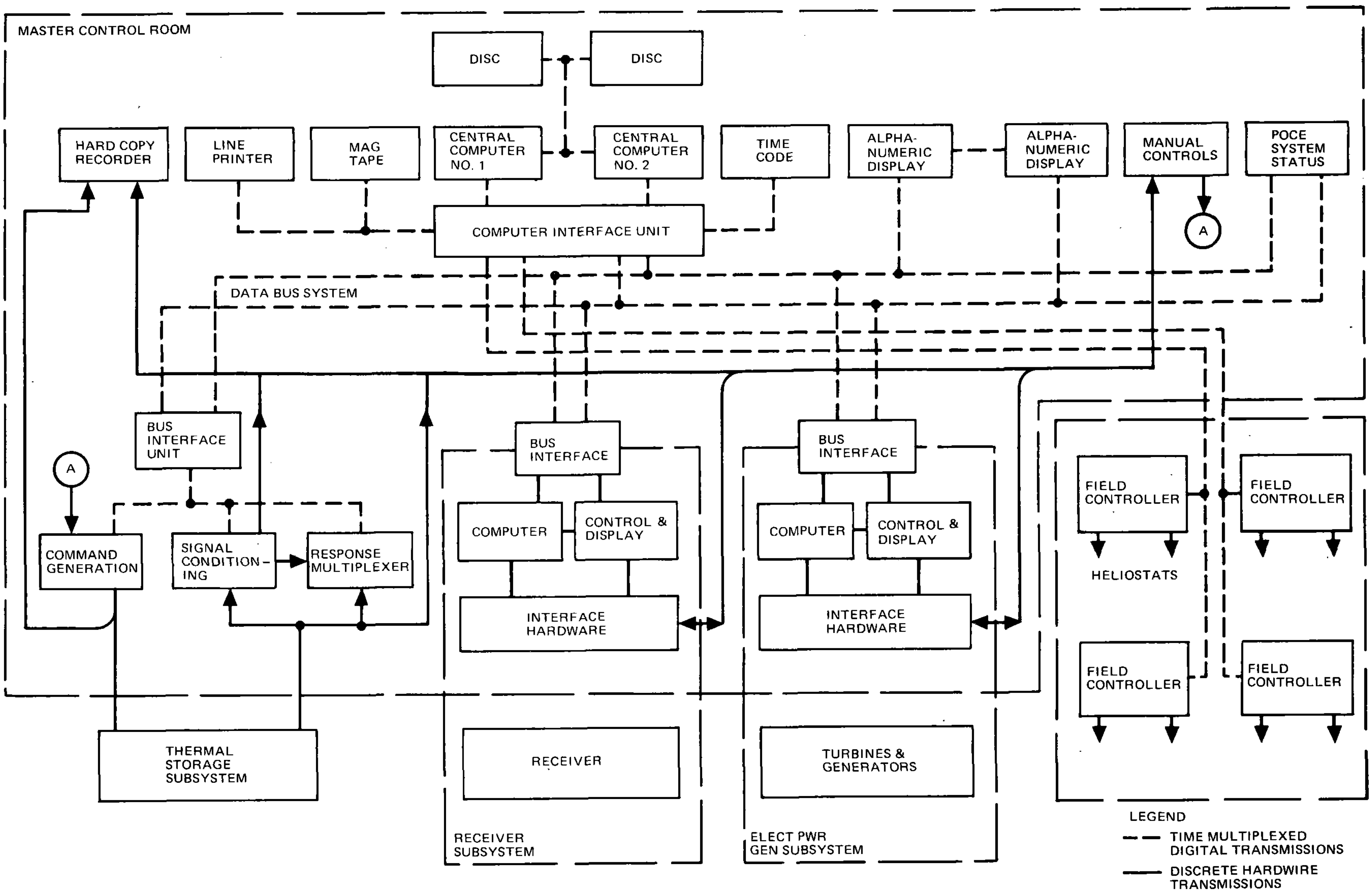


Figure 1. POCE Master Control

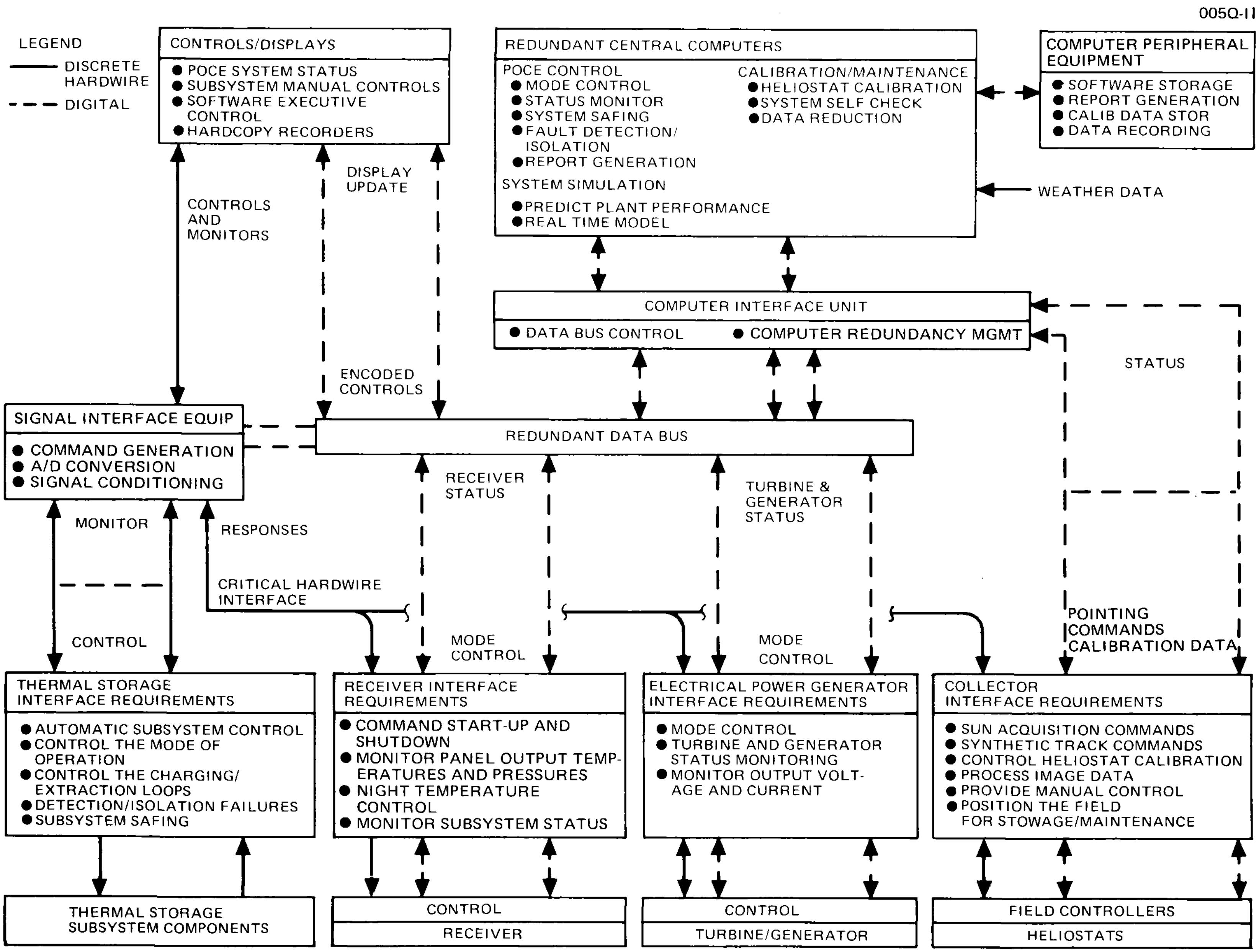


Figure 2. POCE Master Control Information Flow

(f) Detect and isolate faults in the transmission net between the master control and the field controllers.

(g) Display and store field controller and heliostat malfunction data relayed by the field controller.

(h) Store individual heliostat sensor calibration data.

(i) Provide individual heliostat manual control.

(j) Provide offset pointing commands.

(k) Provide an on-line system simulation capability.

3.1.2.1.2 Physical Interfaces. The hardware interface between the master control and the collector subsystem will consist of 16 digital transmission channels. Each channel shall be a half-duplexed, time-multiplexed data path capable of carrying 2 kHz information rate. Biphase encoding shall be utilized to provide DC isolation at each interface. The channels shall be centrally polled by the master control and each message shall require an acknowledgement. Each field controller on any one channel shall have a unique address. The allowable bit error rate on the channel shall be less than (TBD) assuming white Gaussian noise. Erroneous messages shall be detected using reasonability logic at the field controller (e.g., verifying approximate agreement of heliostat pointing angles) and through periodic interrogation of collector status by the master control. Detailed bus formats shall be (TBD).

3.1.2.2 Master Control/Receiver Subsystem

3.1.2.2.1 Functional Interfaces. The master control shall be capable of performing the following control and checkout functions with respect to the receiver subsystem.

(a) Command receiver startup and monitor its operation via the receiver control.

(b) Periodically monitor receiver mode of operation and panel output temperatures and pressures.

(c) Receive an alarm signal in the event of a receiver malfunction and determine the need to offset the collector field.

(d) Command receiver shutdown.

(e) Maintain nighttime temperature control.

3.1.2.2.2 Physical Interfaces. The master control shall interface with the receiver control via redundant digital data buses and limited discrete hardwire control. Data shall be transmitted only on the active bus. The master control shall be responsible for the detection of bus malfunction and the switching of the buses. The receiver control interface mode shall have a unique address and respond only to that address. All messages shall require an acknowledgement to the master control. The data bus shall transmit 1 MHz baseband biphase data and all interfaces with the bus shall be DC isolated. A limited discrete hardwire interface shall be provided to allow the master control to control and monitor critical receiver functions in the event of a computer or data bus system failure. The discrete interface definition and bus format shall be (TBD).

3.1.2.3 Master Control/Thermal Storage Subsystem

3.1.2.3.1 Functional Interfaces. The master control shall be capable of providing direct control over the thermal storage subsystem. In order to accomplish this function the master control shall provide the following:

(a) Automatic control of the thermal storage subsystem.

(b) Determination of the thermal storage mode of operation as a function of the receiver output, time of day, and current weather.

(c) Control of the charging and extraction loops as a function of the mode of operation.

(d) Display of thermal storage subsystem status.

(e) Hardcopy recording and computer storage of thermal storage subsystem status.

3.1.2.3.2 Physical Interfaces. The master control shall interface with the thermal storage subsystem components via discrete hardwire. Required signal conditioning shall be provided by the master control. The hardwire interface requirements defining the component name, type, current voltage, accuracy requirements, etc., are (TBD).

3.1.2.4 Master Control/Electrical Power Generation Subsystem

3.1.2.4.1 Functional Interfaces. The master control shall be capable of performing the following control and checkout functions with respect to the electrical power generation subsystem.

(a) Periodically monitor subsystem status via the electrical power generation subsystem control. Status shall include basic turbine status and generator output voltage, current, and frequency.

(b) Control of the receiver and thermal storage subsystem in the event of a turbine or generator malfunction.

(c) Commanding the turbine mode of operation.

(d) Commanding emergency shutdown in the event of a malfunction in one of the subsystems.

3.1.2.4.2 Physical Interfaces. The master control shall interface with the electrical power generation subsystem control via redundant digital data buses and limited discrete hardwire control. Data shall be transmitted only on the active bus. The master control shall be responsible for the detection of bus malfunction and the switching of the buses. The electrical power generation interface mode shall have a unique address and will only respond to that address. All messages shall require an acknowledgement to the master control. The data bus shall transmit 1 MHz baseband biphase data and all interfaces with the bus shall be DC isolated. A limited discrete hardwire interface shall be provided to allow the master control to control and monitor critical electric power generation function in the event of a computer or data bus failure. The detailed definition of these functions is (TBD).

3.1.3 Major Component List. The master control is comprised of the following major components.

(a) Redundant central computer

(b) Computer interface and self-check logic

(c) Computer peripheral equipment

(1) Redundant disc files

(2) Line printer

(3) Typewriter

(4) Magnetic tape unit

(d) Control and display consoles

(1) Thermal control

(2) POCE master control console

(3) Dedicated subsystem controls and displays

Collector

Thermal storage

Receiver

Electrical power generation

Power distribution

(4) General purpose computer-driven control and display

(e) Digital data bus

(f) Signal interface equipment

(g) Time code generator

(h) Hardcopy recorders

(i) Software

System software

Control application programs

Simulation software

(j) Power distribution equipment

3.2 Characteristics

3.2.1 Performance. The performance requirements of the master control hardware and software are defined in the following paragraphs.

3.2.1.1 General Master Control Functional Requirements. The master control requirements defined in this paragraph are common with respect to all POCE subsystems. They supplement the functional interface requirements defined in paragraph 3.1.2.

The master control shall be capable of meeting the following functional performance requirements.

(a) Provide mode determination (e.g., self-check, startup, shutdown, normal operation, low solar power operation, and night operation).

(b) Provide overall POCE system control as a function of the current performance and status of the individual subsystem.

(c) Provide a POCE system data base that is accessible by the display.

(d) Provide an integrated POCE system status display in engineering units.

(e) Provide emergency hardwire controls.

(f) Predict by a built-in simulation future POCE system power generation capability based on a projection of current subsystem status, time of day, weather, etc.

(g) Provide hardcopy recording and/or computer storage of selected POCE subsystem parameters.

(h) Provide storage of subsystem application programs, self-check results, and calibration data.

(i) Provide an on-line POCE system simulation.

3.2.1.2 Master Control Operating Concepts. The master control shall have three basic modes of operation:

(a) Automatic

(b) On-Line

(c) Manual

In the automatic mode, the POCE system shall be under the control of application programs resident in the active central computer. The standby computer shall be loaded with identical programs but shall not be executing or supporting self-check and maintanance operations. The active programs shall provide control and monitoring of the various POCE subsystems, POCE fault detection and isolation, and the generation of POCE status and error data to hardcopy or recording devices and operator displays. In the event of a POCE anomaly requiring operator intervention, the software shall notify the operator of the problem and accept his inputs while still in the automatic mode.

The standby computer shall automatically become the controlling computer in the event of an active computer malfunction. This switchover shall be performed by logic in the computer interface unit per periodic active computer self-check results, keep-alive logic, or manual operator initiated switching. Keep-alive logic refers to requiring the computer to periodically access the computer interface unit at a predetermined rate or else an alarm is triggered. The standby computer shall initialize itself with data currently stored in the disc system and will then assume control over the system. The total switchover time shall not exceed (TBD) ms. The remainder of the system redundancy management shall be the responsibility of the application program in conjunction with built-in test equipment in the master control end items.

The on-line mode shall provide the operator with the capability of modifying the application program software. This mode will be used primarily to support the initial software development and checkout.

A manual mode of operation shall also be provided wherein the operator has the capability of assuming POCE control via hardwired controls and displays. When the system is in the manual mode of operation, application program control shall be inhibited. The manual mode of operation will be used in the event of multiple computer hardware or software failure or to handle anomalies not previously defined in the application program.

3.2.1.3 Master Control Self-Check. The master control shall be capable of detecting and isolating master control failures to a line replaceable unit. The master control shall be capable of isolating failures between the individual POCE subsystems. The master control hardwire design shall provide the capability of executing system self-check application program without disconnecting electrical connections. The master control software shall be capable of simultaneously executing the POCE control program and POCE system self-check routines.

3.2.1.4 Major Component Characteristics

(a) Central Computer

The central computer shall consist of redundant general-purpose digital computers of the minicomputer class with the following specifications: 16 bits, 1.5 μsec cycle time, one direct memory access channel, 1.5 μsec add (memory to register), 10 μsec multiply, 2 highspeed (2 megabytes/sec) and 2 low-speed input/output channels.

(b) Computer Interface Unit

The computer interface unit shall provide the following bidirectional half duplex communication channels with modular expandability:

(1) Sixteen 2 kHz serial channels to interface with the field controllers.

(2) Two 1 megabit serial channels to interface with the master control controls/displays and hardwire interface equipment.

(3) One 8 bit parallel channel to interface with the master control disc files capable of 2×10^6, 8 bit bytes per second.

(4) One low-speed 8 bit parallel channel to interface with the remainder of the computer peripherals.

(5) A parallel digital interface with the real-time clock.

(6) A serial 1 megabit channel for checkout.

(c) Computer Peripheral Equipment

The following computer peripheral equipment shall be provided: redundant disc file system, line printer, teletypewriter, magnetic tape unit.

(d) Master Control and Displays

(1) General-purpose computer-driven displays and associated controls

(2) POCE master control console that provides the operator with control of the computer system and software execution.

(3) Dedicated subsystem control and displays.

(4) The POCE system status display.

(e) Digital Data Bus

The data bus shall provide redundant communications between the central computers and other master control equipment and POCE subsystems. The interface functions of the data bus system are shown in Figure 1. Each computer shall have access to either data bus through the computer interface unit. The general data bus requirements are as follows:

(1) Control:	Central computer polled Each end item has a unique address
(2) Modulation:	Biphase level (Manchester) at base-band
(3) Speed:	1 MHz bit rate
(4) Bit Error Rate:	(TBD)
(5) Synchronization:	Nonvalid bit code precedes each message
(6) Clock:	Generated from biphase data at the receiver
(7) Cable Type:	Twisted pair

(f) Signal Interface Equipment

The signal interface equipment shall consist of the end items that interface the master control digital control with the individual components required for subsystem control. The signal interface equipment shall be capable of providing the following interface functions:

(1) Generating bilevel commands (0, 28 VDC; (TBD) amps)

(2) Generating discrete commands (0, (TBD) volts; (TBD) amps)

(3) Monitoring bilevel responses (0, 28 VDC)

(4) Monitoring analog responses (0 - ±10 VDC)

(5) Signal conditioning low level analogs (0 - (TBD) volts)

(6) Interfacing with the data bus

The signal interface equipment shall be modular in design to allow for easy expansion to meet the changing interface requirements. The number of each type of channel is (TBD).

(g) Time Code Generator

The master control shall contain a real-time clock that provides time of the year by month-day-time of day. The time code generator shall provide time to a 1 millisecond resolution. The time code generator shall be accessible by the central computer via the computer interface unit. The time code generator shall determine time accurate to (TBD). A display of time and timing controls shall be provided on the time code generator. In addition these functions shall also be controllable from the computer via the computer interface unit.

(h) Hardcopy Recorder

The hardcopy recorder shall provide direct recording of POCE system parameters. Switching shall be provided on each recorder channel to allow multiple inputs to be remotely selectable. Recorder control shall also be designed to allow both local and remote control. The recorders shall have a (TBD) scale, a response time of (TBD) seconds or less from zero to full scale, and chart speeds ranging from (TBD) to (TBD). (TBD) channels shall be provided.

3.2.1.5 Master Control Software

3.2.1.5.1 System Software. The system software shall consist of all software required for the assembly and execution of the POCE application programs.

The system software shall be responsible for the following functions.

(a) Updating and servicing the controls and displays.

(b) Maintanance of a system data base that defines calibration coefficients, parameter addresses, maintenance data, etc.

(c) Generation of plant performance reports.

(d) Management of data bus transmissions including fault detection and isolation.

(e) Self-check of the computer hardware.

(f) Control of the input/output channels.

(g) Scheduling and execution of the application programs.

The system software shall consist of the following:

(a) Real-time disc operating system responsible for application program execution, compiling and assembly, text editing, and real-time self-check.

(b) Standard input/output handlers for the disc, magnetic tape unit, line printer, and teletypewriter.

(c) Nonstandard input/output handlers for the control and displays, time code translator, data bus transmission, and data base access.

The detailed system software requirements for items (a) through (g) are (TBD).

3.2.1.5.2 Application Software. Application software shall be provided to perform the following general functions.

(a) POCE system control.

(b) Data reduction and analysis.

(c) Fault detection and isolation.

(d) Collector system calibration utilizing the digital image radiometer.

(e) Prediction of POCE performance capability for the next 24 hours.

(f) Control and update of the overall POCE status display.

(g) Generation of operator error message.

(h) Decoding and execution of operator commands.

(i) Storage of maintenance and performance monitor data.

The application software shall be written in a real-time higher-order language. The detailed control requirements (i.e., software flow charts) for items (a) through (i) above are (TBD).

3.2.1.5.3 <u>POCE Real-Time Simulation Software</u>. In order to maintain effective control over the entire POCE system, it is necessary to have a real-time simulation of the entire system in the master control software. This software shall consist of math models of each subsystem (collector, receiver, etc.), to which the desired control and external disturbances may be applied. The resulting dynamic changes in the simulated POCE system shall be compared to the desired results and appropriate modifications to the commands made.

This simulation software shall meet the following functional requirements.

(a) Contain mathematical models of each subsystem.

(b) Contain current and long-range meteorological data.

(c) Contain built-in tolerance limits on all states and parameters simulated.

(d) Contain error models for each important simulated state and parameter.

The details of items (a) through (d) shall be (TBD).

3.2.2 Physical Characteristics. The hardware shall be packaged in standard commercial racks with standard slide-in drawers and module frames. The components and modules shall be readily accessible for maintenance. Thermal control shall be provided by rack-mounted blowers where required.

3.2.3 Reliability. High reliability shall be achieved in the master control design by providing adequate operating margins, maximizing the use of proven standard parts, and using conservative design practices such that the reliability performance shall not degrade the capability to achieve the availability specified in paragraph 3.2.5 when operated in the environments specified in paragraph 3.2.6.

Single-point failures that disable the automatic mode of system operation shall be minimized. In cases where it is impossible to eliminate such failure modes, suitable devices shall be used to detect and warn of the occurrence of a failure. As a minimum the following system redundancies shall be incorporated in the master control design.

(a) Redundant central computer.

(b) Internal redundancy in the computer interface unit computer fault detection logic.

(c) Functionally redundant computer driven alphanumeric displays.

(d) Redundant data buses.

(e) Redundant power source.

(f) Redundant disc files.

3.2.4 Maintainability. The master control shall be designed such that required service can be accomplished by personnel of normal skills, with a minimum of nonstandard tools or special equipment.

The master control shall provide malfunction indication and fault isolation information at the control/display consoles for malfunctions within the master control and accept and process such information from the collector, receiver, thermal storage, and electrical power generation subsystems regarding critical components (TBD). Critical components are those components that, because of failure risk, downtime, or effect on the overall POCE performance, materially affect the capability to achieve the system availability requirements.

Items that do not have a redundant mode of operation shall provide a maximum capability for on-line repairs or replacement.

The master control shall be designed such that potential maintenance and test points can be easily reached, components such as electronic modules readily replaced, and elements subject to wear or damage such as supporting wheels, displays, and typewriters easily serviced or replaced.

3.2.5 Availability. The master control shall be available 99.8 percent of the time required for management of the POCE system functions. Availability is measured as the percent of the total scheduled operating time in a period of one year that the master control functions in accordance with the requirements of paragraph 3.2.1 to achieve the POCE system specified performance.

3.2.6 Environmental Conditions

3.2.6.1 General. The conditions described in the following paragraphs are representative of the transportation and operating site environments to be encountered by the master control. For design purposes, safety margins shall be used commensurate with availability and performance requirements to ensure operation in accordance with paragraph 3.2.1 during or after exposure to these conditions.

3.2.6.2 Transportation and Handling. The following conditions occurring separately or in combination may be encountered by packaged equipment during handling and transportation.

3.2.6.2.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.6.2.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.6.2.3 Transportation Vibration and Shock. Vibration and shock as encountered during transport. Conditions are as follows:

VIBRATION

Transportation Mode	Continuous Excitations (Steady-State) in g's	Discrete Impulse (Transient) in g's	Predominant Frequency Range
Highway	0.06	1.5	2 to 200 Hz
Rail	0.05	1.5	2 to 200 Hz
Air (Jet Aircraft)	0.05	1.5	2 to 500 Hz

SHOCK (g's)
(Normal Load Limits)

Transport Media	Longitudinal	Lateral	Vertical	Average Pulse Time msec
Air	2.0	1.5	2.0	11-40
Highway	2.0	1.5	3.0	11-40
Rail (Rolling) (1)	3.0	0.75	3.0	11-40
Cushion Car (Humping)	3.0	2.0	3.0	11-40

(1) Shock loads are for rail cars equipped with standard draft gears.

All critical (frangible) components of the master control shall be designed or packaged such that the conditions described above do not induce a dynamic environmental condition which exceeds the structural capability of the component. These conditions reflect careful handling and firmly constrained (tied down) transporting via common carrier.

All components shall be designed to withstand handling/hoisting inertial loads up to 2 g's considering number, location, and type of hoisting points.

3.2.6.2.4 Handling Shock. Handling shocks may result from drops of packaged equipment. Corresponding acceleration peaks may be of the order of 7 g's vertical and 4 g's horizontal with a (TBD) wave profile and a duration of 10 to 50 milliseconds.

3.2.6.2.5 Other Conditions. The packaged equipment may encounter other conditions during transportation and handling including wind, rain, snow, ice, hail, and blowing sand and dust.

3.2.6.3 Operational. The master control equipment shall be located in an environmentally conditioned enclosure. The hardware shall be designed to operate in accordance with paragraph 3.2.1 during and after exposure to the following combined environments without reduction of reliability or component lifetime.

3.2.6.3.1 Temperature. Controlled air temperature of 21 degrees ± 3 degrees degrees C (70 degrees ± 5 degrees F).

3.2.6.3.2 Humidity. Relative humidity maintained between 40 and 50 percent.

3.2.6.3.3 Lightning. The master control shall be designed to withstand a lightning threat that has a current pulse of 140,000 amperes with a 1.5-microsecond rise time decaying to 50 percent in 40 microseconds. A continuing current of 200 to 400 amperes will follow the main stroke and last for 160 to 300 milliseconds. Up to 10 restrokes can occur with 30,000 to 70,000 amperes peak current each. Total charge transfer of the primary stroke and the restrokes events can reach 200 coulombs.

3.2.6.3.4 Earthquake. The master control shall be designed to withstand, without structural damage, the earthquake environment described in Table 1 and Figure 3. The environment is given in terms of response spectra and ground motion histories for soft rock or firm sediment. If the master control is located on competent rock, the above environment may be reduced by 33 percent. If the master control is located on soft sediment, the above environments shall be increased by 50 percent. The response spectra or ground motion histories shall be used as input to the analytical model of the soil and the analysis of the master control physical design in both vertical and horizontal directions to assess earthquake-induced loads.

Table 1

EARTHQUAKE HORIZONTAL GROUND MOTION HISTORIES

Location	Year	Component	Scale Factor
El Centro	1940	NS	1.0
El Centro	1934	EW	1.4
Olympia	1949	N10W	1.4
Taft	1952	S69E	1.7

Each ground motion history is to be multiplied by the indicated scale factor.

3.2.7 Transportability. The subsystem components shall be designed to meet all applicable Federal and state transportation regulations and be transported by highway or railroad carriers utilizing standard transport vehicles and material handling equipment. Packaged equipment shall be capable of withstanding normal shock and vibration loads and environmental exposure as specified in paragraph 3.2.6.2 without damage.

3.3 Design and Construction

3.3.1 Materials, Processes, and Parts. The materials and parts used in the design and construction of the master control shall be restricted to those which are commercially available and commonly used in the design and manufacture of conventional digital computers, peripheral equipment, and displays. They shall also be compatible with exposure to, and operation in, the environment specified in paragraph 3.2.6 for 30 years. The materials chosen shall reflect an objective of arriving at a cost-effective approach to design solutions. All processes employed in the design and manufacture of the master control shall be fully developed, commercially available, and currently in use in conventional digital equipment.

GROUND SHOCK NOMOGRAPH

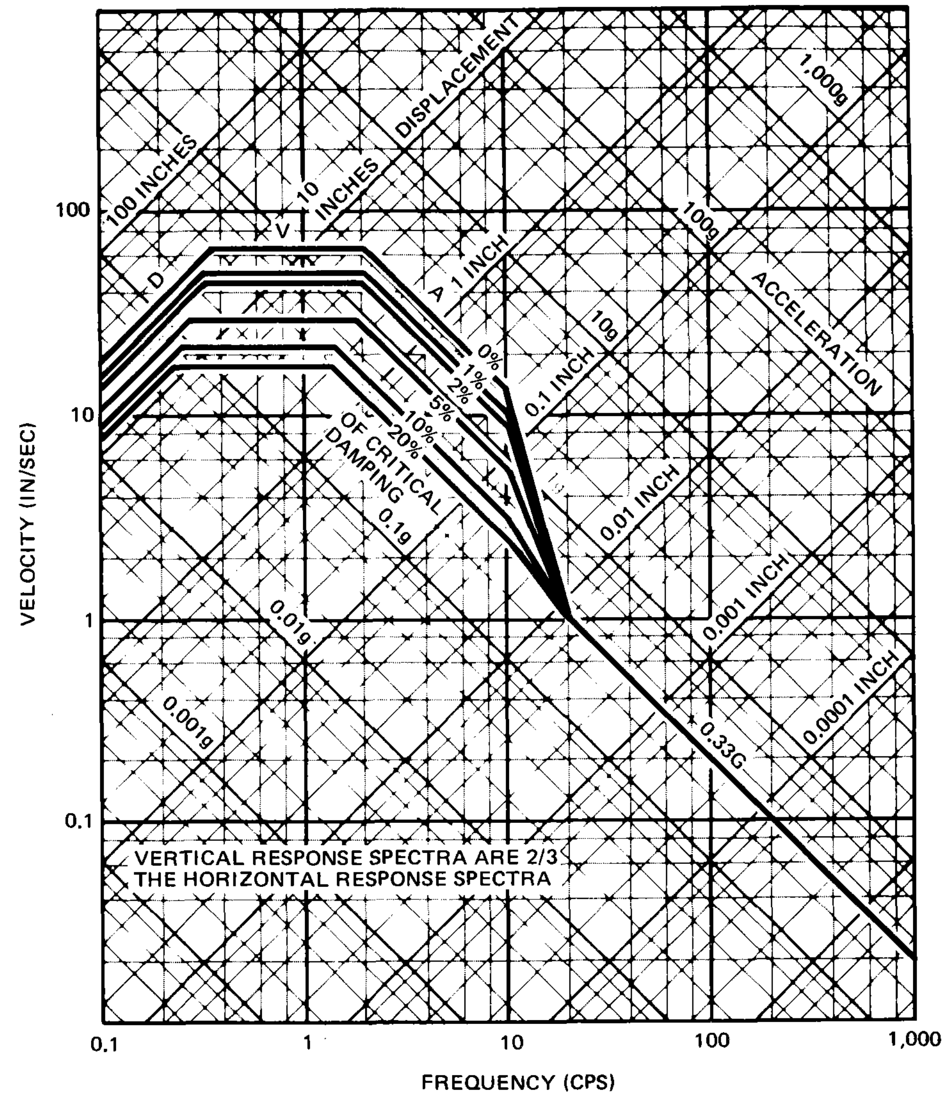


Figure 3. Earthquake Horizontal Response Spectra

3.3.2 Electrical Transients. The master control operation shall not be adversely affected by external or internal power line transients caused by normal switching, fault clearing, or lightning. Switching transients and fault clearing functions will require less than six cycles of the fundamental frequency (100 milliseconds). Power buses supplying the computer and other digital hardware shall be designed to eliminate electrical transients during the switchover from prime to backup power source. Power transients caused by inductive and capacitive coupling and switching shall not cause digital power bus transients greater than ±10 percent.

Components of the master control shall be shielded from the lightning threat specified in paragraph 3.2.6.3.3. Shielding shall protect the electrical components from both the bound charge and induced current threats.

3.3.3 Electromagnetic Radiation. The master control shall be designed to minimize susceptibility to electromagnetic interference and to minimize the generation of conducted or radiated interference. The design criteria contained in the following Air Force design handbooks shall be used to assure electromagnetic compatibility: Design Handbook on Electromagnetic Compatibility (AFSC DH1-4), Checklist of General Design Criteria (AFSC DH1-X), and Instrumentation Grounding and Noise Minimization Handbook (AFRPL-TR-65-1).

3.3.4 Nameplates and Product Marking. All deliverable end items shall be labeled with a permanent nameplate listing, as a minimum, manufacturer name, part number, change letter, serial number, and date of manufacture.

All access doors to replaceable/repairable items shall be labeled to show equipment installed in that area any any safety precautions or special considerations to be observed during servicing.

3.3.5 Workmanship. The level of workmanship shall conform to practices defined in the codes, standards, and specifications applicable to the selected site and the using utility. Where specific skill levels or certifications are required, current certification status shall be maintained with evidences available for examination. Where skill levels or details of workmanship are not specified, the work shall be accomplished in accordance with the level of quality currently in use in the construction, fabrication, and assembly of commercial power plants. All work shall be finished in a manner such that it presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a generally uniform appearance.

3.3.6 Human Engineering. Human engineering design criteria and principles shall be applied in the design of the master control so as to achieve safe, reliable, and effective performance by operator, maintenance, and control personnel, and to optimize personnel skill requirements and training time.

Electronic equipment shall utilize MIL-H-46855 (Human Engineering Requirements for Military Systems, Equipment and Facilities) and MIL-STD-1472 (Human Engineering Design Criteria for Military Systems, Equipment and Facilities) as guidelines in applying human engineering design criteria.

3.4 Documentation

3.4.1 Characteristics and Performance. Equipment functions, normal operating characteristics, limiting conditions, test data, and performance curves, where applicable, shall be provided.

3.4.2 Instructions. Instructions shall cover assembly, installation, alignment, adjustment, checking, and maintenance. Operating instructions shall be included for startup, routine and normal operation, regulation and control, shutdown, and emergency conditions. A guide to troubleshooting instruments and controls shall be provided.

3.4.3 Construction. Engineering and assembly drawings shall be provided to show the equipment construction, including assembly and disassembly procedures. Engineering data, wiring diagrams, and parts lists shall be provided.

3.4.4 Schematics. Master control end item functional schematics shall be provided. These schematics shall provide the level of detail required to fault isolate to a replaceable unit.

3.4.5 Software Documentation. Complete software listings and functional descriptions shall be provided.

3.5 Logistics. The elements required to support the master control are:

Support and test equipment

Technical publications

Personnel and training

Facilities

Spares, repair parts, and consumables

Transportation, handling and packaging

Data file

Field service

The requirements for the elements shall be established as a result of a support requirements analysis to be prepared by the contractor. The results of the analysis shall be documented in accordance with the contract.

3.5.1 Maintenance. Maintenance activities are categorized as follows:

Level 1, On-line maintenance

Level 2, Off-line on-site maintenance

Level 3, Off-line off-site maintenance

Level 1, On-Line Maintenance: The following scheduled and unscheduled maintenance activities shall be identified for the master control.

Task	Frequency
Self-check	Daily
Remove and replace	(TBD)
Repair in place	(TBD)
Adjust	(TBD)
Clean	(TBD)
Calibrate	(TBD)
Paint	(TBD)

Level 2, Off-Line On-Site Maintenance: The following maintenance activities shall be identified in the maintenance plan. Frequencies shall be (TBD).

Fault verification

Fault isolation to a removable item

Remove and replace a faulty item

Verify acceptable repaired item

Repair designated subtiered items

Servicing

Calibration

Visual inspection

Level 3, Off-Line Off-Site Maintenance: Level 3 maintenance activities are those to be performed at the equipment supplier's facility. Frequencies and turnaround times shall be (TBD).

Maintenance Plan: A maintenance plan shall be prepared by the contractor which identifies scheduled and unscheduled maintenance requirements. The maintenance plan shall reflect the results of the system requirements analysis and shall specify the following as appropriate.

Use of multi-purpose test equipment

Items to be repaired

Items to be replaced

Maintenance and repair cycles

Use of operational support equipment for maintenance

Level, frequency, and location of maintenance action

Facilities, equipment, and tools

3.5.2 Supply. The selection and positioning of spares, repair parts, and consumables shall be in accordance with the levels of repair determined by the system requirements analysis, and shall use the following criteria:

Protection Level: Items shall be packaged in accordance with the requirements of section 5.0.

Demand Rate: The mean-time-between-maintenance-actions provided by the maintainability analyses shall be the departure point for spares determinations. The quantities and mix shall be such that there is a (TBD) percent probability of a part being available on demand.

Pipeline: Pipeline quantities shall be determined on the basis of system location demand rate and repair cycle times. Resupply methods, distribution, and location of system stocks shall be determined after site selection.

Procurement and Release for Production: Long-lead-time supply items shall be procured or released early enough to be on-site 30 days prior to initial operation. Other items shall be procured or released lead-time away so as to minimize obsolescence due to design changes, except for those items for which significant cost savings can be achieved through acquisition concurrent with production.

Minimum/Maximum Levels: Minimum and maximum quantities of spares and repair parts to be stocked shall initially be determined by use of predicted failure rates. These levels are to be adjusted as actual usage rates are established.

3.5.3 Facilities and Facility Equipment. To be determined after site selection.

3.6 Personnel and Training

3.6.1 Personnel. The pilot plant is to be installed, checked out, and tested as a proof-of-concept experiment by contractor personnel; then taken over and operated as a commercial power plant by utility personnel. Operation and maintenance personnel requirements shall be satisfied by recruitment from the established utility labor pool. Unique aspects of the master control dictate a need for training existing utility people but do not establish a need for new skills or trades. The types and numbers of utility personnel requiring training, along with the unique tasks, are as follows:

Type	No.	Unique Task
TBD	TBD	Computer peripheral equipment troubleshooting and repair
		Control/display console troubleshooting and repair
		Recorder troubleshooting and repair

Power distribution system troubleshooting and repair

Self-check, startup, and shutdown operations

Contingency/emergency operations

Safety requirements

3.6.2 Training. The contractor shall prepare and conduct a training program for contractor personnel as necessary for performance of the POCE. The contractor shall conduct a training program for utility personnel in accordance with contractual requirements.

3.7 Precedence. The order of precedence of master control requirements and characteristics shall be as follows:

(a) Performance (including scalability to commercial plant requirements)

(b) Safety

(c) Cost

Specific characteristics and requirement precedence shall be established based on system cost effectiveness sensitivity analyses. This specification has precedence over documents referenced herein. The contractor shall notify the procuring activity of each instance of conflicting, or apparently conflicting, requirements within this specification or between this specification and a referenced document.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Tests. All tests shall be performed by the contractor. These tests may be witnessed by ERDA or its representatives or the witnessing may be waived. In either case, substantive evidence of hardware compliance with all test requirements is required.

4.1.2 General Test Requirements. Tests shall be conducted in accordance with a test plan to be prepared by the contractor and approved by ERDA. Specific required tests are identified in subsection 4.2. Tests shall be classified in the test plan as:

(a) Development tests for the purposes of determining the design,

(b) Acceptance tests for the purpose of verifying conformance to design and determining acceptability of product for further operations or for delivery, or

(c) Qualification tests for the purpose of verifying adequacy of design and method of production to yield a product conforming to specified requirements.

Acceptance tests and qualification tests shall be defined for verifications as indicated in subsection 4.3. The test of the master control in conjunction with one or more subsystems is regarded as a system test and shall be as specified in the System Requirements Specification.

4.1.3 Previous Tests. Maximum use shall be made of test data available from the subsystem research experiments and hardware tests already completed. Where conformance to this specification can be established at less cost by analysis of such data, tests shall not be repeated.

4.2 Specific Test Requirements. Specific required tests are defined herein. Additional tests found to be necessary shall be defined by the contractor in the course of design and development.

4.2.1 Master Control Performance Tests. Simulations may be used for inputs from controlled subsystems pending compatibility and operational tests (including demonstration) under the System Requirements Specification. [This portion will define tests for evaluation of the master control as fully assembled in order to assure compatibility before attempting system tests.]

4.2.2 Assembly and Subassembly Performance Tests. (TBD)

4.2.3 Environmental Tests. (TBD)

4.2.4 Materials and Processes Control Tests. (TBD)

4.2.5 Life Tests and Analyses. One set of each major subassembly shall be subjected to extended life testing as follows. [Methods TBD.] Sufficient data shall be gathered from the above life tests and also from component suppliers in order to estimate the MTBF and MTBR for the given design configuration.

4.2.6 Engineering Critical Component Qualification Tests. Components for which reliability data are not available shall be subjected to sufficient qualification testing to estimate their impact on overall device MTBF.

4.3 Verification of Conformance. Verification that the requirements of sections 3 and 5 of this specification are fulfilled shall be performed by the contractor by the methods specified in Table 2. The methods of verification are defined as follows:

(a) Inspection - examination and measurement of product.

(b) Analysis - examination of the design and associated data, which may include relevant test information.

(c) Similarity - demonstration or acceptable evidence of the performance of sufficiently similar product to permit conformance to be inferred.

(d) Test - functional operation or exposure under specified conditions to evaluate product performance.

(e) Demonstration - exhibition of the product or service in its intended modes and conditions.

4.3.1 Hardware Acceptance for POCE. The contractor shall provide a method by which conformance of hardware to the design will be verified prior to initiation of master control tests. This verification of conformance shall include proof-by-assembly and the examination of records as elements of inspection. A record shall be made of each inspection or test performed and of the verification. In addition, evidence shall be maintained of satisfactory accomplishment of inspections and tests required by codes and standards that apply to the master control.

Table 2

MASTER CONTROL REQUIREMENT VERIFICATION MATRIX

Verification Methods	Test Categories
1. Inspection	A. Acceptance Test
2. Analysis	B. Qualification Test (including life tests and critical component qualification)
3. Similarity	
4. Test	
5. Demonstration	

N/A denotes "not applicable"

Requirement (paragraph)	Verification Method	Test Category	Remarks
	TBD		

5.0 PREPARATION FOR DELIVERY

5.1 General. Packaging for subsystem components shall provide adequate protection during shipment by common carrier from supplier to the first receiving activity for immediate use or temporary storage.

5.2 Preservation and Packaging. Subsystem components that may be harmed with exposed to the normal transportation and handling environments (paragraph 3.2.6) shall be protected by inert environments, barrier materials, or equivalent techniques.

5.3 Packing. Shipping containers and their cushioning devices shall ensure protection of subsystem components when exposed to the shock and vibration loads defined in paragraph 3.2.6. Containers shall meet, as a minimum, the requirements in the following regulations as applicable to the mode of transportation utilized.

(a) National Motor Freight Classification (Highway Transportation)

(b) Uniform Freight Classification (Railroad Transportation)

(c) CAB Tariff 96 and 169 (Air Transportation)

(d) R. M. Graziano's Tariff 29 (For Dangerous Articles Surface)

(e) CAB Tariff 82 (For Dangerous Articles Air)

5.4 Handling and Transportability. Containers with gross weights exceeding 60 pounds shall have skids and other provisions for handling by standard materials handling equipment. When feasible, container sizes and configurations shall be compatible with efficient utilization of transport vehicles.

5.5 Marking. Unless otherwise specified, container marking will be standard commercial practice.

PART 2 COLLECTOR SRE

COLLECTOR SUBSYSTEM
RESEARCH EXPERIMENT TEST HARDWARE
REQUIREMENTS SPECIFICATION

VOLUME 2
PART 2

CONTENTS

CONTENTS (Continued)

1.0 SCOPE

This specification establishes the performance, design, and test requirements for the collector subsystem research experiment test hardware (RETH).

2.0 APPLICABLE DOCUMENTS

The equipment, materials, design, and construction of the collector RETH shall comply with all Federal, state, and local standards, regulations, codes, laws and ordinances which are currently applicable for the selected test site. These shall include but not be limited to the government and non-government documents itemized below. If there is an overlap in or conflict between the requirements of these documents and the applicable Federal, state, county, or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent shall take precedence.

The following documents of the issue in effect on the date of request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Government Documents

2.1.1 Specifications

DD-G-451C, Glass, plate, sheet, figured (float, flat, for glazing, corrugated, mirrors and other uses).

DD-M-00411b (GSA-FSS), Mirrors, Glass.

MIL-E-4158, Electronic Equipment Ground; General Requirements for.

Regulations of the Occupational Safety and Health Administration (OSHA).

Regulations of the California Occupational Safety and Health Administration (CAL/OSHA) - If required.

2.1.2 Standards

MIL-STD-454, Standard General Requirements for Electronic Equipment.

MIL-STD-889, Dissimilar Metals.

MIL-STD-1472, Human Engineering Design Criteria.

2.1.3 Other Publications

National Motor Freight Classification 100B — Classes and Rules Apply on Motor Freight Traffic.

Uniform Freight Classification 11 - Railroad Traffic Ratings Rules and Regulations.

CAB Tariff 96 - Official Air Transport Rules Tariff.

CAB Tariff 169 - Official Air Transport Local Commodity Tariff.

R. H. Graziano's Tariff 29 - Hazardous Materials Regulations of the Department of Transportation.

CAB Tariff 82 - Official Air Transport Restricted Articles Tariff.

2.2 Non-Government Documents

2.2.1 Standards

National Electrical Manufacturers Association (NEMA) Standards.

Manual of Steel Construction, 7th Edition, 1974, American Institute of Steel Construction.

Building Code Requirements for Reinforced Concrete, ACI 318-71, American Concrete Institute.

Uniform Building Code - 1973 Edition, Vol. I, by International Conference of Building Officials.

National Electric Code, NFPA 70-1971 (ANSI C1-1971)

2.2.2 Other Publications

"Wind Forces on Structures," ASCE Paper No. 3269 Transactions, American Society of Civil Engineers, Vol. 126, Part II, 1961.

3.0 REQUIREMENTS

3.1 Collector Subsystem RETH Definition. The collector subsystem RETH for the system requirements analysis comprises those items of test hardware needed to evaluate and demonstrate the suitability of the preliminary design POCE collector subsystem baseline. Included in this category are not only those test items representative of the collector subsystem preliminary design baseline itself, but also those items needed to validly demonstrate the functional interactions of the collector subsystem baseline with the other POCE subsystems and assemblies. Because of the intended use of the equipment, and in order to minimize SRE costs, construction approaches which do not affect subsystem performance may vary from those planned for POCE. The collector subsystem shall be capable of scaling to a larger central receiver proof-of-concept experiment (pilot plant) and another larger commercial power generating system.

RETH shall be provided for the two principal components of the collector subsystem described below.

(a) Heliostat

  (1) Reflective surface (glass, silver, and protective coating(s))

  (2) Structural support

  (3) Drive unit (motors, drive trains, housings, and gimbal joints)

  (4) Control sensors (beam sensor, potentiometers, and tachometers)

  (5) Pedestals and foundations for drive unit and beam sensor

(b) Field Controller

  (1) Digital processor

  (2) AC/DC power conversion

  (3) Analog control electronics (servoamplifiers, sample and hold circuitry, switching)

  (4) Digital/analog and analog/digital conversion

  (5) Heliostat cabling

Components and segments of the baseline heliostat may be used as RETH for evaluating heliostat subassemblies to the extent that test validity is not compromised. However, full-scale heliostats equivalent to the POCE baseline shall be employed as RETH for tests of the integrated heliostat subassemblies. In particular, RETH for evaluating performance of the collector subsystem heliostat array shall comprise a minimum of five full-scale heliostats equivalent to the POCE preliminary design baseline in all functional respects, and capable of demonstrating the operational and nonoperational modes of the baseline POCE collector subsystem.

Field controller RETH shall employ circuitry which is functionally equivalent to that of the POCE baseline with sufficient capacity for operating at least five heliostats. The digital processor portion of the field controller RETH shall be reprogrammable to permit test evaluation of alternative control algorithms.

A commercially available digital computer may be employed to simulate the master control functional interactions with the collector subsystem. However, software for the simulated master control shall be readily adaptable for subsequent use in the POCE master control.

The receiver subsystem's elevated absorber (boiler/superheater) surface shall be simulated for the collector subsystem research experiment by an elevated target or targets. Relative geometries of the RETH target/heliostat array shall permit simulation of representative target-heliostat geometries of the POCE preliminary design baseline.

3.1.1 Collector Subsystem RETH Diagram. Figures 1 and 2 describe the functional elements of the heliostat and field controller respectively. Figure 3 shows representative RETH for integrated SRE testing of the collector subsystem.

3.1.2 Interface Definition. External and internal physical and functional interfaces of the RETH for integrated SRE testing of the collector subsystem are as follows:

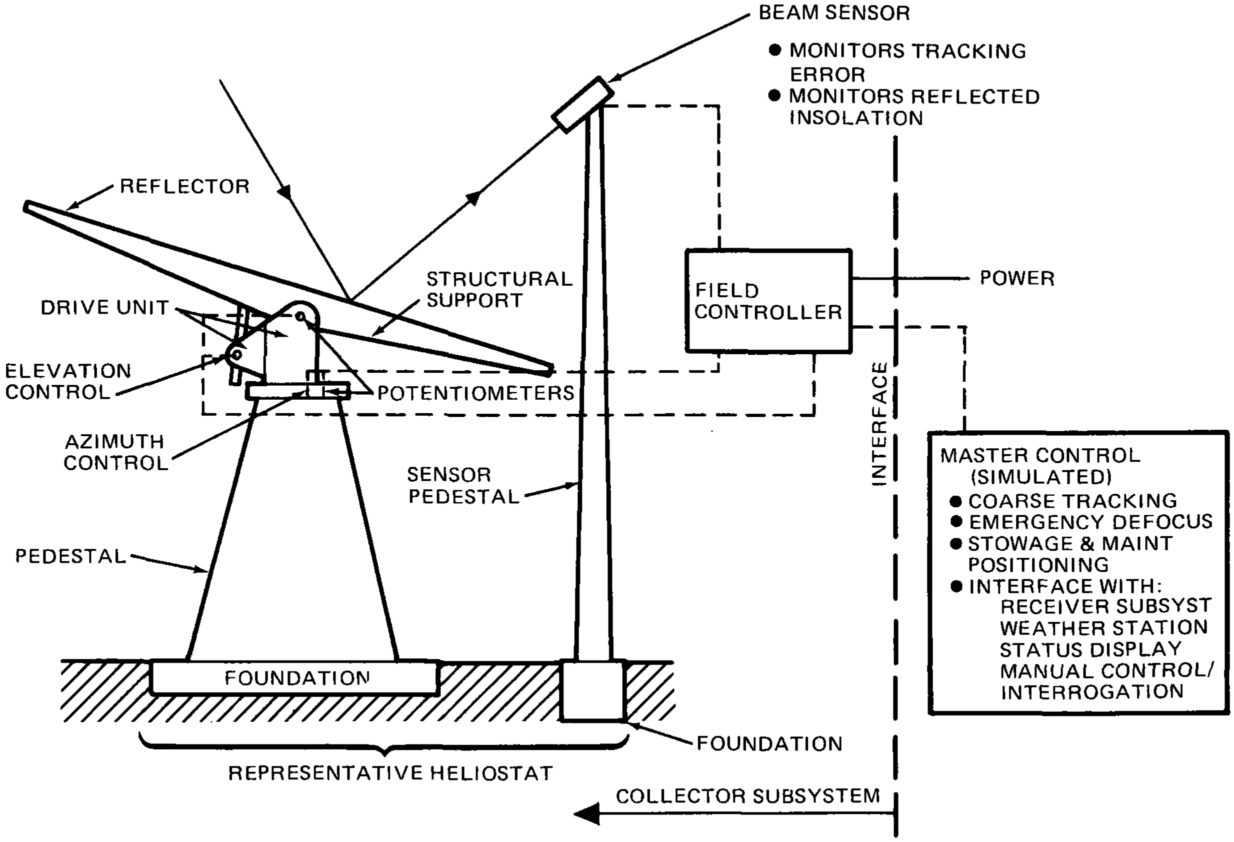


Figure 1. Heliostat Functional Elements

3.1.2.1 Physical Site. The physical arrangement and boundaries for SRE heliostat array tests shall be approximately as shown in Figure 3. Spacing and alignment of heliostats shall be representative of the POCE preliminary design. The site topography, solar insolation, and environmental conditions shall be representative of those specified for the POCE. Heliostat and beam sensor pedestal foundations shall be consistent with site-peculiar stratigraphy and surface soil conditions, and shall be representative of POCE foundations so that realistic settling and alignment data can be obtained.

3.1.2.2 Target. The target to be used to simulate the functional interface between the collector and receiver subsystems shall be capable of sustaining the maximum redirected energy from the array of heliostats. The target to be used for beam flux pattern determinations for individual heliostats shall have a reflective surface suitable for high quality optical measurements under daylight conditions.

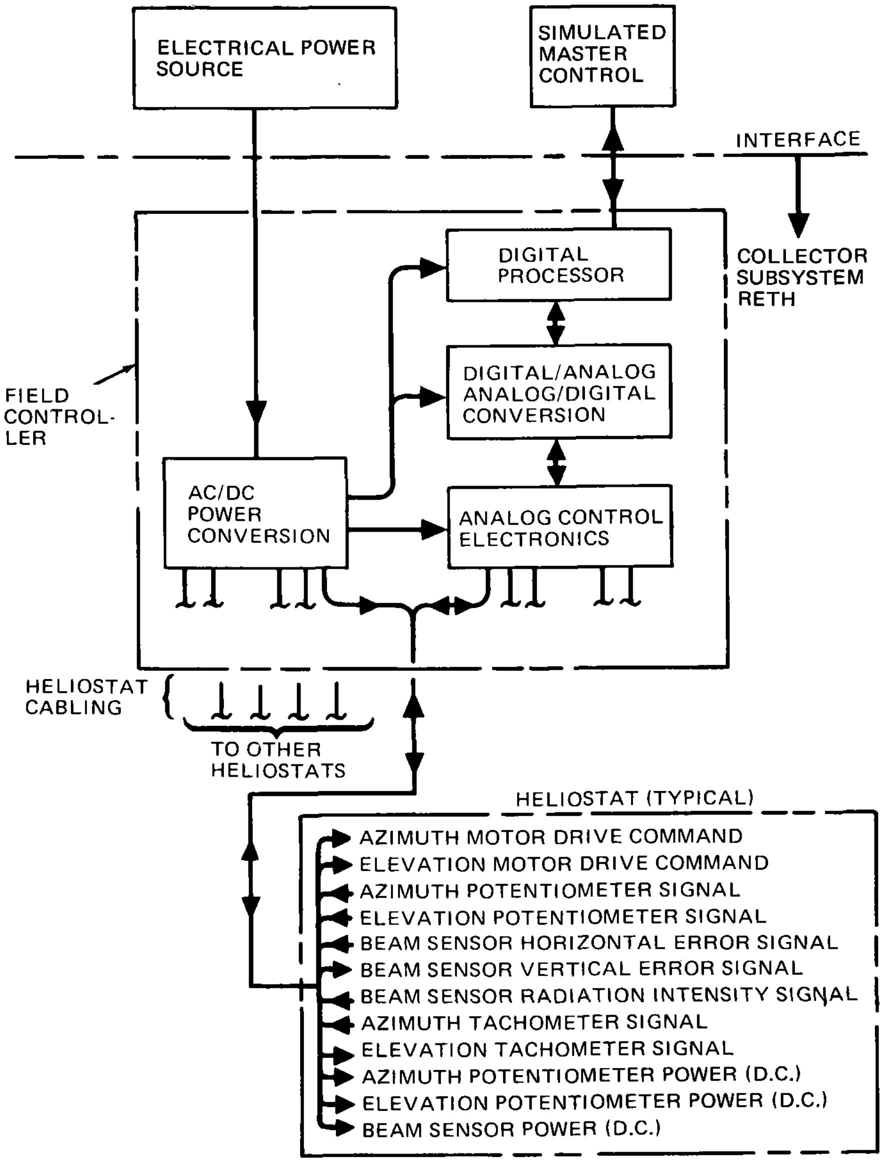


Figure 2. Collector Subsystem RETH Electrical Interfaces

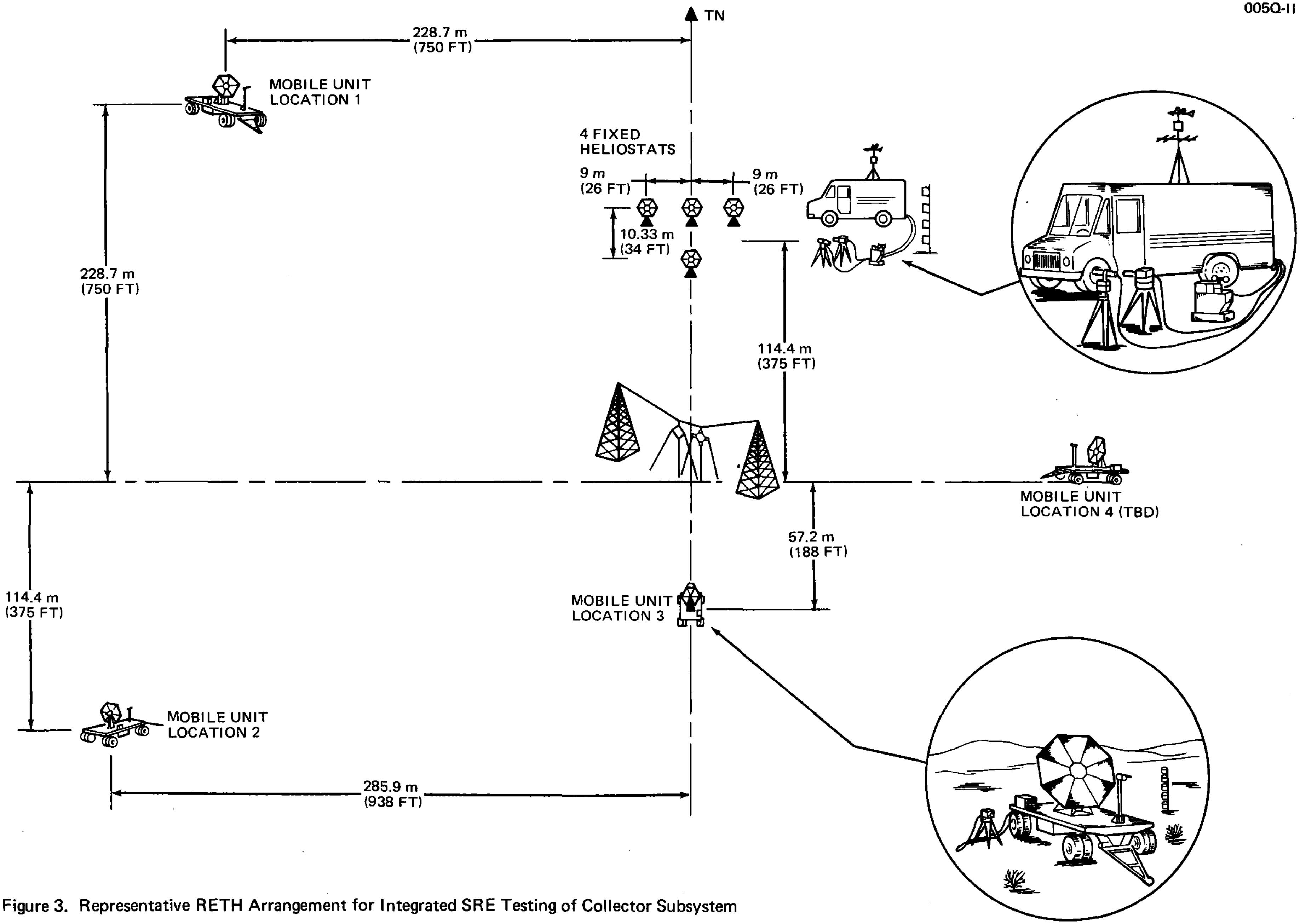


Figure 3. Representative RETH Arrangement for Integrated SRE Testing of Collector Subsystem

3.1.2.3 Simulated Master Control. Conventional wiring or cables shall be substituted for the POCE communication grid to provide for two-way digital communication between the collector subsystem field controller and the simulated master control. Communication may take the form of mandatory commands, information transferral, and information requests. All heliostats shall be uniquely addressable.

3.1.2.4 Electrical Power Generation. Conventional wiring or cables shall be substituted for the POCE power grid to provide power distribution to RETH. A standard facilities or mobile source of 277V single phase AC power shall be substituted for the POCE power generation subsystem counterpart. The AC power source shall provide voltage regulation comparable to that of the planned POCE power source.

3.1.2.5 Internal Interfaces. Principal interfaces within the collector subsystem RETH include:

(a) Digital Processor/Analog Control Electronics

These two functional elements are interconnected by analog/digital and digital/analog signal converters, permitting two-way signal transmission and digital interactions with the heliostat control servos including signal conditioning, transformation, and summation.

(b) Field Controller/Heliostat

The field controller is interconnected with the heliostat by the heliostat cabling, providing for transmission of motor drive commands, beam sensor signals, potentiometer signals, tachometer signals, and sensor power.

(c) AC/DC Power Conversion

This functional element receives AC power from the simulated power grid and converts it into DC power at various voltages suitable for excitation of the beam sensors and potentiometers. This power is supplied to the individual heliostats via the heliostat cabling. The AC/DC power conversion circuitry also supplies DC power to the analog control electronics, digital processor and analog/digital-digital/analog elements within the field controller.

3.2 Characteristics

3.2.1 Performance. The following performance requirements apply to the RETH for integrated collector subsystem SRE testing. The heliostats shall reflect solar radiation onto the elevated target with a beam pointing accuracy of ±3 milliradians whenever the insolation exceeds 100 W/m^2, the sun is more than 20° above the horizon, and the environmental conditions are within normal operational limits as defined in the POCE collector subsystem specification document. Reflectance of clean heliostat reflective surfaces shall exceed 85 percent average over an air mass 2 solar spectrum and within a 4-milliradian cone. The optical spreading due to surface irregularities shall be less than 0.05°. The heliostat structural support shall be designed to prevent reflective surface deflection from exceeding 0.1° under the normal SRE test wind conditions specified in paragraph 3.2.3.3. The heliostat shall incorporate limit switches to avoid overdriving of the reflector and to limit wrapup of wiring. An override provision shall be included in the drive unit to permit local feathering of the reflector.

A capability for emergency defocus shall be provided. The defocus shall be accomplished at a rate equal to that which would reduce the incident radiation on the POCE receiver to less than 0.02 MW/m^2 within 10 seconds. The collector subsystem RETH shall automatically provide synthetic heliostat tracking during obscuration (shadowing) such that normal tracking is resumed within 120 seconds after removal of the obscuration(s). Nonoperational heliostat slewing provisions shall be incorporated such that the heliostat reflectors can be (1) aligned horizontally within 15 minutes to accommodate high winds or sandstorm conditions, (2) aligned 70° from horizontal and parallel to prevailing winds within 15 minutes in anticipation of severe hail, sleet, or ice storms, and (3) aligned in any preferred orientation within 30 minutes to facilitate cleaning or maintenance.

The optical properties of the target surface shall permit the incident radiation from one or more heliostats to be readily observed and to be recorded with good contrast using normal photographic and television equipment. The target to be used to simulate the functional interface with the receiver absorber shall be designed to withstand the maximum steady state redirected energy from the heliostat array and provide the necessary orientation for optical measurements. The target to be used for beam flow pattern determinations from individual heliostats shall permit the incident radiation to be readily observed and recorded with good contrast using photographic and digital image radiometer equipment, such that accurate incident flux distribution measurements can be made.

The simulated master control and its related software shall be capable of performing the following control and checkout functions with respect to the collector subsystem RETH.

(a) Provide field controller with sun acquisition aximuth and elevation commands. These commands shall point the invididual heliostats to the accuracy required to acquire the solar disc image within the field of view of the beam sensor.

(b) Provide a periodic update of the sun acquisition commands to allow the heliostats to maintain the solar disc image within the beam sensor's field of view during periods of cloud cover.

(c) Command the heliostat array to slew off the target, simulating emergency defocusing.

(d) Command the heliostat array to a stowage position.

(e) Store individual heliostat sensor calibration data.

(f) Provide individual heliostat manual control.

(g) Provide offset pointing commands.

A weather station and associated data acquisition equipment at the test site shall have the capability to provide real-time data. The weather station shall record the wind velocity, temperature, humidity, and solar insolation. In addition to the weather station, sand and dust collection shall be provided at various elevations with data obtained by sample weighing at (TBD) intervals.

3.2.2 Physical Characteristics. Each target shall be supported at a height approaching that of the POCE receiver subsystem absorber, and shall be alignable so that its surface is normal to the incident radiation within $\pm 5°$. The target used for array tests shall be capable of receiving the combined radiation from all test heliostats over a sustained period without experiencing structural damage or permanent deformation. The target used for determining individual heliostat flux pattern and intensity distributions shall employ a retroreflecting surface to provide a high contrast image.

The heliostats shall be full-scale POCE baseline units. At least four of the heliostats shall be mounted on POCE baseline foundations, and one additional heliostat shall be mounted on a portable (trailerable) foundation to allow greater test flexibility.

3.2.3 Environmental Conditions

3.2.3.1 General. The conditions described in the following paragraphs are representative of the transportation and test site environments to be encountered by the collector RETH. For design purposes, safety margins shall be used commensurate with performance requirements and cost to ensure operation in accordance with paragraph 3.2.1 during or after exposure to these conditions.

3.2.3.2 Transportation and Handling. The following conditions occurring separately or in combination may be encountered by packaged equipment during handling and transportation.

3.2.3.2.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.3.2.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.3.2.3 Transportation Vibration and Shock. Vibration and shock as encountered during transport. Conditions are as follows:

VIBRATION

Transportation Mode	Continuous Excitations (Steady-State) in g's	Discrete Impulse (Transient) in g's	Predominant Frequency Range
Highway	0.06	1.5	2 to 200 Hz
Rail	0.05	1.5	2 to 200 Hz
Air (Jet Aircraft)	0.05	1.5	2 to 500 Hz

SHOCK (g's)
(Normal Load Limits)

Transport Media	Longitudinal	Lateral	Vertical	Average Pulse Time msec
Air	2.0	1.5	2.0	11 to 40
Highway	2.0	1.5	3.0	11 to 40
Rail (Rolling) (1)	3.0	0.75	3.0	11 to 40
Cushion Car (Humping)	3.0	2.0	3.0	11 to 40

(1) Shock loads are for rail cars equipped with standard draft gears.

All critical (frangible) components of the collector subsystem RETH shall be designed or packaged such that the vibration conditions described above do not induce a dynamic environmental condition which exceeds the structural capability of the component. These conditions reflect careful handling and firmly constrained (tied down) transporting via common carrier. All components shall be designed to withstand handling/hoisting inertial loads up to 2 g's considering number, location, and type of hoisting points.

3.2.3.2.4 Handling Shock. Shipment shocks may result from drops of packaged equipment. Corresponding acceleration peaks may be of the order of 7 g's vertical and 4 g's horizontal with a (TBD) wave profile and a duration of 10 to 50 milliseconds.

3.2.3.2.5 Other Conditions. The equipment may encounter other conditions during transportation and handling including wind, rain, snow, ice, hail, and blowing sand and dust. These are not expected to exceed the SRE test conditions of paragraph 3.2.3.3.

3.2.3.3 SRE Conditions. The following conditions occurring separately or in combination may be encountered by the collector RETH during the subsystem research experiments. Unless specified otherwise, the collector RETH shall be designed to perform in accordance with paragraph 3.2.1 during and after exposure to these conditions.

3.2.3.3.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C(140 degrees F).

3.2.3.3.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.3.3.3 Wind. Sustained surface winds up to 8.9 m/sec (20 mph) for a period of (TBD) hours with gust RMS velocities up to 11.6 m/sec (25.9 mph). The collector RETH shall survive, in a nonoperational state with the reflector in any position, sustained surface wind velocities up to 20.5 m/sec (45.9 mph) for (TBD) hours with gust RMS velocities up to 26.7 m/sec (59.7 mph). In addition, nonoperational survival in a feathered position shall be maintained in surface winds of 35.7 m/sec (79.9 mph) for periods up to (TBD) hours with gust RMS velocities to 46.4 m/sec (103.8 mph). These are derived from 35.7 m/sec (79.9 mph) base, 50-year fastest mile (Reference ASCE Paper 3269, Vol 126). Maximum steady winds with gusts during operation are to be considered throughout a complete daylight operational period. Practices recommended in the ASCE Paper 3269, Vol. 126 and the Uniform Building Code, 1973, Vol. 1 shall be employed in designing the RETH for winds.

3.2.3.3.4 Vibration (Wind-Induced). The natural wind environment to which the collector subsystem will be periodically exposed induces a vibratory response. Based on the wind conditions specified in paragraph 3.2.3.3.3, the fluctuating loads on the large exposed surfaces of the heliostat assemblies are as follows:

Frequency of Resonances	Fatigue Equivalent Wind Velocity	Equivalent Static Moment	Modal Force	Duration (at resonance)
0 to 40 Hz	14.7 m/sec (32.9 mph)	22,500 in-lb	529.5 kg (1,165 lb)	2.1×10^7 sec

To preclude fatigue due to these fluctuating loads, the structure shall be designed such that stresses are below the endurance limits for this loading. These pressures are to be assumed in-phase over the structure.

The fluctuating pressure induced response results in mechanical vibration of the heliostat assemblies. Components or mechanical assemblies shall be designed to withstand these vibrations which are represented by sinusoidal excitation of the following amplitudes:

Frequency	Amplitude
1 to 6 Hz	1-inch double amplitude
6 to 200 Hz	2 g's 0-peak

3.2.3.3.5 Sand and Dust. The collector RETH shall not evidence operation degradation or component destruction following exposure to sand and dust storms. The design shall withstand dust fluxes 10^{-4} g/cm^2-sec at velocities up to (TBD) meters/second. Dust is defined to be those particles up to 100 μm in diameter with the mean diameter of 40 to 50 μm.

Sand is defined as particles greater than 100 μm in diameter. Desert sand flux declines approximately exponentially with height above the surface. For the surface roughness expected at the test site, 90 percent of the sand flux will be within 25 cm (10 in) of the surface. The design shall withstand a sand flux which averages 0.3 g/cm^2- sec within that region at velocities up to (TBD) meters/second.

The frequency of storm occurrence and duration to be considered will depend on the site selected. In the Inyokern desert area, blowing sand and dust approaching these levels is experienced an average of about 9 days per year.

The effect of dust devils shall also be considered in the design. The maximum core diameter and tangential velocities to be considered are 70 m (230 ft) and 30 m/sec (67 mph), respectively. The maximum vertical velocity to be considered is 15 m/sec (34 mph).

RETH components shall be protected from the electrostatic charging and discharging associated with sand and dust storms. This shall include grounding the silvered surface on the reflector to prevent attraction of charged dust particles.

3.2.3.3.6 Rain, Hail, and Snow. Storms of the following types and intensities:

Rain: Average storm intensity of (TBD) cm/hour (TBD in/hr) for (TBD) hours with peak periods of (TBD) cm/hour (TBD in/hr) lasting (TBD) minutes. Three to five storms per year.

Hail: Mean particle diameter of 5 to 10 mm (0.20 to 0.39 in) extreme maximum diameter of 25 mm (1 inch). Fall velocity of 20 m/sec (65.6 ft/sec). Hail stone compressive strength of 1.03 MN/m^2 (150 psi) for 25 mm stone; 5.07 MN/m^2 (735 psi) for stones less than 10 mm (0.39 in) in diameter. Storm intensity of (TBD) particules per square meter per minute lasting 10 to 20 minutes. Frequency of occurrence — one in 5 to 6 years.

Snow: (TBD)

3.2.3.4 Support Equipment Environmental Conditions. The simulated master control shall be housed in a controlled environment (trailer or van) and, therefore, will be protected from the environmental conditions of paragraph 3.2.3.2 or 3.2.3.3. The weather station sensing components shall be capable of surviving and operating in the environments specified in paragraph 3.2.3.3. The data acquisition system for the weather station shall also be housed in a controlled environment and shall not be required to operate in the environments of paragraph 3.2.3.3. The targets and their means of support shall not be damaged by winds up to (TBD) meters/sec.

3.2.4 Transportability. RETH components shall be designed for transportability within applicable Federal and state regulations by highway and railroad carriers utilizing standard transport vehicles and materials handling equipment. The components in their packaged condition shall be capable of withstanding the climatic conditions and shock and vibration environments defined in paragraph 3.2.3.2. Whenever feasible, components shall be segmented and packaged to sizes that are transportable under normal commercial transportation limitations (see (a) below). Components that exceed normal transportation limits (see (b) below) shall be transportable with the use of special routes, clearances, and permits.

(a) Transportability Limits for Normal Conditions (Permits Not Required)

	Truck	Rail
Height:	13 ft 6 in above road	16 ft 0 in
Width:	8 ft 0 in	10 ft 6 in
Length:	55 ft 0 in - Eastern States 60 ft 0 in - Western States	60 ft 6 in
Gross Wt:	73,280 lb; 18,000 lb/axle	200,000 lb

(b) Transportability Limits for Special Conditions

	Truck	Rail
Height:	14 ft 6 in above road	16 ft 0 in above rail
Width:	12 ft 0 in	12 ft 0 in
Length:	70 ft 0 in	80 ft 6 in
Gross Wt:	100,000 lb with sufficient axles to distribute weight over highway not to exceed 18,000 lb/axle.	400,000 lb

3.3 Design and Construction. Design and construction standards applicable to the intended use of the collector RETH component or structure in question shall be employed. Where applicable, the "Uniform Building Code (1973 edition)", the American Institute of Steel Construction "Manual of Steel Construction (7th ed.)", and the American Concrete Institute "Building Code Requirements for Reinforced Concrete" shall be used. The ASCE paper No. 3269, "Wind Forces on Structures" (ASCE Transactions, Vol. 126, Part II, 1961), shall be used during design when determining loading due to winds. For electrical components, the National Electric Code (ANSI CI), the National Electrical Manufacturers Association (NEMA), and the MIL-STD-454 standards for electronic equipment shall be used. The electronic equipment shall be grounded in conformance with MIL-E-4158.

3.3.1 Materials, Processes, and Parts. To the maximum extent possible, standard materials, processes, and off-the-shelf components shall be used. Wherever possible, industry specifications and standards shall be employed. The glass to be used for mirror panels shall meet the requirements of specifications DD-G-451C type I and DD-M-00411b (GSA-FSS). The reflective surface of the heliostat shall be vapor-deposited silver. Dissimilar materials as defined by MIL-STD-889 shall not be used in direct contact (i.e., suitable protection shall be provided to avoid galvanic corrosion).

3.3.2 Electrical Transients. The RETH operation shall not be adversely affected by external or internal power line transients caused by normal switching or fault clearing. Switching transients and fault clearing functions will require less than six cycles of the fundamental frequency (100 milliseconds) and shall be limited to 1.7 P.U. voltage (1.7 per unit or 170 percent).

3.3.3 Nameplate and Product Marking. All deliverable end items shall be labeled with a permanent nameplate listing, as a minimum, manufacturer name, part number, change letter, serial number, and date of manufacture.

All access doors to replaceable/repairable items shall be labeled to show equipment installed in that area, and any safety precautions or special considerations to be observed during servicing.

3.3.4 Workmanship. The collector RETH shall be constructed, fabricated, and assembled in accordance with the best modern engineering, shop and field practices consistent with cost and performance requirements. The work shall be accomplished in the manner intended for the approved hardware (e.g., installations meeting the NFPA National Electrical Code). All work shall be finished in a manner such that it presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a generally uniform appearance.

3.3.5 Safety. The collector RETH shall be designed to minimize safety hazards to operating and service personnel and equipment. Electrical components shall be insulated and grounded. All parts or components with elevated temperatures shall be insulated against contact with or exposure to personnel. Any moving elements shall be shielded to avoid entanglements and safety override controls/interlocks shall be provided for servicing. All pertinent OSHA rules and regulations shall be observed.

3.4 Documentation. The contractor shall provide the following SRE documentation in accordance with the contract data requirements list:

(a) Collector Subsystem Research Experiment Conceptual Design

(b) Collector Subsystem Research Experiment Detail Design

(c) Operating Instructions

3.5 Precedence. The order of precedence of collector RETH characteristics and requirements shall be as follows:

(a) Performance

(b) Capability to withstand natural environmental conditions

(c) Cost

This specification has precedence over documents referenced herein. The contractor shall notify the procuring activity of each instance of conflicting, or apparently conflicting, requirements within this specification or between this specification and a referenced document.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Tests. All tests shall be performed by the contractor. These tests may be witnessed by ERDA or its representative or the witnessing may be waived. In either case, substantive evidence of compliance with all test requirements is required.

4.1.2 General Test Requirements. Tests shall be conducted in accordance with a test plan to be prepared by the contractor and approved by ERDA. Specific required tests are identified in subsection 4.2. Tests are classified in the test plan as:

(a) Engineering tests for the purposes of acquiring engineering design information and confirming engineering hypotheses.

(b) Preliminary qualification tests for the purpose of testing collector elements under simulated operating conditions.

(c) Life tests for the purposes of testing collector elements under accelerated or extended life conditions.

4.2 Specific Test Requirements. Specific required tests are defined herein. Additional tests shall be defined by the contractor in the course of design and development where necessary to properly validate the performance and configuration parameters of the projected POCE.

4.2.1 Engineering Tests. Definition to be completed in Phase I to include but not be limited to the following:

Field Controller Development Tests

Digital processor hardware/software development (including defocusing)

Digital processor/simulated master control interface development

Heliostat hardware interface development

Operational performance development

Reflector and Structural Support Tests

Static deflections and stresses

Vibration mode survey

Heliostat Array Tests

Reflective surface (mirror) performance

Drive unit/field controller tracking performance

Drive unit/field controller off-nominal performance (variable conditions)

Exposure effects (including solar exposure of mirror)

Wind load effects (sustained and gust loads, and induced vibration)

Field installation procedures

Operations and maintenance procedures (including emergency response/defocusing)

4.2.2 Preliminary Qualification Tests. Definition to be completed in Phase I to include but not be limited to the following on major elements of the heliostat (reflective surface, structural support, drive unit, control sensors).

Humidity effects

Precipitation effects

Icing effects

Hail and dust (reflector only) effects

Wind loads (static)

Temperature cycling effects

4.2.3 Life Tests. Definition to be completed in Phase I to include but not be limited to the following:

Reflector segment loading

Controls sensors including motor tachometer, position potentiometers, beam sensor/mount

Heliostat pedestal with drive unit and reflector hub

4.3 Verification of Conformance. Verification that the requirements of Sections 3 and 5 of this specification are fulfilled shall be performed by the contractor by the methods specified in Table 1. The methods of verification are defined as follows:

(a) Inspection - examination and measurement of product.

(b) Analysis - examination of the design and associated data, which may include relevant test information.

(c) Similarity - demonstration or acceptable evidence of the performance of sufficiently similar product to permit conformance to be inferred.

Table 1

COLLECTOR SUBSYSTEM RETH REQUIREMENTS
VERIFICATION MATRIX

VERIFICATION METHODS

1. Inspection
2. Analysis
3. Similarity
4. Test
5. Demonstration

N/A denotes "not applicable".

TEST CATEGORY

A. Engineering Test
B. Preliminary Qualification Test
C. Life Tests

Requirement (by paragraph)	Verification Method(s)	Test Category	Remarks
3.1 Collector RETH Definition	1	N/A	
3.1.1 Interface Definition	1, 4, 5	A	
3.1.2 Major Component List	N/A	N/A	
3.2 Characteristics	N/A	N/A	
3.2.1 Performance	2, 4	A, B, C	
3.2.2 Physical Characteristics	1		
3.2.3 Environmental Conditions	2, 4	A, B, C	
3.2.4 Transportability	2, 5	N/A	
3.3 Design and Construction	1	N/A	

Table 1

COLLECTOR SUBSYSTEM RETH REQUIREMENTS VERIFICATION MATRIX (Continued)

Requirement (by paragraph)	Verification Method(s)	Test Category	Remarks
3.3.1 Materials, Processes and Parts	1,2	N/A	
3.3.2 Electrical Transients	1,2,4	A	
3.3.3 Nameplates	1	N/A	
3.3.4 Workmanship	1	N/A	
3.3.5 Safety	1,2	N/A	
3.4 Documentation	1,2	N/A	
3.5 Precedence	N/A	N/A	
5.0 Preparation for Delivery	1,2	N/A	

(d) Test - functional operation or exposure under specified conditions to evaluate product performance.

(e) Demonstration - exhibition of the product or service in its intended modes and conditions.

4.3.1 Hardware Design Verification for SRE. The contractor shall provide a system by which conformance of hardware to the DDR approved design and any authorized changes thereto will be verified prior to initiation of SRE level tests. This verification of conformance to design shall include inspection, proof-by-assembly, the examination of records, or a combination of these.

A record shall be made of each inspection or examination and of the verification. In addition, evidence shall be maintained of satisfactory accomplishment of inspections and examinations required by applicable codes and standards that apply to the collector SRE test hardware.

5.0 PREPARATION FOR DELIVERY

5.1 General. Packaging for collector RETH components shall provide adequate protection during shipment by common carrier from supplier to the first receiving activity for immediate use or temporary storage.

5.2 Preservation and Packaging. RETH components that may be harmed when exposed to the normal transportation and handling environments (paragraph 3.2.3.2) shall be protected by inert environments, barrier materials, or equivalent techniques.

5.3 Packing. Shipping containers and their cushioning devices shall ensure protection of collector RETH components when exposed to the shock and vibration loads defined in paragraph 3.2.3.2. Containers shall meet, as a minimum, the requirements in the following regulations as applicable to the mode of transportation utilized.

(a)	National Motor Freight Classification	(Highway Transportation)
(b)	Uniform Freight Classification	(Railroad Transportation)
(c)	CAB Tariff 96 and 169	(Air Transportation)
(d)	R. M. Graziano's Tariff 29	(For Dangerous Articles Surface)
(e)	CAB Tariff 82	(For Dangerous Articles Air)

5.4 Handling and Transportability. Containers with gross weights exceeding 60 pounds shall have skids and other provisions for handling by standard materials handling equipment. When feasible, container sizes and configurations shall be compatible with efficient utilization of transport vehicles.

5.5 Marking. Unless otherwise specified, container marking shall be standard commercial practice.

PART 3 RECEIVER SRE

PART 3 RECEIVER SRE

RECEIVER SUBSYSTEM

RESEARCH EXPERIMENT TEST HARDWARE

REQUIREMENTS SPECIFICATION

APRIL 1975

VOLUME 2
PART 3

CONTENTS

CONTENTS (Continued)

1.0 SCOPE

This specification establishes the performance, design and test requirements for the receiver subsystem research experiment test hardware (RETH).

2.0 APPLICABLE DOCUMENTS

The equipment, materials, design, and construction of the receiver RETH shall comply with all Federal, state, and local standards, regulations, codes, laws, and ordinances which are currently applicable for the selected test site. These would include but not be limited to the government and non-government documents itemized below. If there is an overlap in or conflict between the requirements of these documents and the applicable Federal, state, county, or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent shall take precedence.

The following documents of the issue in effect on the date of request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Government Documents

2.1.1 Specifications

Regulations of the Occupational Safety and Health Administration (OSHA)

Regulations of the California Occupational Safety and Health Administration (CAL/OSHA) - if required

2.1.2 Other Publications

National Motor Freight Classification 100B - Classes and Rules Apply on Motor Freight Traffic

Uniform Freight Classification 11 - Railroad Traffic Ratings Rules and Regulations

CAB Tariff 96 - Official Air Transport Rules Tariff

CAB Tariff 169 - Official Air Transport Local Commodity Tariff

R. H. Graziano's Tariff 29 - Hazardous Materials Regulations of the Department of Transportation

CAB Tariff 82 - Official Air Transport Restricted Articles Tariff

2.2 Non-Government Documents

2.2.1 Standards

American National Standards Institute, B31.1 Power Piping

Manual of Steel Construction, 7th Edition, 1974, American Institute of Steel Construction, Building Code Requirements For Reinforced Concrete, ACI 318-71, American Concrete Institute

Uniform Building Code - 1973 Edition, Volume 1 by International Conference of Building Officials

American Society of Mechanical Engineering, Boiler and Pressure Vessel Code:

- Section 1, Rules for Construction of Power Boilers
- Section 2, Material Specifications
- Section 5, Nondestructive Examination
- Section 8, Unfired Pressure Vessels
- Section 9, Welding and Brazing Qualifications

National Electric Code, NFPA 70-1971 (ANSI C1-1971)

3.0 REQUIREMENTS

3.1 Receiver Subsystem RETH Definition. The receiver RETH shall provide a means of transferring radiant energy which is thermodynamically similar to that to be used in the proof-of-concept experiment (POCE) into steam to establish receiver performance. The receiver RETH consists of:

(a) A POCE receiver segment (absorber (boiler superheater), headers, valves, controls and instrumentation) per ASME Boiler and Pressure Vessel Code.

(b) Single tubes representative of POCE counterparts.

(c) A segment of a POCE panel representative of POCE thermal/structural restraints to demonstrate cycle life.

(d) A POCE panel segment representative of POCE mass distribution, stiffness, and structural attachments for investigating aerodynamic flutter and wind loading.

(e) A small segment of a POCE panel for determination of high intensity solar insolation effects.

The receiver RETH design shall be capable of scaling to a larger central receiver proof-of-concept experiment (pilot plant) and another larger commercial power generating system. The receiver RETH shall be controlled from a master control room in the test facility.

3.1.1 Receiver RETH Diagram. Figures 1, 2, and 3 show schematically the major RETH test configurations and the interfaces with the facility and instrumentation.

3.1.2 Interface Definition

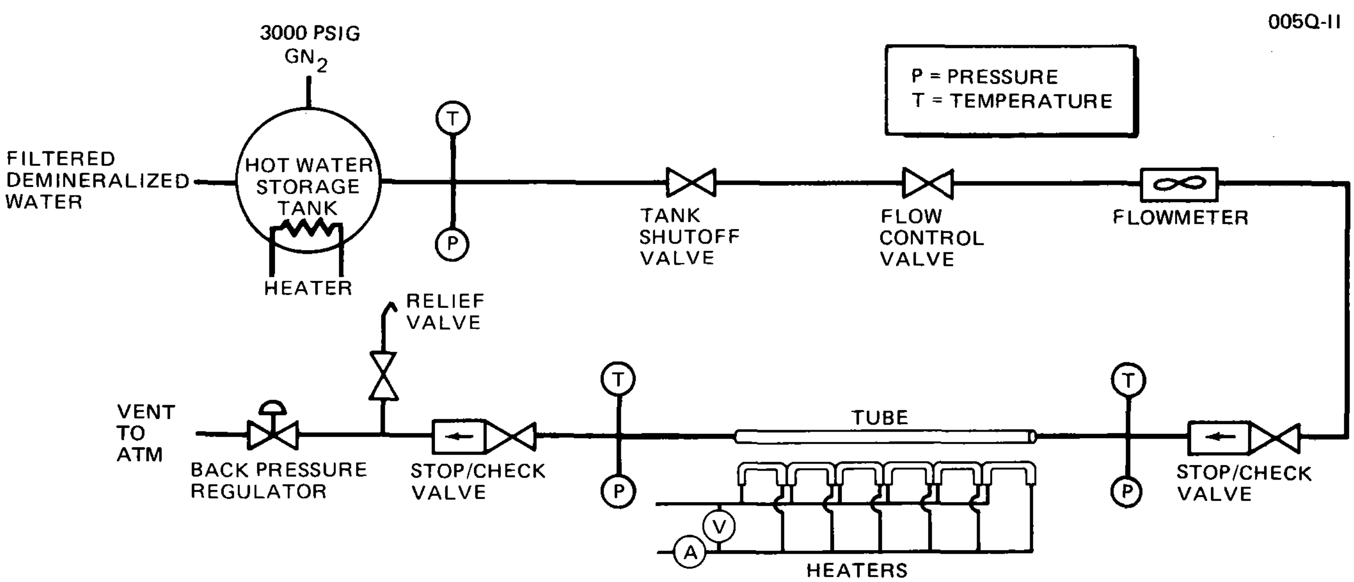


Figure 1. Configuration for Steady-State Tube Tests

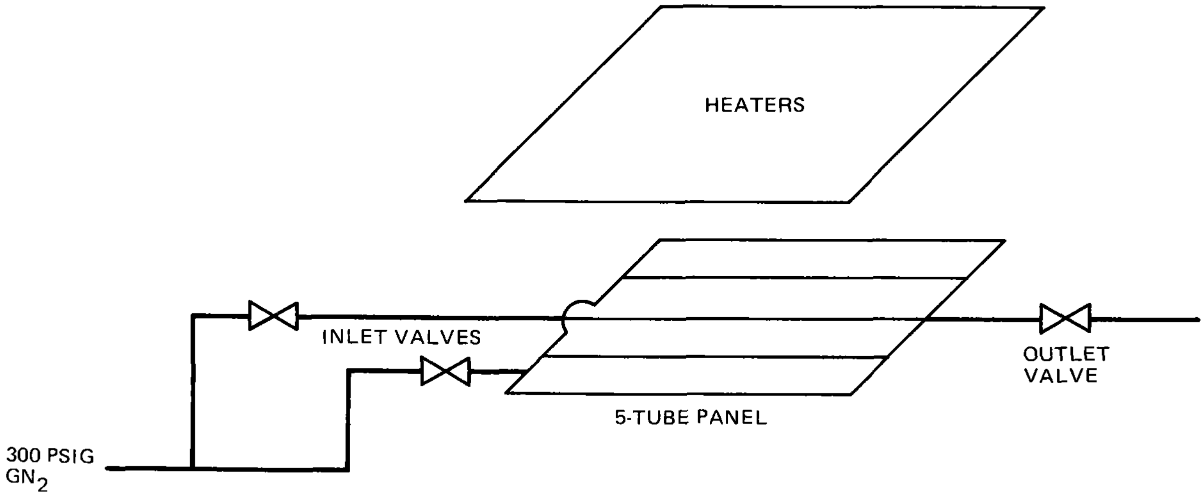


Figure 2. RETH for Panel Cycling Test

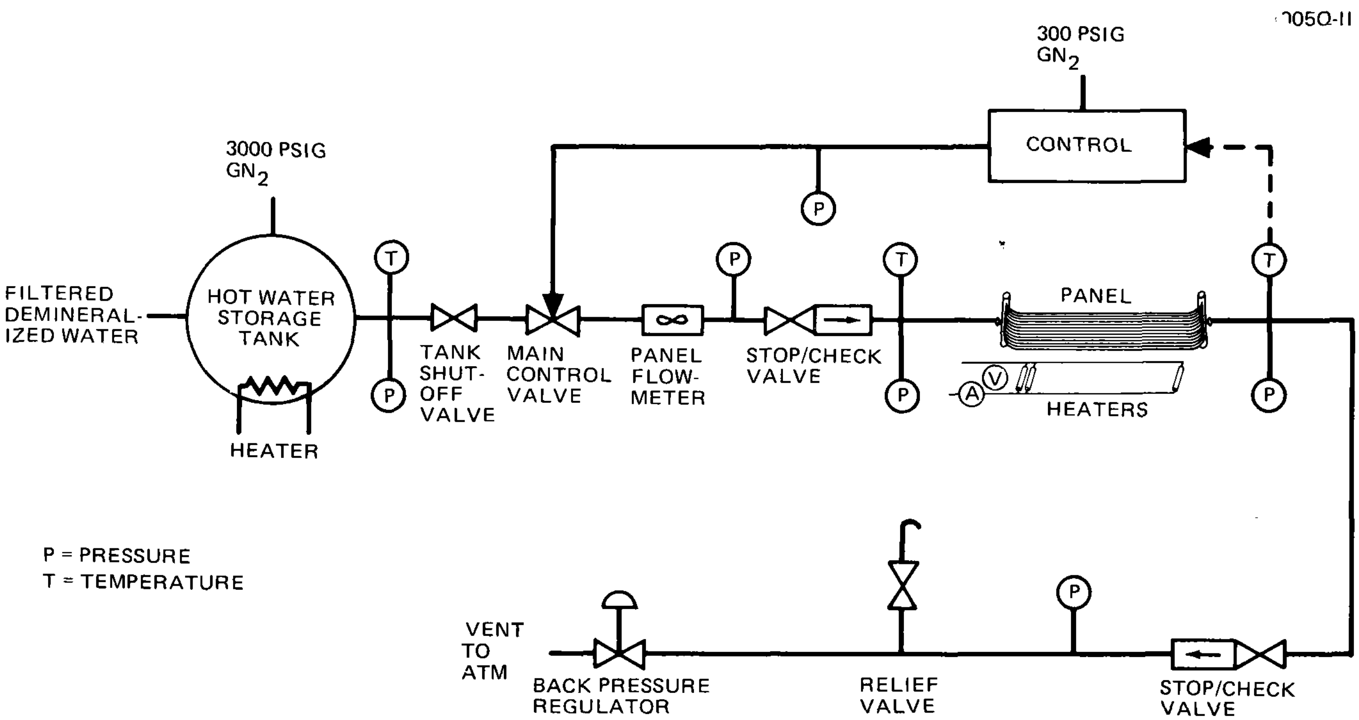


Figure 3. Configuration for Controlled Panel

3.1.2.1 <u>Physical and Functional Interfaces.</u> The physical and functional interfaces between the RETH and test facilities are defined in Table 1.

3.1.2.2 <u>Receiver Control/Master Control.</u> The RETH controls shall be responsive to standard control signals (per power industry practice) from the centralized master control room of the test facility.

Table 1

RETH INTERFACES

RETH Item	Physical Interfaces	Functional Interfaces
Single Tube	Water inlet	205 to 260 degrees C (400 to 500 degrees F) temperature 13.8 MN/m^2 (2,000 psia) pressure 0.045 to 0.132 kg/sec (0.01 to 0.06 lb/sec) flow
	Steam outlet	510 degrees C (950 degrees F) temperature 12.4 MN/m^2 (1,800 psia) pressure 0.045 to 0.132 kg/sec (0.01 to 0.06 lb/sec) flow
	Vertical installation Fixed at upper end Guided along length	
	Radiant heated	25 kW Power 0.3 MW/m^2 maximum heat flux (0.185 Btu/in^2-sec)
POCE Receiver Segment	Water inlet	205 to 260 degrees C (400 to 500 degrees F) 13.8 MN/m^2 (2,000 psia) 0.45 to 2.7 kg/sec (1 to 6 lb/sec)
	Steam outlet	510 degrees C (950 degrees F) 12.4 MN/m^2 (1,800 psia) 0.45 to 2.7 kg/sec (1 to 6 lb/sec)
	Vertical installation Fixed at top Guided along length	
	Radiant power Peak heat flux	2.5 MW 0.3 MW/m^2 (0.185 Btu/in^2-sec)
	GN_2	0.21 MN/m^2 (30 psia)
	Electric power	110 VAC (TBD) watts
Thermal Cycle Sample	GN_2 inlet	2.1 MN/m^2 (300 psia) (TBD) lb/sec
	GN_2 outlet	2.1 MN/m^2 (300 psia)

Table 1

RETH INTERFACES (Continued)

RETH Item	Physical Interfaces	Functional Interfaces
	Radiant heated	5 kW 0.5 MW/m^2 (0.3 Btu/in^2-sec)
	Support	No axial restraint
Mechanical Integrity Test Panel Segment	Steam inlet	Ambient to 38 degrees C (100 degrees F)
	Sandbags	Simulate
	Horizontal support	3 to 51 m/sec wind
Solar Insolation Sample	Water inlet	Ambient temperature (TBD) lb/sec (TBD) pressure
	Solar insolation	0.3 MW/m^2

3.2 Characteristics

3.2.1 Performance. The subsystem test receiver shall have a steam generating capacity sufficient to produce 2.5 MWth. The subsystem test receiver design shall provide for maximum technology transferability to an approximately 40 MWth receiver which could be used for a POCE (pilot plant) and also to a 300 MWth to 900 MWth receiver for a commercial power plant. Specific characteristics of the RETH are as follows:

(a) Maximum skin temperature or average wall temperature (whichever governs) of any component of the receiver shall be in accordance with the ASME Boiler and Pressure Vessel Code, Section 1, at the maximum operating pressure and temperature for the incident flux levels.

(b) The pressure differential between the superheat header and the feedwater header shall be within the range of 0.55 to 0.83 MN/m^2 (80 to 120 psia) when the receiver is generating steam at the specified capacity.

(c) The effective absorptance of the receiver boiler and superheat surfaces at operating temperatures shall be 0.9 or greater.

(d) The total emittance of the receiver boiler and superheat surfaces shall be as small as practical, consistent with maintaining the specified solar absorptance.

(e) Instrumentation and controls shall respond to transient conditions rapidly enough to avoid adverse effects on receiver components. Instrumentation shall be installed per NEMA standards. Control valve response time shall be less than 10 seconds.

3.2.2 Physical Characteristics. The RETH segment shall have a maximum operating weight less than 2,000 kg (4,400 lb), a maximum vertical dimension less than 17m (56 ft), and a maximum projected horizontal dimension less than 1m (3.3 ft). The receiver RETH shall be of such a design that it can be readily erected on and removed from the test facility tower. The panel shall have provisions to facilitate replacement of flow control orifices. The main receiver (boiler) header and downcomer connectors shall be capable of withstanding not less than 454 kg (1,000 lb) axial and transverse loads.

3.2.3 Environmental Conditions

3.2.3.1 General. The receiver RETH shall be designed to withstand the same natural environmental conditions expected to be encountered during installation and operation on the POCE tower. The conditions described in the following paragraphs are representative of the transportation and POCE site environments to be encountered by the receiver. For RETH design purposes, safety margins shall be used commensurate with cost and performance requirements to ensure operation in accordance with paragraph 3.2.1 during or after exposure to these conditions.

3.2.3.2 Transportation and Handling. The following conditions occurring separately or in combination may be encountered by packaged RETH during handling and transportation.

3.2.3.2.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.3.2.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.3.2.3 Transportation Vibration and Shock. Vibration and shock as encountered during transport. Conditions are as follows:

VIBRATION

Transportation Mode	Continuous Excitations (Steady-State) in g's	Discrete Impulse (Transient) in g's	Predominant Frequency Range
Highway	0.06	1.5	2 to 200 Hz
Rail	0.05	1.5	2 to 200 Hz
Air (Jet Aircraft)	0.05	1.5	2 to 500 Hz

SHOCK (g's)

(Normal Load Limits)

Transport Media	Longitudinal	Lateral	Vertical	Average Pulse Time msec
Air	2.0	1.5	2.0	11 to 40
Highway	2.0	1.5	3.0	11 to 40
Rail (Rolling)[1]	3.0	0.75	3.0	11 to 40
Cushion Car (Humping)	3.0	2.0	3.0	11 to 40

(1) Shock loads are for rail cars equipped with standard draft gears.

All critical (frangible) components of the receiver subsystem RETH shall be designed or packaged such that the conditions described above do not induce a dynamic environmental condition which exceeds the structural capability of the component. These conditions reflect careful handling and firmly constrained (tied down) transporting via common carrier.

All components shall be designed to withstand handling/hoisting inertial loads up to 2 g's considering number, location, and type of hoisting points.

3.2.3.2.4 Handling Shock. Handling shocks may result from drops of packaged equipment. Corresponding acceleration peaks may be of the order of 7 g's vertical and 4 g's horizontal with a (TBD) wave profile and a duration of 10 to 50 milliseconds.

3.2.3.2.5 Other Conditions. The equipment may encounter other conditions during transportation and handling including wind, rain, snow, ice, hail, and blowing sand and dust. These are not expected to exceed the operational conditions of paragraph 3.2.3.3.

Sand is defined as particles greater than 100 μm in diameter. Desert sand flux declines approximately exponentially with height above the surface. For the surface roughness expected at the POCE site, 90 percent of the sand flux will be within 25 cm (10 in) of the surface. The design shall withstand a sand flux which averages 0.3 g/cm^2-sec within that region at velocities up to (TBD) meters/second.

The frequency of storm occurrence and duration to be considered will depend on the POCE site selected. For example, in the Southwestern desert area a major storm frequency of four or less per year with a maximum duration of 36 hours are to be assumed. Minor storms of nine per year and a maximum duration of 6 hours are to be assumed.

The effect of dust devils shall also be considered in the design. The maximum core diameter and tangential velocities to be considered are 70 m (230 ft) and 30 m/sec (98 ft/sec), respectively. The maximum vertical velocity to be considered is 15 m/sec (49 ft/sec).

3.2.3.3.5 Rain, Hail, and Snow. Storms of the following types and intensities:

Rain: Average storm intensity of (TBD) cm/hour (TBD in/hr) for (TBD) hours with peak periods of (TBD) cm/hour (TBD in/hr) lasting (TBD) minutes. Three to five storms per year.

Hail: Mean particle diameter of 5 to 10 mm (0.20 to 0.39 in), extreme maximum diameter of 25 mm (10 in). Fall velocity of 20 m/sec (65.6 ft/sec). Hail stone compressire strength of 1.03 MN/m^2 (150 psi) for 25 mm stone; 5.07 MN/m^2 (735 psi) for stones less than 10 mm in diameter. Storm intensity of (TBD) particles per square meter per minute lasting 10 to 20 minutes. Frequency of occurrence -- one in 5 to 6 years.

Snow: (TBD)

3.2.3.3 POCE Site. The following conditions occurring separately or in combination may be encountered by the receiver during the pilot plant 30-year operational life. Unless specified otherwise, the receiver RETH shall be designed to perform in accordance with paragraph 3.2.1 during and after exposure to these conditions.

3.2.3.3.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.3.3.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.3.3.3 Wind. Sustained surface winds up to 8.9 m/sec (20 mph) for a period of (TBD) hours with gust RMS velocities up to 11.6 m/sec (25.9 mph). While nonoperational, the receiver RETH shall not be damaged by surface winds of 35.7 m/sec (79.9 mph) for periods up to (TBD) hours with gust RMS velocities to 46.4 m/sec (103.8 mph).

These are derived from 35.7 m/sec (79.9 mph) base, 50-year fastest mile (Reference ASCE Paper 3269, Vol. 126). Maximum steady winds with gusts during operation are to be considered throughout a complete daylight operational period. Practices recommended in the ASCE Paper 3269, Vol. 126 and the Uniform Building Code, 1973, Vol. 1 shall be employed in designing the receiver RETH winds.

3.2.3.3.4 Sand and Dust. The receiver RETH shall not evidence operational degradation or component destruction following exposure to sand and dust storms. The design shall withstand dust fluxes of 10^{-4} g/cm^2-sec at velocities up to (TBD) meters/second. Dust is defined to be those particles up to 100 μm in diameter with the mean diameter being 40 to 50 μm.

3.2.3.3.6 Lightning. The receiver RETH shall be designed to withstand a lightning threat that has a current pulse of 140,000 amperes with a 1.5 microsecond rise time decaying to 50 percent in 40 microseconds. A continuing current of 200 to 400 amperes will follow the main stroke and last for 160 to 300 milliseconds. Up to 10 restrokes can occur with 30,000 to 70,000 amperes peak current each. Total charge transfer of the primary stroke and the restroke events can reach 200 coulombs.

3.2.4 Transportability. RETH components shall be transportable within applicable Federal and state regulations by highway and railroad carriers utilizing standard transport vehicles and materials handling equipment. The components, in their packaged condition, shall be capable of withstanding the climatic conditions and shock and vibration environments defined in paragraph 3.2.3.2. Whenever feasible, components shall be segmented and packaged to sizes that are transportable under normal commercial transportation limitations (see (a) below). Components that exceed normal transportation limits (see (b) below) shall be transportable with the use of special routes, clearances, and permits.

(a) Transportability Limits for Normal Conditions (Permits Not Required)

	Truck	Rail
Height:	13 ft 6 in above road	16 ft 0 in
Width:	8 ft 0 in	10 ft 6 in

Length:	55 ft 0 in - Eastern States 60 ft 0 in - Western States	60 ft 6 in
Gross Wt:	73,280 lb; 18,000 lb/axle	200,000 lb

(b) Transportability Limits for Special Conditions

	Truck	Rail
Height:	14 ft 6 in above road	16 ft 0 in above rail
Width:	12 ft 0 in	12 ft 0 in
Length:	70 ft 0 in	80 ft 6 in
Gross Wt:	100,000 lb with sufficient axles to distribute weight over highway not to exceed 18,000 lb/axle.	400,000 lb

3.3 Design and Construction. The receiver RETH shall be designed and constructed in accordance with the ASME Boiler and Pressure Vessel Code, Sections 1, 2, 5 and 9. Piping shall be provided as specified in ANSI B31.1.

3.3.1 Materials, Processes, and Parts. The receiver RETH shall be fabricated from materials as specified in the ASME Boiler and Pressure Vessel Code, Sections 1, 2 and ANSI B31.1. Materials shall be suitable for the conditions of intended usage. Except where otherwise specified, all structural materials and fabricated steel used in items of equipment shall conform to the Standards of the American Institute of Steel Construction and Uniform Building Code as applicable.

3.3.2 Electrical Transients. The electrical components of the receiver RETH shall not be adversely affected by external or internal power line transients caused by normal switching, fault clearing, or lightning. Switching transients and fault clearing functions will require less than six cycles of the fundamental frequency (100 milliseconds) and shall be limited to 1.7 P.U. voltage (1.7 per unit or 170 percent). Appropriate electrical fusing will be used in the controller to protect against internal excessive electrical transients.

3.3.3 Nameplates. Major components, instruments, and controls shall be labeled with a permanent nameplate listing, as a minimum, manufacturer name, part number, change letter, serial number and date of manufacture.

3.3.4 Workmanship. The receiver RETH and all associated items shall be constructed, fabricated and assembled in accordance with the best modern engineering, shop and field practices consistent with cost and performance requirements. The work shall be accomplished in the manner intended for the approved hardware (e.g., installations meeting the NFPA National Electrical Code). All work shall be finished in a manner such that it presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a generally uniform appearance.

3.3.5 Safety. The receiver RETH shall be designed to minimize safety hazards to operating and service personnel and equipment. Electrical components shall be insulated and grounded. Safety override controls/interlocks shall be provided for servicing. Insulation shall be provided in all parts or components with elevated temperatures exposed to personnel access required for inspections, servicing, repair and maintenance procedures. All pertinent OSHA rules and regulations shall be observed.

3.4 Documentation. The contractor shall provide the following SRE documentation in accordance with the contract data requirements list:

(a) Receiver Subsystem Research Experiment Conceptual Design

(b) Receiver Subsystem Research Experiment Detail Design

(c) Operating Instructions

3.5 Precedence. The order of precendence of receiver RETH requirements and characteristics shall be as follows:

(a) Performance (including scalability to commercial power levels)

(b) Safety

(c) Cost

This specification has precedence over documents referenced herein. The contractor shall notify the procuring activity of each instance of conflicting, or apparently conflicting, requirements within this specification or between this specification and a referenced document.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Tests. All tests shall be performed by the contractor. These tests may be witnessed by ERDA or its representative or the witnessing may be waived. In either case, substantive evidence of compliance with all test requirements is required.

4.1.2 General Test Requirements. Tests shall be conducted in accordance with a test plan to be prepared by the contractor and approved by ERDA. Specific required tests are identified in subsection 4.2. Tests shall be classified in the test plan as:

(a) Engineering tests for the purposes of acquiring engineering design information and confirming engineering hypotheses.

(b) Preliminary qualification tests for the purpose of testing receiver elements under simulated operating conditions.

(c) Life tests for the purposes of testing receiver elements under accelerated or extended life conditions.

4.2 Specific Test Requirements. Specific required tests are defined herein. Additional tests shall be defined by the contractor in the course of design and development where necessary to properly validate the performance and configuration parameters of the projected POCE.

4.2.1 Engineering Tests. Definition to be completed in Phase I to include but not be limited to the following:

Receiver Performance

Cooling/Steam Generation

Mechanical Integrity

Wind load of 3 to 51 meters/second (6.7 to 114 mph)

Flow Control

Flow stability

Flow distribution

Power level control

Emergency responses

Control under variable solar conditions

Receiver Surface Performance

Absorptivity

4.2.2 Preliminary Qualification Tests. Definition to be completed in Phase 1 to include but not be limited to the following:

Temperature cycling (-20 to 60 degrees C) under simulated load

Wind

Precipitation

Earthquake

Other meteorological phenomena

4.2.3 Life Tests. Definition to be completed in Phase 1 to include but not be limited to the following:

Solar exposure

Tube fouling

Receiver control

Structural loading

4.3 Verification of Conformance. Verification that the requirements of sections 3 and 5 of this specification are fulfilled shall be performed by the contractor by the methods specified in Table 2. The methods of verification are defined as follows:

(a) Inspection - examination and measurement of product.

(b) Analysis - examination of the design and associated data, which may include relevant test information.

Table 2

RECEIVER SUBSYSTEM RETH
REQUIREMENTS VERIFICATION MATRIX

Verification Methods	Test Category
1. Inspection	A. Engineering Test
2. Analysis	B. Preliminary Qualification Test
3. Similarity	C. Life Tests
4. Test	
5. Demonstration	

N/A denotes "not applicable"

Requirement (by Paragraph)	Verification Method(s)	Test Category	Remarks
3.1 Receiver RETH Definition	N/A	N/A	
3.1.1 Receiver RETH Diagram	N/A	N/A	
3.1.2 Interface Definition	N/A	N/A	
3.1.2.1 Physical and Functional Interfaces	1, 2, 5	N/A	
3.1.2.2 Receiver Control/ Master Control	1, 2, 5	N/A	
3.2 Characteristics	N/A	N/A	
3.2.1 Performance	2, 4	A, B, C	
3.2.2 Physical Characteristics	1, 2, 4	B, C	

Table 2

RECEIVER SUBSYSTEM RETH
REQUIREMENTS VERIFICATION MATRIX (Continued)

Requirement (by Paragraph)	Verification Method(s)	Test Category	Remarks
3.2.3 Environmental Conditions	2, 4	B, C	
3.2.4 Transportability	2, 5	N/A	
3.3 Design and Construction	1	N/A	
3.3.1 Materials, Processes and Parts	1, 2	N/A	
3.3.2 Electrical Transients	1, 2, 4	B	
3.3.3 Nameplates	1	N/A	
3.3.4 Workmanship	1	N/A	
3.3.5 Safety	1, 2	N/A	
3.4 Documentation	1, 2	N/A	
3.5 Precedence	N/A	N/A	
5.0 Preparation for Delivery	1, 2	N/A	

(c) Similarity - demonstration or acceptable evidence of the performance of sufficiently similar product to permit conformance to be inferred.

(d) Test - functional operation or exposure under specified conditions to evaluate product performance.

(e) Demonstration - exhibition of the product or service in its intended modes and conditions.

4.3.1 Hardware Design Verification for SRE. The contractor shall provide a system by which conformance of hardware to the DDR approved design and any authorized changes thereto will be verified prior to initiation of SRE level tests. This verification of conformance to design shall include inspection, proof-by-assembly, the examination of records, or a combination of these. A record shall be made of each inspection or examination and of the verification. In addition, evidence shall be maintained of satisfactory accomplishment of inspections and examinations required by applicable codes and standards that apply to the receiver SRE test hardware.

5.0 PREPARATION FOR DELIVERY

5.1 General. Packaging for receiver RETH components shall provide adequate protection during shipment by common carrier from supplier to the first receiving activity for immediate use or temporary storage.

5.2 Preservation and Packaging. Receiver RETH components that may be harmed when exposed to the normal transportation and handling environments of paragraph 3.2.6 shall be protected by inert environments, barrier materials, or equivalent techniques.

5.3 Packing. Shipping containers and their cushioning devices shall ensure protection of RETH components when exposed to the shock and vibration loads defined in paragraph 3.2.3. Containers shall meet, as a minimum, the requirements in the following regulations as applicable to the mode of transportation utilized.

(a) National Motor Freight Classification (Highway Transportation)

(b) Uniform Freight Classification (Railroad Transportation)

(c) CAB Tariff 96 and 169 (Air Transportation)

(d) R. M. Graziano's Tariff 29 (For Dangerous Articles Surface)

(e) CAB Tariff 82 (For Dangerous Articles Air)

5.4 Handling and Transportability. Containers with gross weights exceeding 60 pounds shall have skids and other provisions for handling by standard materials handling equipment. When feasible, container sizes and configurations shall be compatible with efficient utilization of transport vehicles.

5.5 Marking. Unless otherwise specified, container marking shall be standard commercial practice.

PART 4 THERMAL STORAGE SRE

THERMAL STORAGE SUBSYSTEM
RESEARCH EXPERIMENT TEST HARDWARE
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CONTENTS (Continued)

1.0 SCOPE

This specification establishes the performance, design, and test requirements for the thermal storage subsystem research experiment test hardware (RETH).

2.0 APPLICABLE DOCUMENTS

The equipment, materials, design, and construction of the thermal storage subsystem RETH shall comply with all Federal, state, and local standards, regulations, codes, laws, and ordinances which are currently applicable for the selected test site. These shall include but not be limited to the government and non-government documents itemized below. If there is an overlap in or conflict between the requirements of these documents and the applicable Federal, state, county, or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent shall take precedence.

The following documents of the issue in effect on the date of request for proposal form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Government Documents

2.1.1 Specifications

Regulations of the Occupational Safety and Health Administration (OSHA)

Regulations of the California Occupational Safety and Health Administration CAL/OSHA - if required.

2.1.2 Other Publications

National Motor Freight Classification 100B - Classes and Rules Apply on Motor Freight Traffic

Uniform Freight Classification 11 - Railroad Traffic Ratings Rules and Regulations

CAB Tariff 96 - Official Air Transport Rules Tariff

CAB Tariff 169 - Official Air Transport Local Commodity Tariff

R. H. Graziano's Tariff 29 - Hazardous Materials Regulations of the Department of Transportation

CAB Tariff 82 - Official Air Transport Restricted Articles Tariff

2.2 Non-Government Documents

2.2.1 Standards

Manual of Steel Construction, 7th Edition, 1974, American Institute of Steel Construction.

Building Code Requirements for Reinforced Concrete, ACI 318-71, American Concrete Institute.

American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section 8, Unfired Pressure Vessels.

American National Standards Institute, B31.1, Power Piping.

National Electric Code, NFPA 70-1971 (ANSI CI-1971).

3.0 REQUIREMENTS

3.1 Thermal Storage Subsystem RETH Definition. The thermal storage subsystem for a central receiver solar thermal power system provides a means of transferring to stored thermal energy any portion of the thermal output from the receiver subsystem and subsequently transferring stored thermal energy to the working fluid in a form suitable for generating electrical power with a conventional turbine-generator. The thermal storage subsystem research experiments will be conducted to verify the approach to storage of thermal energy, and to establish data needed to ensure success in the POCE (pilot plant) design and operation. The thermal storage subsystem RETH design shall be capable of scaling to a larger central receiver proof-of-concept experiment (pilot plant) and another larger commercial power generating system.

3.1.1 Thermal Storage Subsystem RETH Diagram. The RETH functional schematic diagram is given in Figure 1, showing all major components and their interrelationships.

3.1.2 Interface Definition. Interfaces between major components of the thermal storage subsystem RETH are shown in Figure 1. The major components of the thermal storage subsystem shall be physically and functionally compatible with each other. Piping, connections, and mounting fixtures shall be provided to physically interface major components, as shown in Figure 1. The physical and functional interfaces between the RETH and the test facilities are defined in Table 1.

3.1.3 Major Component List. The major components comprising the subsystem RETH are as follows:

(a) Thermal storage unit, including rock, heat transfer fluid, containers, structures, internal piping, insulation.

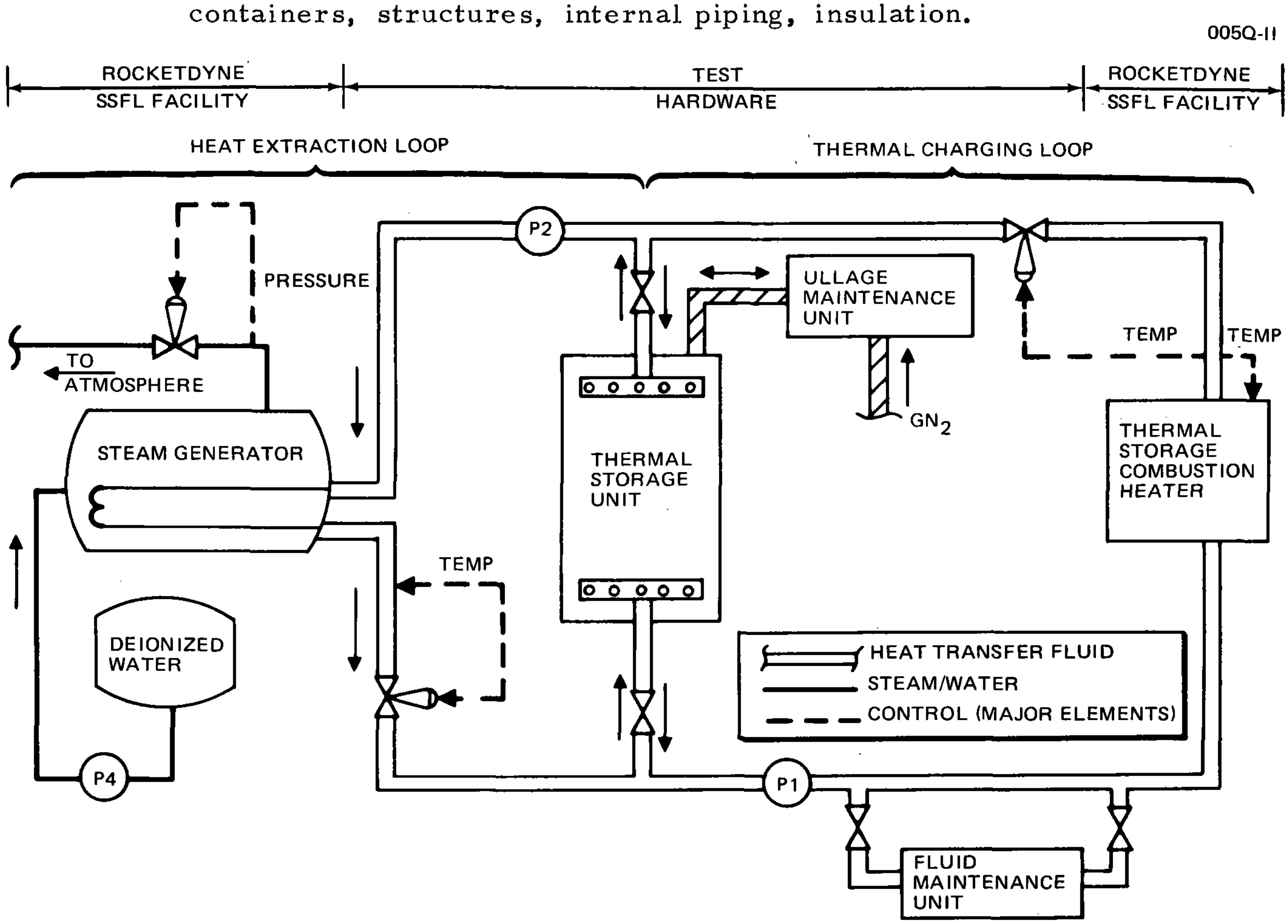

Figure 1. SRE Thermal Storage Subsystem Process Flow Diagram

Table 1

THERMAL STORAGE SUBSYSTEM RETH INTERFACES WITH TEST FACILITY

RETH Function	Physical Interfaces	Functional Interfaces
Heat transfer fluid heating	Piping to and from storage tank	Minimum temperature 344 degrees C (650 degrees F) Heating rate 0. 15 to 2 MWth
Heat rejection from heat transfer fluid	Piping to and from thermal storage tank	Maximum temperature 150 degrees C (300 degrees F) Extraction rate 0. 15 to 5 MWth
Inert gas tank ullage	Piping to ullage maintenance unit	Gaseous nitrogen (GN_2) 6. 4 scmh (180 scfh) for 2 hours 0. 5 scmh (14 scfh) for 6 hours
Electrical power	Wiring to two fluid circulation pump motors	25 kW each
Thermal storage unit installation	Concrete foundation 4m (12 ft) diameter	250, 000 kg (550, 000 lb) weight

(b) Thermal storage heater

(c) Steam generator

(d) Thermal charging loop pump

(e) Energy extraction loop pump

(f) Fluid maintenance unit

(g) Ullage maintenance unit for thermal storage unit

(h) Deionized water supply tank and pump

(i) Piping, valves, instrumentation, and controls required to regulate and direct the fluid flows and conditions, as indicated by Figure 1.

3.2 Characteristics

3.2.1 Performance. The thermal storage subsystem RETH shall have an extractable thermal storage capacity of not less than 4 MWth-hr, with thermal charging rates up to 2 MWth and energy extraction rates from 1 to 5 MWth. The instrumentation and controls response times shall be adequate to ensure stable, flexible, safe operation during all test modes.

3.2.2 Physical Characteristics. Specific size, shape, and configuration constraints will be governed only by the test facility layout and design to facilitate efficient and safe operation and maintenance. The thermal storage subsystem shall be designed to provide safe and reasonable ingress, egress, and access for proper inspection, maintenance and repair of the structure, steam lines, utilities, instrumentation, and controls.

The thermal storage tank shall have a diameter not greater than 3.6m (12 ft) for transportability. The tank shall be designed to permit handling and shipping while empty in vertical or horizontal orientations. All of the above shall be consistent with cost considerations.

3.2.3 Environmental Conditions

3.2.3.1 General. The conditions described in the following paragraphs are representative of the transportation and test site environments to be encountered by the thermal storage RETH. For design purposes, safety margins shall be used commensurate with cost and performance requirements to ensure operation in accordance with paragraph 3.2.1 during or after exposure to these conditions.

3.2.3.2 Transportation and Handling. The following conditions occurring separately or in combination may be encountered by packaged equipment during handling and transportation.

3.2.3.2.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.3.2.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.3.2.3 Transportation Vibration and Shock. Vibration and shock as encountered during transport. Conditions are as follows:

VIBRATION

Transportation Mode	Continuous Excitations (Steady-State) in g's	Discrete Impulse (Transient) in g's	Predominant Frequency Range
Highway	0.06	1.5	2 to 200 Hz
Rail	0.05	1.5	2 to 200 Hz
Air (Jet Aircraft)	0.05	1.5	2 to 500 Hz

SHOCK (g's)
(Normal Load Limits)

Transport Media	Longitudinal	Lateral	Vertical	Average Pulse Time msec
Air	2.0	1.5	2.0	11 to 40
Highway	2.0	1.5	3.0	11 to 40
Rail (Rolling) (1)	3.0	0.75	3.0	11 to 40
Cushion Car (Humping)	3.0	2.0	3.0	11 to 40

(1) Shock loads are for rail cars equipped with standard draft gears.

All critical (frangible) components of the subsystem shall be designed or packaged such that the conditions described above do not induce a dynamic environmental condition which exceeds the structural capability of the component. These conditions reflect careful handling and firmly constrained (tied down) transporting via common carrier.

All components shall be designed to withstand handling/hoisting inertial loads up to 2 g's considering number, location, and type of hoisting points.

3.2.3.2.4 Handling Shock. Handling shocks may result from drops of packaged equipment. Corresponding acceleration peaks may be of the order of 7 g's vertical and 4 g's horizontal with a (TBD) wave profile and a duration of 10 to 50 milliseconds.

3.2.3.2.5 Other Conditions. The equipment may encounter other conditions during transportation and handling including wind, rain, snow, ice, hail, and blowing sand and dust. These are not expected to exceed the SRE conditions of paragraph 3.2.3.3.

3.2.3.3 SRE Conditions. The following conditions occurring separately or in combination may be encountered by the thermal storage RETH. Unless specified otherwise, the RETH shall be designed to perform in accordance with paragraph 3.2.1 during and after exposure to these conditions.

3.2.3.3.1 Temperature. Surrounding air temperature from a minimum of -20 degrees C (-4 degrees F) to a maximum of 60 degrees C (140 degrees F).

3.2.3.3.2 Humidity. Relative humidity up to 100 percent with conditions such that condensation takes place in the form of water or frost.

3.2.3.3.3 Wind. Sustained surface winds up to 8.9 m/sec (20 mph) for a period of (TBD) hours with gust RMS velocities up to 11.6 m/sec (25.9 mph). While nonoperational, the thermal storage RETH shall not be damaged by surface winds of 35.7 m/sec (79.9 mph) for periods up to (TBD) hours with gust RMS velocities to 46.4 m/sec (103.8 mph). These are derived from 35.7 m/sec (79.9 mph) base, 50-year fastest mile (Reference ASCE Paper 3269, Vol. 126). Maximum steady winds with gusts during operation are to be considered throughout a complete daylight operational period. Practices recommended in the ASCE Paper 3269, Vol. 126 and the Uniform Building Code, 1973, Vol. 1 shall be employed in designing the thermal storage RETH for winds.

3.2.3.3.4 Sand and Dust. The RETH shall be designed to withstand dust fluxes of 10^{-4} g/cm^2-sec at velocities up to (TBD) meters/second. Dust is defined to be those particles up to 100 µm in diameter with the mean diameter being 40 to 50 µm.

Sand is defined as particles greater than 100 µm in diameter. Sand flux at the SRE test site will be negligible.

The RETH design shall provide protection of components from the electrostatic charging and discharging associated with dust storms.

3.2.3.3.5 Rain, Hail, and Snow. Storms of the following types and intensities:

Rain: Average storm intensity of (TBD) cm/hour (TBD in/hr) for (TBD) hours with peak periods of (TBD) cm/hour (TBD in/hr) lasting (TBD) minutes. Three to five storms per year.

Hail: Mean particle diameter of 5 to 10 mm (0.20 to 0.39 in) extreme maximum diameter of 25 mm (1 in). Fall velocity of 20 m/sec (65.6 ft/sec). Hail stone compressive strength of 1.03 MN/m^2 (150 psi) for 25 mm stone; 5.07 MN/m^2 (735 psi) for stones less than 10 mm in diameter. Storm intensity of (TBD) particles per square meter per minute lasting 10 to 20 minutes. Frequency of occurrence -- one in 5 to 6 years.

Snow: (TBD)

3.2.4 Transportability. Thermal storage subsystem RETH shall be transportable within applicable Federal and state regulations by highway and railroad carriers utilizing standard transport vehicles and materials handling equipment. RETH components, in their packaged condition, shall be capable of withstanding the climatic conditions and shock and vibration environments defined in paragraph 3.2.3.2. Whenever feasible, components shall be segmented and packaged to sizes that are transportable under normal commercial transportation limitations (see (a) below). Components that exceed normal transportation limits (see (b) below) shall be transportable with the use of special routes, clearances, and permits.

(a) Transportability Limits for Normal Conditions (Permits Not Required)

	Truck	Rail
Height:	13 ft 6 in above road	16 ft 0 in
Width:	8 ft 0 in	10 ft 6 in
Length:	55 ft 0 in - Eastern States 60 ft 0 in - Western States	60 ft 6 in
Gross Wt:	73, 280 lb; 18, 000 lb/axle	200, 000 lb

(b) Transportability Limits for Special Conditions

	Truck	Rail
Height:	14 ft 6 in above road	16 ft 0 in above rail
Width:	12 ft 0 in	12 ft 0 in
Length:	70 ft 0 in	80 ft 6 in
Gross Wt:	100, 000 lb with sufficient axles to distribute weight over highway not to exceed 18, 000 lb/axle.	400, 000 lb

3.3 Design and Construction. The RETH thermal storage tank shall be designed, fabricated, and inspected to conform to the ASME Code for Unfired Pressure Vessels. Piping shall be designed and fabricated in accordance with the American National Standard Code for Pressure Piping. Piping shall be largely field-fabricated, although shop prefabrication of selected segments may be used, where cost effective. Insulation of components and piping shall be installed at the test site, except where cost effective to be prefabricated and/or preinstalled.

3.3.1 Materials, Processes, and Parts. Materials of construction throughout shall be selected to ensure compatibility with the process fluids at the maximum operating conditions. Materials shall be suitable for the conditions of intended usage. Special attention shall be directed to prevent unnecessary use of costly materials. No toxic or exotic materials shall be used. Except where otherwise specified, all structural materials and fabricated steel used in items of equipment shall conform to the standards of the American Institute of Steel Construction and the Uniform Building Code, as applicable. Whenever possible, standard and commercial parts shall be used. Specifically, the following shall be commercial parts:

Heat transfer fluid pumps

Water pumps

Valves and controls

(others TBD)

3.3.2 Electrical Transients. The RETH operation shall not be adversely affected by external or internal power line transients caused by normal switching or fault clearing. Switching transients and fault clearing functions will require less than six cycles of the fundamental frequency (100 milliseconds) and shall be limited to 1.7 P.U. voltage (1.7 per unit or 170 percent).

3.3.3 Nameplates. Major components, instruments, and controls shall be labeled with a permanent nameplate listing, as a minimum, manufacturer name, part number, change letter, serial number, and date of manufacture.

3.3.4 Workmanship. The thermal storage subsystem RETH shall be constructed, fabricated, and assembled in accordance with the best modern engineering, shop, and field practices consistent with cost and performance requirements. The work shall be accomplished in the manner intended for the approved hardware (e.g., installations meeting the NFPA National Electrical Code). All work shall be finished in a manner such that it presents no unintended hazard to operating and maintenance personnel, is neat and clean, and presents a generally uniform appearance.

3.3.5 Safety. The thermal storage subsystem RETH shall be designed to minimize safety hazards to operating and service personnel and equipment. Electrical components shall be insulated and grounded. All parts or components with elevated temperatures shall be insulated against contact with or exposure to personnel. Any moving elements shall be shielded to avoid entanglements and safety override controls/interlocks shall be provided for servicing. All pertinent OSHA rules and regulations shall be observed.

3.4 Documentation. The contractor shall provide the following SRE documentation in accordance with the contract data requirements list:

(a) Thermal storage research experiment conceptual design

(b) Thermal storage subsystem research experiment detail design

(c) Operating instructions

3.5 Precedence. The order of precedence of RETH characteristics and requirements shall be as follows:

(a) Performance (including scalability to commercial power levels)

(b) Safety

(c) Cost

This specification has precedence over documents referenced herein. The contractor shall notify the procuring activity of each instance of conflicting, or apparently conflicting, requirements within this specification or between this specification and a referenced document.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Tests. All tests shall be performed by the contractor. These tests may be witnessed by ERDA or its representatives or the witnessing may be waived. In either case, substantive evidence of compliance with all test requirements is required.

4.1.2 General Test Requirements. Tests shall be conducted in accordance with a test plan to be prepared by the contractor and approved by ERDA.

Specific required tests are identified in subsection 4.2. Tests shall be classified in the test plan as:

(a) Engineering tests for the purposes of acquiring engineering design information and confirming engineering hypotheses.

(b) Preliminary qualification tests for the purposes of testing a thermal storage subsystem or assembly thereof under simulated operating conditions.

(c) Life tests for the purposes of testing a thermal storage subsystem or assembly thereof under accelerated or extended life conditions.

4.2 Specific Test Requirements. Specific required tests are defined herein. Additional tests shall be defined by the contractor in the course of design and development where necessary to properly validate the performance and configuration parameters of the projected POCE.

4.2.1 Engineering Tests

- Thermal storage performance
  - Storage efficiency
  - Charging and extraction
  - Thermocline characteristics
- Mechanical integrity
- Thermal storage controls
  - Steady-state operation
  - Variable-rate operation
  - Transition between modes
  - Emergency responses
- Heat loss

4.2.2 Preliminary Qualification Tests

- Thermal stability of heat transfer fluid
- Tank/rock bed thermal cycle interactions

4.2.3 Life Tests

Thermal stability of heat transfer fluid

Tank/rock bed thermal cycle interactions

4.3 Verification of Conformance. Verification that the requirements of sections 3 and 5 of this specification are fulfilled shall be performed by the contractor by the methods specified in Table 2. The methods of verification are defined as follows:

(a) Inspection - examination and measurement of product.

(b) Analysis - examination of the design and associated data, which may include relevant test information.

(c) Similarity - demonstration or acceptable evidence of the performance of sufficiently similar product to permit conformance to be inferred.

(d) Test - functional operation or exposure under specified conditions to evaluate product performance.

(e) Demonstration - exhibition of the product or service in its intended modes and conditions.

4.3.1 Hardware Design Verification for SRE. The contractor shall provide a system by which conformance of hardware to the DDR approved design and any authorized changes thereto will be verified prior to initiation of SRE level tests. This verification of conformance to design shall include inspection, proof-by-assembly, the examination or records, or a combination of these. A record shall be made of each inspection or examination and of the verification. In addition, evidence shall be maintained of satisfactory accomplishment of inspections and examinations required by applicable codes and standards that apply to the thermal storage SRE test hardware.

5.0 PREPARATION FOR DELIVERY

5.1 General. Packaging for RETH components shall provide adequate protection during shipment by common carrier from supplier to the first receiving activity for immediate use or temporary storage.

Table 2

THERMAL STORAGE SUBSYSTEM RETH
REQUIREMENTS VERIFICATION MATRIX

Verification Methods	Test Category
1. Inspection 2. Analysis 3. Similarity 4. Test 5. Demonstration	A. Engineering Test B. Preliminary Qualification Test C. Life Tests

N/A denotes "not applicable"

Requirement (by paragraph)	Verification Method(s)	Test Category	Remarks
3.1 RETH Thermal Storage Subsystem Definition	2	N/A	Verify in design review
3.1.1 RETH Thermal Storage Subsystem Diagram	N/A	N/A	
3.1.2 Interface Definition	1, 2	N/A	Verify compatibilities in design review
3.1.3 Major Component List	N/A	N/A	
3.2 Characteristics	N/A	N/A	
3.2.1 Performance	2, 4	A, B, C	
3.2.2 Physical Characteristics	1, 2, 4	B, C	
3.2.3 Environmental Conditions	N/A	N/A	

Table 2

THERMAL STORAGE SUBSYSTEM RETH
REQUIREMENTS VERIFICATION MATRIX (Continued)

Requirement (by paragraph)	Verification Method(s)	Test Category	Remarks
3.2.3.1 General	2	N/A	
3.2.3.2 Transportation and Handling	N/A	N/A	See 3.2.3.1
3.2.3.2.1 Temperature	N/A	N/A	See 3.2.3.1
3.2.3.2.2 Humidity	N/A	N/A	See 3.2.3.1
3.2.3.2.3 Vibration	2	N/A	
3.2.3.2.4 Shock	N/A	N/A	See 3.2.3.1
3.2.3.2.5 Other Conditions	N/A	N/A	See 3.2.3.1
3.2.3.3 SRE Conditions	2	N/A	
3.2.3.3.1 Temperature	N/A	N/A	See 3.2.3.3
3.2.3.3.2 Humidity	N/A	N/A	See 3.2.3.3
3.2.3.3.3 Wind	2	N/A	
3.2.3.3.4 Sand and Dust	2	N/A	
3.2.3.3.5 Rain, Hail and Snow	N/A	N/A	See 3.2.3.3

Table 2

THERMAL STORAGE SUBSYSTEM RETH
REQUIREMENTS VERIFICATION MATRIX (Continued)

Requirement (by paragraph)	Verification Method(s)	Test Category	Remarks
3.2.4 Transportability	2, 5	N/A	
3.3 Design and Construction	1, 2	N/A	
3.3.1 Materials, Processes, and Parts	1, 2	N/A	
3.3.2 Electrical Transients	1, 2	N/A	
3.3.3 Nameplate	1	N/A	
3.3.4 Workmanship	1	N/A	
3.3.5 Safety	1, 2	N/A	
3.4 Documentation	1, 2	N/A	
3.5 Precedence	N/A	N/A	
5.0 Preparation for Delivery	N/A	N/A	
5.1 General	5	N/A	
5.2 Preservation and Packaging	2, 5	N/A	

Table 2

THERMAL STORAGE SUBSYSTEM RETH
REQUIREMENTS VERIFICATION MATRIX (Continued)

Requirement (by paragraph)	Verification Method(s)	Test Category	Remarks
5.3 Packing	1, 2, 5	N/A	
5.4 Handling and Transportability	1, 2, 5	N/A	
5.5 Marking	1	N/A	

5.2 Preservation and Packaging. RETH components that may be harmed when exposed to the normal transportation and handling environments (paragraph 3.2.3) shall be protected by inert environments, barrier materials, or equivalent techniques.

5.3 Packing. Shipping containers and their cushioning devices shall ensure protection of RETH components when exposed to the shock and vibrations loads defined in paragraph 3.2.3. Containers shall meet, as a minimum, the requirements in the following regulations as applicable to the mode of transportation utilized.

(a) National Motor Freight Classification (Highway Transportation)

(b) Uniform Freight Classification (Railroad Transportation)

(c) CAB Tariff 96 and 169 (Air Transportation)

(d) R. M. Graziano's Tariff 29 (For Dangerous Articles Surface)

(e) CAB Tariff 82 (For Dangerous Articles Air)

5.4 Handling and Transportability. Containers with gross weights exceeding 60 lb shall have skids and other provisions for handling by standard materials handling equipment. When feasible, container sizes and configurations shall be compatible with efficient utilization of transport vehicles.

5.5 Marking. Unless otherwise specified, container marking shall be standard commercial practice.

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