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5 MEGAWATT SOLAR THERMAL TEST FACILITY

FACILITY CAPABILITIES DEFINITION

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

San Francisco Operations Office

1333 Broadway

Oakland, California 94612

Contract E(04-3)-1078

BLACK & VEATCH

HONEYWELL, INC.

GEORGIA INSTITUTE OF TECHNOLOGY

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SUMMARY

This report discusses the capabilities which the 5 MW Solar Thermal Test Facility must have to meet the needs of the national effort to develop solar thermal electrical power systems. To define these capabilities, the overall objectives of the facility have been identified. The objectives are as follows:

- To test scale models of the major 10 MWe Solar Pilot Plant subsystems now under design
- To test the one MWt bench model water/steam receiver now under development by ERDA
- To test components and subsystems of advanced solar thermal systems as they are developed by ERDA and by other institutions; e.g. Universities, Electric Power Research Institute (EPRI)
- To establish correlations between solar and radiant heat testing methods and results
- To test the use of concentrated solar energy for high temperature chemical and metallurgical processing
- To utilize the facility for high temperature materials research and testing

Specific requirements in support of the above objectives are being solicited from university and industry sources. The capabilities required to meet these objectives will be developed in phases. The goals are for the test facility to be operational for evaluating receivers at a reduced power level of one MWt by December 1976, and capable of evaluating receivers at the design power level of 5 MWt by July 1977. The major objective of the fully operational facility will be to test experimental receiver designs. Secondary objectives include testing of heliostat and thermal storage subsystems. Additional capabilities to meet the needs for advanced systems

testing, high temperature processing, and high temperature materials research will be implemented as demand and funding permit. The facility and its testing capabilities will be available for use by organizations other than ERDA on a planned schedule basis.

The specific test capabilities required for the Pilot Plant Subsystem Research Experiments, advanced concepts, and other high temperature applications are described herein. The capabilities required to support these tests are then identified. Support capabilities include central control of the facility, instrumentation, data acquisition and reduction equipment, testing operations (e.g. receiver support tower, heat rejection equipment), laboratory areas, administration and public relations areas, personnel, and safety considerations. These test and support capabilities are described in sufficient depth for subsequent requirements definition and conceptual design of the facility.

Data supplied by the 10 MWe Pilot Plant Phase I Contractors and by EPRI in support of their testing requirements are included in Appendices A and B. The initial capabilities of the facility will be limited to receiver subsystems utilizing water/steam; however, space will be available for the ancillary equipment required for testing receivers using other working fluids.

INTRODUCTION

A 5 MW Solar Thermal Test Facility is to be built at the ERDA facility operated by Sandia Laboratories in Albuquerque, New Mexico as part of ERDA's Solar Thermal Program. On completion, this facility will be the world's largest in terms of solar power collection capability. It is ERDA's intent and plan that this facility be designed with the capabilities and flexibility required to support the continuing development of solar thermal systems.

Therefore, it is important that the first step in facility design be a careful consideration and definition of the required testing capabilities. To meet this objective, the advice and input of ERDA officials and technical advisors has been obtained, the requirements of the 10 MWe Pilot Plant Phase 1 Contractors have been solicited by questionnaire and personal contact, and the needs of EPRI and other potential university/industry groups have been received. These inputs, plus the experience and knowledge of Black & Veatch and its subcontractors, have been combined to produce the information in this report.

1. GENERAL OBJECTIVES AND CAPABILITIES OF THE 5 MEGAWATT SOLAR THERMAL TEST FACILITY.

A key aspect of the ERDA Solar Thermal Program is to design, build, and operate a 10 MWe (megawatt electric) water/steam pilot plant by 1980. To support this program as well as more advanced future systems, it is essential to have a facility wherein various prototypes or scale models of the important subsystems can be tested prior to final design. Such a test program is accepted practice in the development of complex systems. The testing program allows parallel development and comparison of alternate concepts and assures a high probability for successful operation of pilot plants. An integrated facility in which such a testing program can be carried out does not exist in the United States today.

Presently, experiments with solar receivers (boilers) and heliostats are being performed at numerous locations, including the large CNRS Solar Furnace in France and private- and government-owned radiant heat facilities in the United States which lend themselves to modification for certain specific qualification or screening tests.

To meet the testing needs of the Solar Thermal Program, ERDA has decided to design and build a 5 MWt Solar Test Facility to be located at Albuquerque, New Mexico. This facility will have the capability for testing scale models of major subsystems of a solar thermal electrical power plant. Also, the facility is planned to be flexible enough to meet both the current and long range needs of ERDA as well as needs of other organizations engaged in major solar development activities.

1.1 GENERAL OBJECTIVES.

1.1.1 Immediate Objectives. It is planned that the facility will be operational at a one MWt power level by December 1976, 11 months from the start of detailed design. The facility will then be capable of testing the one MWt bench model cavity receiver now being built by the Martin Marietta Co. This receiver will first be tested at the CNRS Solar Furnace in France.

The primary objective of the facility is to test experimental receiver designs which could be scaled up for use in the 10 MWe Pilot Plant. These tests will require, in most cases, operation of the facility at the full 5 MWt power level, scheduled for July 1977, 18 months after the start of the detailed design. Secondary objectives may include the testing of heliostat and thermal storage modules. The first subsystems to be tested will be the Subsystem Research Experiments (SRE's) hardware scheduled for delivery to ERDA in mid 1977 by ERDA contractors. These SRE's, discussed in more detail in paragraph 2.1, will consist of three different receivers, three thermal storage concepts, and four different heliostat designs.

The facility may also be used to perform verification tests of some of the components and subsystems designed for the 10 MWe Pilot Plant itself.

In addition, the facility will have the capability of testing subsystems and components being developed by private organizations which will require the solar capabilities of this 5 MWt test facility in the near term.

1.1.2 Other Objectives. The other objectives of the facility are to meet the needs of developing solar technology, both in solar thermal conversion and related developments which utilize highly concentrated solar energy. The facility will be designed to provide flexibility for future expansion and addition of specializdd equipment so that these objectives can be met.

Advanced System Concepts. Receivers which utilize heat transfer fluids other than water/steam will form the basis of advanced solar thermal conversion systems (see paragraph 2.2.2). Examples are air, helium, liquid metals, molten salts, and organic liquids. Design of these receivers may be complex and will require performance verification tests in the facility. Provisions to accommodate such tests will be incorporated to the extent practicable in the initial design of the facility.

High Temperature Processing. The existence of the 5 MWt Solar Test Facility will substantially extend the United States' capabilities for testing certain high temperature chemical and metallurgical reactions in a controlled solar energy environment (paragraph 2.2.3).

Materials Research. The capability for experimentation at high temperatures offered by the 5 MWt Solar Test Facility may provide a new tool for high temperature materials research (paragraph 2.2.4).

1.2 GENERAL CAPABILITIES.

The major initial activity at the 5 MWt flux level will consist of testing experimental central receiver designs. Heliostats and thermal storage modules will also be evaluated. The principle tests will be performance tests and radiant heat/solar correlation tests, the results of which will be used to improve design and materials selection (paragraph 2.1).

1.2.1 Receiver Subsystems.

The facility will have the capability for testing both once-through and recirculating drum-type receiver/boilers. This capability requires a tower to support the receiver and a working heliostat field to redirect and concentrate solar radiation onto the receiver aperture or surface. The capability will exist for testing cavity and exposed tube receivers which subtend either a 90°, 5 MWt heliostat field sector or a full 360°, 5 MWt heliostat field. The facility will also be capable of testing either of the receiver/field geometries at power levels below 5 MWt. The facility should have the capability of preparing additional receivers for testing while a receiver is being tested. Design options will be addressed in the conceptual design of the facility.

1.2.2 Heliostat Subsystems. The facility will have the capability of testing individual heliostats or heliostat arrays whose design is different from those in the working heliostat field. This capability will include the option of testing the heliostats at various positions in the working field using the main test tower as a target, or in a separate dedicated area, external to the working field, which has its own target tower(s).

1.2.3 Thermal Storage Subsystems. The facility will be expandable to have the capability of supplying charging steam to thermal storage modules. The primary source of the charging steam would be an auxiliary package boiler, although charging from a test receiver should be an option so that integrated testing and control of both subsystems can be achieved.

1.2.4 Subsystem Interface Tests. Capability for operating the facility heliostats with experimental receivers and thermal storage subsystems as integrated systems will be considered in the initial design, and may be provided as part of the initial operating capability. This capability will allow testing of interfaces between the various subsystems and will help identify control, operating mode, startup, and shutdown problems.

1.2.5 High Temperature Processing and Materials Testing. The facility will be designed such that capabilities for these types of testing and experimentation can be installed at the appropriate time.

1.3 FACILITY OPERATION. The 5 MWt Solar Test Facility will be operated by Sandia Laboratories, Albuquerque. The operational relationships between contractors who have hardware to be tested and the facility personnel will be coordinated for each test. The facility will have extensive onsite subsystem assembly capabilities for contractors to prepare their hardware for testing. Scheduling of tests will be the responsibility of the facility manager under direction from ERDA and Sandia.

1.4 SUPPORT CAPABILITIES. The facility will have those capabilities required to support the objectives and tests described in paragraphs 1.1 and 1.2. These capabilities will include spaces and physical support for the subsystem tests, central control of the various subsystem tests, instrumentation, data acquisition, assembly areas including machine shops and hoists, heat transfer fluid handling, water treatment, laboratory areas, and heat rejection equipment including cooling towers.

Capabilities for handling public relations, contractor personnel, visiting scientists and engineers, and tours of the facility will be provided.

1.5 SAFETY. The safety of operating, contractor, and visiting personnel will be a prime concern in the design and operation of the facility. In addition to the usual safety considerations and capabilities for personnel protection at such a facility, special attention will be given for protection for personnel and equipment against concentrated solar radiation and fire/explosion prevention and control (paragraph 4.). Air space exclusion zones will be established near the facility, if necessary, to avoid hazards to aircraft resulting from reflected sunlight. Safety procedures to be followed by visiting personnel and the public will be specified.

2. SPECIFIC TEST CAPABILITIES.

2.1 10 MWe PILOT PLANT SUBSYSTEM RESEARCH EXPERIMENTS. ERDA is currently sponsoring major research and development programs with four contractors to prepare preliminary designs for central receiver solar thermal power systems. Conceptually, the solar thermal power systems are divided into four subsystems:

- The collector subsystem, which is composed of a number of heliostats and their control and drive mechanisms;
- The receiver subsystem, which consists of the boiler/superheater in which the working fluid (water) is heated to produce superheated steam;
- The thermal storage subsystem, which stores thermal energy for subsequent production of steam during periods of low or no isolation; and,
- The electric power generation subsystem (there are presently no plans for testing this subsystem at the 5 MWt Solar Test Facility).

Each of the four contractors will construct subsystem research experiments (SRE's) which are scaled-down versions of the subsystems expected to be used in the 10 MWe Pilot Plant. Receiver SRE's will become available for tests in the 5 MWt Solar Test Facility in the summer of calendar year 1977.

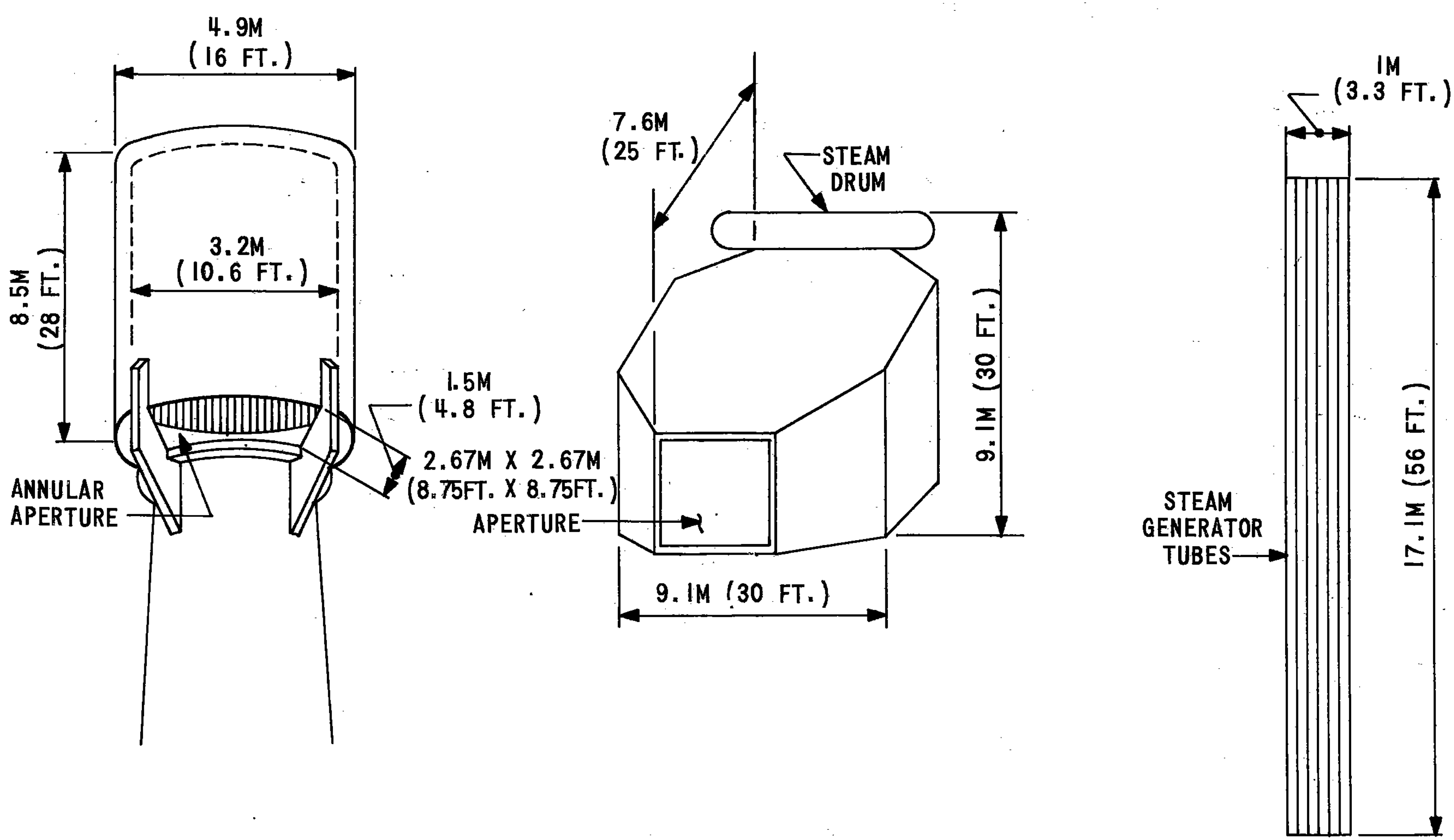
The following paragraphs describe the SRE's and the anticipated tests for which capability will be provided. The facility will have a tower to support the receiver SRE's above the ground and a field of working heliostats to provide concentrated solar flux for testing the receivers. The capabilities required of the tower, heliostat field, and other facility components are described in Section 3.

2.1.1 Receiver Research Experiments. Three receiver experiments require testing. They are identified in this section by the names of the prime contractors for the respective programs. Conceptual sketches are shown on Figures 1 and 2; details are given in Appendices A and B.

Honeywell. The Honeywell receiver is a vertical, 4.9-meter (16-foot) diameter cylindrical cavity configuration. The solar radiant energy enters through an annular aperture 1.5 meters (4.8 feet) in height (slant) at the bottom of the receiver from a 360-degree surrounding heliostat field. The fluid circulation system employs a steam drum and separate boiling and superheating circuits. Vertical boiler tubes are positioned around the inner walls of the cavity and helical superheater tubes are positioned near the top of the cavity.

Martin Marietta. The Martin Marietta receiver is a cavity configuration resembling a box with eight vertical sides and a sloping roof and floor. Radiant energy enters the cavity through a 2.67-meter (8.75-foot) square aperture located on one of the sides. The radiation should arrive from the heliostat field within a horizontal included angle of 90 degrees and a vertical included angle of 45 degrees. The fluid circulation system uses a steam drum and separate boiling and superheating circuits. Vertical tubes are positioned on the cavity walls. The cavity aperture faces due north and downward approximately 20 degrees from horizontal.

McDonnell Douglas. The McDonnell Douglas receiver is a cylindrical exposed tube configuration. The research experiment receiver consists of one panel, 1 meter (3.3 feet) wide, of a vertical-axis cylinder 17.1 meters (56 feet) high. The system operates as a "once-through" boiler/superheater in which the feedwater enters at the bottom of the parallel



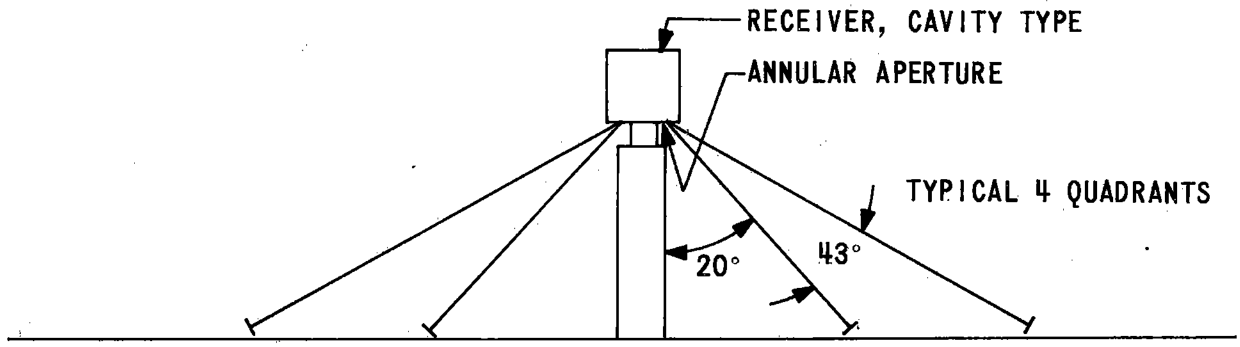
CAVITY TYPE
HONEYWELL

CAVITY TYPE
MARTIN MARIETTA

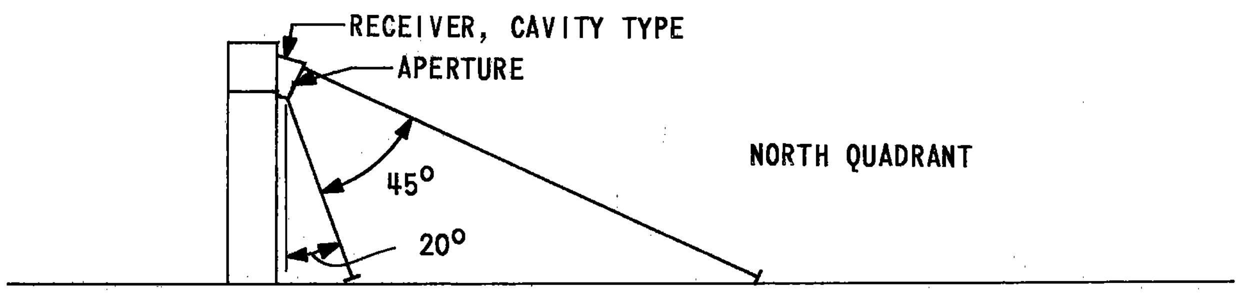
EXPOSED SURFACE
TYPE
MCDONNELL DOUGLAS

RESEARCH EXPERIMENT RECEIVERS

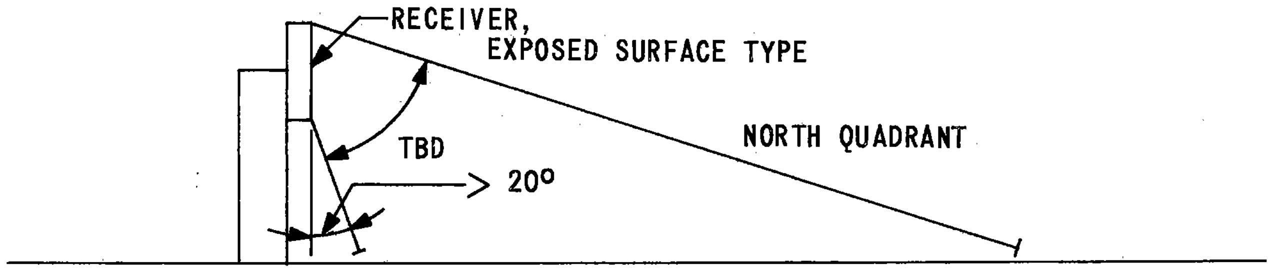
FIGURE 1



HONEYWELL - 360° HELIOSTAT FIELD



MARTIN MARIETTA - 90° HELIOSTAT FIELD



MCDONNELL DOUGLAS - 90° HELIOSTAT FIELD

ORIENTATION OF RECEIVERS TO
WORKING HELIOSTAT FIELD

FIGURE 2

vertical tubes and superheated steam is extracted at the top. Incident solar flux varies with longitudinal position along the tubes and is controlled with respect to position and power level. Incident solar flux arrives from the north heliostat field at vertical angles greater than 20 degrees to the vertical tube surfaces (Figure 2) and at horizontal angles within plus or minus 45 degrees.

It is anticipated that all three research experiement receivers will be carried through similar test sequences. At this time, the tests listed in Table 1 are foreseen and appropriate testing capability will be provided. These tests are described briefly in the following paragraphs.

2.1.1.1 Pre-Operational Tests. The receivers will be given a hydrostatic pressure test after they have been mounted on the facility support tower to verify pressure integrity. Instrumentation will be checked for proper installation, operational readiness, and proper calibration. The feedwater-receiver-high pressure steam-condenser test loop will be given a hot functional test at a reduced power level to ensure operational readiness.

2.1.1.2 Control System Verification. The receivers will be tested to verify the adequacy of control systems supplied by the respective contractors. Startup and shutdown procedures and operation will be verified both at the beginning and end of the solar day, and by changing the number of heliostats focused on the receiver. Performance of the control system under conditions of changing solar insolation, such as caused by cloud cover or loss of power to a portion of the heliostat field, will be emphasized in these tests. Key operation parameters such as temperatures, pressures, flow rates, and liquid levels

TABLE 1

PRIMARY TESTS TO BE PERFORMED ON RECEIVERS

- PRE-OPERATIONAL TESTS

  Hydrostatic Pressure Test

  Instrumentation

  Test Loop Check

- CONTROL SYSTEM VERIFICATION

  Startup/Shutdown

  Insolation Changes, Including Transients

  Emergency Shutdown

- PERFORMANCE TESTS

  Production of Steam at Design Pressures and Temperatures as a Function of:

  - Insolation Level, Including Transients
  - Air Temperatures
  - Wind Speed and Direction
  - Flux Levels Above Design Limits

  Emergency Operation and Safety Checks

- POST-OPERATIONAL TESTS AND FIELD DESIGN MODIFICATIONS

  Pressure Test

  Visual Inspection

  Modifications

at selected locations within the receiver will be monitored for real-time control and recorded for subsequent analysis. Emergency shutdown operation will be verified.

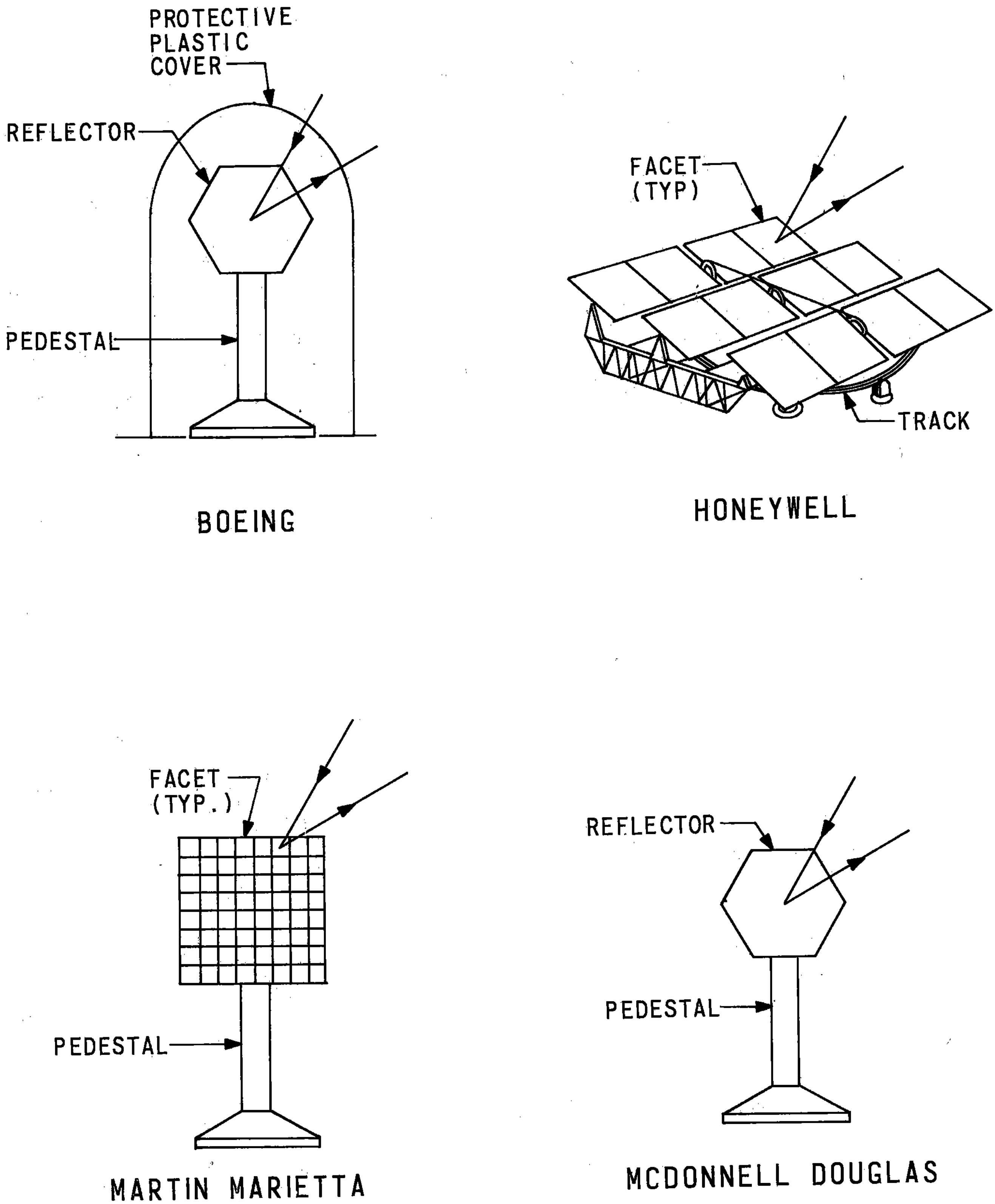
2.1.1.3 Receiver Performance and Design Margins. The receivers will be operated to demonstrate their capacity for producing superheated steam at design temperatures, pressures, and flow rates under the varying operating conditions which will occur in a solar plant. Environmental conditions at the receiver location will be recorded for documentation and correlation. These environmental conditions include direct insolation, air temperature, relative humidity, wind speed and direction, and other pertinent conditions such as the presence of ice or snow. Capabilities will also be provided for measuring concentrated solar flux at the focal zone of the heliostat field. Under high insolation conditions, flux levels substantially higher than the design level can be provided in order to identify incipient failure conditions and verify failure mode predictions and safety measures. Provisions will be made in the test facility to simulate variable environmental and operational conditions where practical; for example, the passage of clouds and the transient heat inputs associated with startup and shutdown can be simulated by proper control of the test facility (working) heliostats.

2.1.1.4 Post-Operational Tests and Field Design Modifications. Following the performance tests, the receivers will be subjected to static pressure tests to determine whether any leaks have developed. Visual inspection will be made to determine causes of any failures or the presence of incipient failures. As with any newly developed engineering system, possible component design improvements are likely to be recognized when actual operations are begun. It is probable that minor modifications in the receivers and associated equipment will be performed at the test facility.

Depending on the circumstances in the individual case, these modifications might require time periods ranging from one or two days to several weeks; therefore, it is necessary that changeover time from the testing of one research experiment receiver to another be minimized. Provisions will be made for disconnecting, moving, and reconnecting receivers within two weeks to permit efficient use of the test facility.

2.1.2 Heliostats. The facility will have the capability of testing all four pilot plant SRE heliostat types either in small arrays or individually positioned on the working heliostat field. These four heliostat types (conceptually shown on Figure 3) will be identified in this text by the name of the major contractor leading the Phase I work on the concept: Boeing, Honeywell, Martin Marietta, and McDonnell Douglas. The objectives of the heliostat equipment tests, in all cases, will be the evaluation of their optical and operational performance, and the effectiveness of their control mechanization at various field positions, as well as the investigation of their behavior under adverse environmental conditions, such as wind loading.

The facility, therefore, will test the ability of the individual heliostat and the heliostat array to reproduce the desired flux density pattern on an appropriate surface and to meet the specified redirected power per square meter of reflecting area. To achieve this, the facility test tower will be instrumented to allow testing of the degree of focusing, beam spreading, and optical error characteristics of the individual heliostats and the effects of off-axis aberrations on focusing. It will also permit the testing of appropriate aim strategies, tracking accuracy, and the ability of individual heliostats to maintain their sun image at the desired location on an appropriate surface. These investigations will include the stability and accuracy of aiming with time, temperature changes, and wind over a range of mirror orientations.



PILOT PLANT
HELIOSTAT CONCEPTS

FIGURE 3

The tests to be performed on both individual heliostats and heliostat arrays are summarized in Table II. Brief descriptions of these tests are given in the following paragraphs.

2.1.2.1 Individual Heliostat Tests. The facility will have the capability of testing the tracking performance of the heliostat. The combined azimuth-elevation tracking performance will be evaluated under the wind, temperature, and other environmental conditions encountered at the site. These tests will cover the complete range of azimuth-elevation tracking capability required for year-round, dawn-to-dusk operation.

The facility will have the capability of checking heliostat performance in the following modes of operation.

- Restart after power loss
- Restart after emergency mode shutdown
- Restart after stow mode shutdown
- Update aimpoint after error detection

The tests will also involve the functions of emergency slewing to remove flux from the focal zone, and command movement to a stow position. The effects of shadowing/blocking among the individually movable facets of certain heliostats will be investigated as a function of heliostat position on the field and time. The facility will have the capability of testing the optical performance of individual heliostats as a function of time. The receiver test tower or a suitable alternate target tower will be instrumented to measure sun image shape, size, and brightness as a function of the slant range and position of the heliostat with respect to the tower. In this way, the effects of mirror roughness, focusing, off-axis aberrations, rain, surface dust, and age can be evaluated.

TABLE II

PRIMARY TESTS TO BE PERFORMED ON HELIOSTATS

INDIVIDUAL HELIOSTATS

- TRACKING TESTS

  Asimuth and Elevation vs. Time

  Sensitivity to Wind, Temperature Changes

  Restart After Power Loss

  Restart After Emergency Shutdown

  Restart After Stow Mode

  Update Aimpoint After Error Detection

- OPTICAL TESTS

  Image Shape and Size vs. Distance

  Image Brightness vs. Distance

  Sensitivity to Heliostat Position

  Sensitivity to Rain, Dust, Age

- EXTENDED OPERATION TESTS

  Blowing Sand

  Rain, Ice, Snow

  Wind

  Temperature Extremes

TABLE II (CONT'D)

HELIOSTAT ARRAYS

- OPTICAL TESTS

  Combined Image Size, Shape, Brightness vs. Distance

  Sensitivity to Wind and Temperature Changes

  Shadowing/Blocking

- OPERATIONAL CONTROL

  Different Control Mechanisms - Open Loop Computer, Closed Loop

  Response to Wind Gusts, Cloud Passage, Temperature Changes

  Aim Strategies

A few heliostats will be subjected to extended operational testing. The facility will have the capacity of testing the natural cummulative environmental effects of blowing sand, rain, ice, snow, wind, and temperature extremes which occur at the site on heliostat operation.

2.1.2.2 <u>Heliostat Array Tests</u>. The facility will have the capability of testing optical performance of heliostat arrays. These tests will include the determination of the combined image size, shape, and brightness as a function of distance, degree of control on these factors, and their sensitivity to wind and temperature variations. Determining the effects of shadowing and blocking among the heliostats of the array will also be a part of the test capabilities of the facility. Investigations will include the variation of the position of the array in the field and sun position.

The facility will have the flexibility to accommodate and test the various control schemes which include.

- Centralized open loop computer control with/or without axes position sensors
- Centralized open loop control with periodic active update
- Local closed loop control
  - Sun position sensing
  - Reflected beam position sensing

The facility will test these schemes to evaluate their operational function behavior and response to dynamic inputs such as wind gusts, solar outage due to cloud cover, and abrupt temperature changes.

The facility will be designed such that future capability may be added for testing the heliostat array behavior under the range of environmental conditions encountered at the facility location. These tests will lead to an estimate of the expected lifetime of the heliostats and their components and a definition of the appropriate maintenance schedule.

2.1.3 Thermal Storage. The facility will be expandable to have the capability of testing a wide variation in thermal storage mechanisms. The facility will be initially designed to accommodate each of the current SRE (latent or sensible heat) subsystems for thermal storage with minimum modifications. The tests which are foreseen are listed in Table III.

The objective of the tests would be to establish the ability of the storage subsystem to deliver steam at rated conditions and to continue normal operation through an extended series of charge-discharge thermal cycling. The facility would have an auxiliary steam generation source (packaged boiler) to allow each thermal storage SRE to be tested up to a maximum of 5 MWt, independent of receiver operation.

Extended operation tests would be conducted to establish reliability as well as expected lifetime of the thermal storage subsystem. The tests will include components of the subsystem such as the thermal storage material, thermal storage material handling equipment, drain valves, pressure valves, fire/explosion prevention and control equipment, and other emergency/safety components.

2.1.4 Interfacing of Subsystems. The facility will be designed so as to allow for the possible eventual testing of integrated subsystems to investigate the interface match-up capabilities and performance. These tests will be done with the test facility working heliostats.

The ability to charge the thermal storage with steam generated by the heliostat/receiver subsystem would be tested to establish charge response times and steam flow control. Integrated heliostat/receiver/storage tests would establish operational control strategy and stability as well as capability to meet the interface requirements of the proposed power generation subsystem.

TABLE III

PRIMARY TESTS TO BE PERFORMED ON THERMAL STORAGE UNITS

- PERFORMANCE TESTS

  Charge/Discharge Cycle - Flow Rates, Pressures, Temperatures

  Variable Charging Conditions

- OPERATIONAL TESTS

  Life Cycling/Failure Modes

  Energy/Safety

2.1.5 Comparison of SRE Test Results. An important capability of the 5 MWt Solar Test Facility is to provide meaningful comparisons of the performance of alternate receiver, heliostat, and thermal storage subsystems. These comparisons will provide the basis for selection of the best design for use in future solar/electric power generation plants. However, tests will be performed under those insolation and environmental conditions which happen to exist at the particular time scheduled for test of a particular candidate subsystem. There is no reason to expect that these conditions will remain the same from one test to another. Therefore it will be necessary that test results be normalized to a set of standard conditions for valid comparisons.

To make such a normalization possible, the facility will have the capability of continuously recording insolation at various locations in the working field and of continuously recording meteorological conditions (wind velocity, temperature, precipitation, humidity) both at ground level and at the receiver test elevation. Both the procedure for normalizing test data and the definition of standard conditions will require development by ERDA prior to the beginning of test operations.

2.2 OTHER USES. At the time of its completion, the 5 MWt Solar Test Facility will be the world's largest in terms of power collection capability. The next largest will be the one megawatt CNRS Solar Furnace in France. The CNRS facility is capable of supplying a greater energy density (heat flux on a small area) than the 5 MWt system, but for many purposes the higher energy density is not needed. For example, in the development of heat receivers for various solar thermal electric power generation cycles, the energy density supplied by the 5 MWt facility will be sufficient for present foreseeable requirements. The facility's heliostat control system and large energy collection capacity will make it the most valuable in the world for power system development.

The 5 MWt Solar Test Facility will be a valuable national resource and should be designed with a high degree of experimental flexibility to facilitate other uses beyond the tests described in paragraph 2.1. It is impossible at this time to foresee all the test demands that might ultimately be placed on the facility, but several can be anticipated and are described in this section. It is of interest to note that at the time of its design in the late 1950's, the CNRS Solar Furnace was viewed primarily as a research and development facility for high temperature chemical processing. In addition to this work, it has subsequently been used for simulation of nuclear thermal pulses and aerodynamic heating and is soon to become an important facility for energy related research.

2.2.1 10 MWe Pilot Plant Hardware. Testing of the SRE hardware is likely to identify problem areas which will result in design improvement. Components and subsystems chosen for the design and construction (Phase II) of the 10 MWe Pilot Plant may be tested in the 5 MWt Solar Test Facility.

Improved heliostat designs can be tested without significant changes in the SRE test capabilities. In order to test improved receiver subsystems and thermal storage for the pilot plant, two options are available.

- Improved 5 MWt subsystems can be built for test without significant change in the facility capabilities; or,
- Larger versions of these subsystems may be required, in which case expansion of the working heliostat field (up to 30 percent) and extension of the tower may be required.

The conceptual design of the facility will take the second option into consideration.

Interface testing of improved subsystems and control tests of simulated transients will be required during Phase II design for the pilot plant. The facility will have the capability to perform such tests. Space for a one MW turbine-generator will be made available so that such interface testing may include an electrical load, if required.

2.2.2 Advanced Concepts. To the extent practical, the initial design of the test facility will include capabilities, or provide space and utilities for future expansion, for testing of advanced or alternate solar thermal conversion concepts/systems. These concepts/systems will include, but will not be limited to, the following.

- Rankine steam cycles which use receiver heat transfer fluids other than water/steam. Possible fluids include liquid metals, molten salts, and other high temperature liquids.
- Brayton cycles consisting of either an open cycle using air as the working fluid, or a closed cycle using helium or other gas under high pressure as the working fluid.
- Combined Brayton-Rankine cycles.
- Advanced energy storage subsystems such as chemical storage, flywheels, compressed air, etc.
- Advanced heliostat subsystems.

Some of these systems will utilize receiver designs which are different than the present SRE receivers. Capabilities for testing these receivers will require space for pumps and fluid handling and storage systems for the alternate heat transfer fluids.

Specific examples of advanced receivers which will be available for testing are the gas-cooled receivers currently under development by EPRI. (See Appendices A & B for a summary description.) The flux densities required at the apertures of these receivers (0.75 - 1.5 MW/m^2 average) are within the capabilities of the heliostat field which will serve the SRE water/steam receivers. The types of receiver tests to be performed would be much the same as described in paragraph 2.1.1.

Capabilities for installation and testing of the more exotic energy storage systems would require additional space external to the working heliostat field. Both belowground and aboveground space may be required. Electromechanical storage systems would require large amounts of electrical power; interface testing of these storage systems with receivers would require the capability of operating a turbine-generator directly from receiver stream or alternate heat transfer fluid.

2.2.3 High Temperature Processing. The use of high temperature solar energy for chemical and metallurgical processing is a subject of growing interest because of process energy and product purity considerations. For several years the CNRS Solar Furnace has been producing fused refractory materials such as zirconium oxide on a limited batch production basis (100-200kg/hr). CNRS has also melted special metal alloys in controlled atmospheres and is currently active in the development of improved material handling techniques for manufacturing materials with the furnace. Georgia Tech has received two inquiries from U. S. industrial organizations concerning commercial manufacturing operations in large solar facilities. It is probable that many proposals for materials processing using high temperature solar energy will be made in the future, and U. S. industry will require the services of a large solar test facility to develop and evaluate these processes.

The extent to which the facility can be used in these applications will be limited only by the maximum temperature which can be achieved by a central receiver solar concentrator of this type. Theoretical calculations show this to be 2,900 C (5,275 F). Practically, the upper temperature limit will be of the order of 1,725 C (3,140 F).

Other chemical process operations which might affect the national energy economy in the future are thermal decomposition of water, coal, and organic material to produce gaseous hydrogen; production of water gas (a combustible mixture of hydrogen and carbon monoxide) by reaction of coal and steam at elevated temperature; and fixation to produce ammonia which is required for production of fertilizers. All of these operations are endothermic, and depending on economic considerations, might be conducted commercially using solar energy at high concentration levels. It is virtually certain that a demand will exist for a solar facility in which research can be conducted in these or similar areas.

At the present time the exact requirements for conducting research in high temperature processing cannot be specified because an extremely large number of possible processes might be proposed. However, versatility will be maintained in the facility by providing an open platform at the top of the tower so that water-cooled shields, flux redirectors, and other devices peculiar to very high temperature solar test operations may be incorporated. In addition utilities such as process water, cooling water, compressed air, data collection channels, etc., and shop facilities will be provided.

2.2.4 Materials Research and Testing. The design of solar receivers within the last two years has led to the identification of a number of fundamental problems concerning the response of materials to high radiant heat fluxes. Some of these are:

- Measurement and prediction of absorptivity and reflectivity of construction materials used in receivers;
- Changes of these properties with temperature and prolonged exposure times;

- Stresses and fatigue in asymmetrically heated tubes; and
- The behavior of structural and protective materials inadvertently exposed to high radiant fluxes.

All of these problems require the use of high radiant fluxes with the approximate spectral distribution of sunlight for adequate investigation. In addition, during the past few years the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA) have encountered problems related to simulation of aerodynamic heating in which a solar test facility would have been useful; two research programs for DOD have been conducted at the CNRS Solar Furnace.

This background indicates that a variety of materials test activities related to solar thermal conversion and other areas of technology can be expected at the 5 MWt Solar Test Facility. As in the case of chemical processing, it is not possible at this time to specify test capabilities in detail but the versatility of the facility described in paragraph 2.2.3 would assure its applicability for Materials Research and Testing.

3. SUPPORT CAPABILITIES.

The 5 MWt Solar Test Facility will provide a variety of support capabilities for the testing programs just described. These capabilities will include: The general physical plant with central control, instrumentation, assembly area, and all facilities relating to the testing operation; and the personnel to man the facility, including management, professional staff, and technician team.

Descriptions of these capabilities are given in the following paragraphs. Numerical listings of the capabilities required to test SRE hardware for Phase I, Pilot Plant Contractors and for planned EPRI hardware are shown in Appendices A and B.

3.1 TESTING OPERATION. Facilities relating to the testing operation include the tower and working heliostat field, a working receiver, foundations for test heliostats, heat rejection equipment, a packaged auxiliary boiler, and a water treatment system.

3.1.1 Receiver Support. The facility tower will be capable of supporting receivers or research hardware weighing up to 64,000 kilogram (140,000 pounds), and having a variety of target sizes ranging from one meter (3.3 feet) wide by 17.1 meters (56 feet) high to 3.2 meters (10.6 feet) wide by 1.5 meter (4.8 feet) high. The tower will be capable of supporting receivers at various heights so that they may receive the appropriate solar flux from the desired field sectors (Appendices A and B). Suitable access to the test receivers will be provided when they are mounted in place so that maintenance and servicing of equipment and data acquisition sensors can be carried out. The tower will be capable of supporting feedwater and steam lines as well as other utilities and signal transport lines necessary for receiver testing. Elevator and hoist capabilities will be provided for both personnel and receiver hardware.

3.1.2 Working Heliostat Field. The working heliostat field will have the capability of providing a maximum flux density of one MW/m^2 for a one MWt receiver having a one meter square aperture and lower flux densities as required by 5 MWt receivers having larger apertures or target sizes. Signals from the central computer to the working heliostat controls will be programmed to give any desired flux distribution at the target within the constraints of the field geometry. The working heliostat field will be capable of providing 5 MWt solar flux from the north quadrant for 90° illumination of the receiver aperture area, or 5 MWt total flux from the four quandrants for 360° illumination of the target area.

Heliostats will be capable of being re-focused in the field and of being moved from one field position to another. Mirror surfaces will be capable of being cleaned periodically.

The working heliostat field will be designed so as to obtain a significant number of days each month for which five hours testing can be achieved with 5.5 MWt at the focal zone of the test receivers.

3.1.3 Working Receiver. A simple one MWt working receiver will be provided for dissipating heat during alining, aiming, and testing sections of the working heliostat field.

3.1.4 Foundations for Test Heliostats. The facility may provide foundations for the test research heliostats. The foundations would be provided individually and in arrays at various locations in the working heliostat field and elsewhere to evaluate the heliostats at typical azimuth and elevation positions.

3.1.5 Heat Rejection Equipment. The facility will provide equipment for rejecting 5 MW of thermal energy without interfering with facility operation by plumes of water vapor. A cooling tower will be a major item of this equipment.

3.1.6 Packaged Boiler. Included in the facility will be space for a packaged fossil-fueled boiler to provide water/steam at the various design temperatures and pressures for testing thermal storage hardware.

3.1.7 Water Treatment System. A supply of treated water will be provided by a water treatment system to the various heat transfer circuits in the facility. The water treatment system will be capable of maintaining water quality, compatible with SRE requirements, in the circuits at a condition typical of that used in boiler feedwater. An adequate supply of treated water will be available for flushing research hardware during cleaning operations. In addition, the supply of treated water would be adequate for testing "once-through" receivers.

3.1.8 Capabilities for Gas-Cooled Receivers. Testing of gas-cooled receivers will require the following support capabilities.

- A source of compressed air or helium. Nominal pressures and capacities required: Air - 150 psig, 3,600 scfm; helium - 500 psig, 54,500 scfm
- A preheater capable of heating air to 1,000 F
- A heat exchanger capable of cooling 500 psig helium from 1,600 F to approximately 800 F
- Compressed air and helium piping in the test tower
- Helium storage tanks

These capabilities will not be included in the conceptual design and cost budget of the 5 MW Test Facility. However, adequate space will be provided so that the support equipment can be added as required.

3.2 CENTRAL CONTROL. The master controller for operating the overall system and all subsystems will be an on-line, real-time computer which will be able to use signals from a wide variety of sensors as inputs for control action. Control signals from the computer will be capatible with commercially available control devices. The computer will have a multiprogramming capability to permit rapid conversion from one control routine to another. In addition, the computer will be field-expandable to allow for growth in complexity of control requirements.

3.3 INSTRUMENTATION. The facility instrumentation will include a data acquisition system for logging large quantities of data from the testing operation, hard copy recorders for selected channels of data, optical instrumentation for visual observations, instruments for chemical analysis of heat transfer fluids, and instruments for meterology and insolation measurements.

3.3.1 Data Acquisition System. This system will be an integral part of the control computer. Hence, sensor input signals for the computer will be logged with all other signals. All necessary signals will be recorded for rapid retrieval. The Data Acquisition System (DAS) will have signal conditioning circuits so that all parametric data will be logged in a common language. The data could be signals from a variety of detectors for measuring temperature, pressure, flow rates, strain, radiant flux, and positions. The DAS will have a multiplexer to permit logging of data from 500 or more detectors and devices. Data retrieval will be by means of digital printout or CRT display. Other data retrieval options can be added if needed. Microwave relay equipment will be provided to telemeter data from DAS to an Area III data reduction computer.

3.3.2 Hard Copy Recorders. Multi-channel analog recording of critical signals will be provided by hard copy recorders.

3.3.3 Optical Instrumentation. Visual monitoring of testing operations at the top of the tower (the focal zone of the heliostat field) will be provided. The capability will consist of remote-controlled cameras for closed circuit television and motion picture photography, and optical pyrometers for temperature measurements.

3.3.4 Chemical Analysis. Instrumentation will be provided so that the composition and/or quality of the heat transfer fluid can be determined. For water, instruments will include pH and conductivity meters.

3.3.5 Meterology and Insolation. Capabilities will be provided for obtaining meterological and insolation data by weather station and solar radiation instruments. Operational data will be provided on solar radiation by a pyranometer and a pyrheliometer. Cloud cover will be recorded on a periodic basis with an all-sky camera. Basic research data will be provided on atmospheric particulate loading with a nephelometer and precepitable water with a rawinsonde.

3.4 ASSEMBLY AREAS. The facility will provide assembly areas for preparation and checkout of research and subsystem hardware. There will be an enclosed area, 23.2 meters (76 feet) by 52.7 meters (173 feet) with a ceiling height of 18.3 meters (60 feet), for setting up the hardware and several smaller secured areas for storage of equipment and supplies. In addition, a small work area and welding receptacles will be provided at the top of the tower for further checkout of receiver hardware and maintenance activities. The assembly area, experiment transport, and tower facilities will be such that a turn-around period of two weeks between removal of a receiver and installation of another receiver for testing can be achieved.

3.4.1 Machine Shop. Facilities will be provided in or adjacent to the assembly areas to permit minor modifications to the research hardware. The facilities would include welding equipment, elementary machining equipment, secured hard tools storage, and work benches.

3.4.2 Hoists and Cranes. Moving and positioning the various types of hardware will be accomplished by hoists and cranes. They will be installed in the assembly areas. A mobile crane will be available for transporting and positioning heliostats. An elevating device will be located within the tower for raising receivers and other research hardware to the top for testing.

3.5 PERSONNEL. The facility will have sufficient personnel to operate the facility as an independent entity. There will be permanent management personnel for scheduling tests and providing logistics for the tests. In addition, a professional staff with scientific and engineering experience will be maintained for supervising tests, analyzing data, and interpreting results. A technician team will be available to assist in installing test hardware, conducting tests, and maintaining instruments, controls, and test hardware. Sufficient area shall be provided in the assembly and administration buildings to accomodate contractor personnel for the duration of a test.

3.6 LABORATORY AREA. Approximately 278 square meters 2,991 square feet) will be provided in the facility for laboratory activities such as chemical analysis of heat transfer fluids and metallurgical specimen studies.

3.7 ADMINISTRATION AND PUBLIC RELATIONS AREAS. The facility will have administration areas commensurate with the management staff. The public relations area will be capable of containing exhibits for demonstrating the functions of the 5 MW Solar Thermal Test Facility.

3.8 FACILITY SECURITY. The facility will be enclosed by an anti-personnel fence to prevent unauthorized access. A security gate will be provided adjacent to the Administration Building.

4. SAFETY.

Safety considerations will be of prime importance. The facility will adhere to OSHA requirements in all areas. In hazardous areas, special precautions will be observed. The tower will have interlocks with the controls of the heliostat field to prevent focusing of the heliostat field onto the target area while personnel are in the tower test area. Protection from concentrated solar flux will also be provided for personnel in nearby buildings and other access areas at ground level. Exclusion zones will be established, if required, to avoid eye hazards to aircraft crews and passengers resulting from momentary coincident beams reflected from mirrors during slewing operations. Removable guarded working platforms will be installed around receivers and other research hardware for installing and servicing the hardware. Lightning protection will be installed for the facility.

During a stoppage of the flow of the heat transfer fluid in receivers or other research hardware, a "scramble" procedure would be actuated to defocus the heliostat field before damage occurs to the equipment. In the event liquid metals, molten eutectic salts, or other high temperature liquids are used, handling and storage of these materials will be in accordance with industry-accepted procedures. Liquids for thermal storage subsystems will also have special fire protection procedures. Tanks containing thermal storage liquids will have safety dikes. Venting of pressure vessels and their safety valves will be in accordance with ASME standards.

APPENDIX A

SUMMARY OF CONTRACTOR

RESPONSES TO FACILITY REQUIREMENTS

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SUMMARY OF CONTRACTOR RESPONSES TO

FACILITY REQUIREMENTS FOR 5 MW SRE RECEIVERS

ITEM	HONEYWELL	MARTIN MARIETTA	MCDONNELL DOUGLAS
RECEIVER			
SIZE	4.9 m DIA x 8.5 m H (16 FT DIA x 28 FT H)	9.1 m W x 15.2 m H x 7.6 m DEPTH (30 FT W x 50 FT H x 25 FT DEPTH)	1 m W x 17 m H x 4 m DEPTH (3.3 FT W x 56 FT H x 13.2 FT DEPTH)
WEIGHT	27,216 KG (60,000 LB)	63,504 KG (140,000 LB)	2,722 KG (6,000 LB)
TARGET SIZE	ANNULUS: 3.2 m DIA, 1.8 m DIA x 1.3 m H (10.6 FT DIA, 6 FT DIA x 4.2 FT H)	2.67 m x 2.67 m (8.75 FT x 8.75 FT)	1 m W x 17 m H (3.3 FT W x 56 FT H)
CYCLE CONDITIONS			
IN	11.7 MPa - 271 C (1,700 PSI - 520 F)	9.99 MPa - 177C (1,450 PSI - 350 F)	13.8 MPa - 204 C (2,000 PSI - 400 F)
OUT	10.3 MPa - 513 C (1,500 PSI - 955 F)	9.13 MPa - 516 C (1,325 PSI - 960 F)	10.4 MPa - 477 C (1,500 PSI - 890 F)
FLOW RATE	0.19-1.9 KG/ SEC (1,530-15,300 LB/HR)	0-2.5 KG/ SEC (0-20,000 LB/HR)	0.25-2.25 KG/SEC (0.6-5 LB/SEC)
FLUX DENSITY			
OPERATING	0.4 MW/m^2	0-0.70 MW/m^2 (0-225,000 BTU/HR FT^2)	0.4 MW/m^2
MAXIMUM	0.45 MW/m^2	0.70 MW/m^2	0.45 MW/m^2
HELIOSTAT FIELD			
HORIZONTAL ANGLE OF FLUX	360°	90° RECTANGULAR NORTH	90°
VERTICAL ANGLE OF FLUX	43° INCLUDED	45° INCLUDED	LESS THAN 70° INCLUDED
INSTRUMENTS			
DATA ACQUISITION SYSTEM CHANNELS			
TEMPERATURE	250	150	100
PRESSURE	10	20	10
FLOW RATE	10	20	2
HEAT FLUX	10	25	2
STRAIN	10	100	5
OTHER	TBD*	20 (DEFLECTION)	30 (VALVE POSITIONS)
RECORDER, HARD COPY, CHANNELS	NONE	20	20
CLOSED CIRCUIT TV	3 CHANNELS	2 CHANNELS	2 CHANNELS
MOTION PICTURE PHOTOGRAPHY	NO (STILL - YES)	NO	NO
CHEMICAL ANALYSIS	ALL	ALL	ALL
CONTROLS	0.02-0.1 MPa GAGE, 4-20 MA (3-15 PSIG)	0.02-0.1 MPa, 4-20 MA (3-15 PSIG)	0.02-0.1 MPa, 4-20 MA (3-15 PSIG)
SUPPORT FACILITIES			
ENCLOSED TEST PREPARATION AREA	743 SQ m x 15.2 m H (8,000 SQ FT x 50 FT H)	372 SQ m x 15.2 m H (4,000 SQ FT x 50 FT H)	30.5 m W x 30.5 m DEPTH x 7.6 m H (100 FT W x 100 FT DEPTH x 25 FT H)
OFFICES	12 SQ m x 2.4 m H (1,200 SQ FT x 8 FT H)	92.9 SQ m (1,000 SQ FT)	92.9 SQ m (1,000 SQ FT)
STORAGE	139 SQ m (1,500 SQ FT)	92.9 SQ m (1,000 SQ FT)	46.5 SQ m (500 SQ FT)
AUXILIARY ROOM, TOP OF TOWER	3.1 m W x 2.4 m H x 3.1 m DEPTH (10 FT W x 8 FT H x 10 FT DEPTH)	3.1 m W x 3.1 m H x 1.8 m DEPTH (10 FT W x 10 FT H x 6 FT DEPTH)	3.1 m W x 2.4 m H x 3.1 m DEPTH (10 FT W x 8 FT H x 10 FT DEPTH)
FIELD CRANE CAPACITY	27,210 KG (30 TONS)	45,350 KG (50 TONS)	2,721 KG (3 TONS)
MONORAIL HOIST CAPACITY	9,070 KG (10 TONS)	9,070 KG (10 TONS)	227 KG (1/4 TON)

* TO BE DETERMINED

SUMMARY OF CONTRACTOR RESPONSES TO FACILITY REQUIREMENTS FOR OTHER RECEIVERS

ITEM	1 MW BENCH MODEL MARTIN MARIETTA - STEAM	EPRI GAS-COOLED RECEIVERS BLACK & VEATCH - AIR 1 MW	 BOEING - HELIUM 5 MW
RECEIVER			
SIZE	3 m W x 3 m H x 3 m DEPTH (10 FT W x 10 FT H x 10 FT DEPTH)	4 m W x 3 m H x 4 m DEPTH (13.1 FT W x 9.8 FT H x 13.1 FT DEPTH)	5 m DIA x 5 m H (16.5 FT DIA x 16.5 FT H)
WEIGHT	7,258 KG (16,000 LB)	3,178 KG (7,000 LB)	36,280 KG (80,000 LB)
TARGET SIZE	1 m x 1 m SQ 3.35 FT x 3.35 FT SQ)	1.0 m SQUARE	1 m RAD (3.3 FT RAD)
CYCLE CONDITIONS			
IN	10.3 MPa - 232 C (1,500 PSI - 450 F)	0.83 MPa - 427 C (120 PSI - 800 F)	3.45 MPa - 649 C (500 PSI - 1,200 F)
OUT	8.96 MPa - 513 C (1,300 PSI - 955 F)	0.83 MPa - 982 C (120 PSI - 1,800 F)	3.45 MPa - 871 C (500 PSI - 1,600 F)
FLOW RATE	0-0.38 KG/SEC (0-3,000 LB/HR)	0.45-1.36 KG/SEC (1-3 LB/SEC)	0.45-4.5 KG/SEC (1-10 LB/SEC)
FLUX DENSITY			
OPERATING	0-0.47 MW/m^2 (0-150,000 $BTU/HR\ FT^2$)	1.0 MW/m^2	1.5 MW/m^2 AT APERTURE
MAXIMUM	0.47 MW/m^2 (150,000 $BTU/HR\ FT^2$)	TBD*	TBD*
HELIOSTAT FIELD			
HORIZONTAL ANGLE OF FLUX	90° - RECTANGULAR NORTH	90°	360°
VERTICAL ANGLE OF FLUX	45° INCLUDED	TBD*	60° INCLUDED
INSTRUMENTS			
DATA ACQUISITION SYSTEM CHANNELS			
TEMPERATURE	100	50	250
PRESSURE	10	10	50
FLOW RATE	10	4	50
HEAT FLUX	25	2	40
STRAIN	20	TBD*	100
OTHER	10 (DEFLECTION)	TBD*	TBD*
RECORDER, HARD COPY, CHANNELS	20	TBD*	TBD*
CLOSED CIRCUIT TV	2 CHANNELS	YES - CHANNELS TBD*	YES - CHANNELS TBD*
MOTION PICTURE PHOTOGRAPHY	NO	NO	NO
CHEMICAL ANALYSIS	ALL	N/A	GAS ANALYSIS
CONTROLS	0.02-0.1 MPa - 420 MA (3-15 PSIG)	TBD*	TBD*
SUPPORT FACILITIES			
ENCLOSED TEST PREPARATION AREA	37.2 SQ m x 4.6 m H (400 SQ FT x 15 FT H)	9.1 m x 9.1 m (30 FT x 30 FT)	370 SQ m x 12.2 m H (4,000 SQ FT x 40 FT H)
OFFICES	18.6 SQ m (200 SQ FT)	74.3 SQ m (800 SQ FT)	92.9 SQ m (1,000 SQ FT)
STORAGE	18.6 SQ m (200 SQ FT)	92.9 SQ m (1,000 SQ FT)	92.9 SQ m (1,000 SQ FT)
AUXILIARY ROOM, TOP OF TOWER	3 m W x 3 m H x 3 m DEPTH (10 FT W x 10 FT H x 10 FT DEPTH)	TBD*	TBD*
FIELD CRANE CAPACITY	9,072 KG	TBD*	TBD*
MONORAIL HOIST CAPACITY	9,072 KG (10 TONS)	TBD*	TBD*

* TO BE DETERMINED

SUMMARY OF CONTRACTOR RESPONSES TO

FACILITY REQUIREMENTS FOR SRE THERMAL STORAGE

ITEM	BOEING CHEMICAL ENERGY STORAGE	BOEING FUSIBLE SALT	HONEYWELL	MARTIN MARIETTA	MCDONNELL DOUGLAS
TANKS					
NO. OF TANKS	14	1	1	7	1
FOUNDATIONS	4 TANKS - 0.9 m x 3.1 m (3 FT x 10 FT) 4 TANKS - 0.9 m x 3.7 m (3 FT x 12 FT) 6 TANKS - 0.6 m x 9.1 m (2 FT x 30 FT)	UNDEFINED 1.8 m x 3.7 m (6 FT x 12 FT)	3.7 W x 2.4 m H x 1.8 m DEPTH (12 FT W x 8 FT H x 6 FT DEPTH)	2 TANKS - 1.8 m DIA x 3.7 m H (6 FT DIA x 12 FT H) 4 TANKS - 3.1 m DIA x 9.5 m H (10 FT DIA x 31.25 FT H) 1 TANK - 2.4 m DIA x 5.1 m H (8 FT DIA x 16.7 FT H)	3.2 m DIA (10.5 FT DIA)
TOTAL WEIGHT	18,144 KG (40,000 LB)	34,020 KG (75,000 LB)	31, 745 KG GROSS (70,000 LB GROSS)	226,750 KG (500,000 LB)	209,000 KG (458,000 LB)
LAND AREA	112 SQ m (1,200 SQ FT)	18.6 SQ m (200 SQ FT)	23.2 SQ m - 5.5 m x 4.3 m (250 SQ m - 18 FT x 14 FT)	36.6 m x 67.1 m (120 FT x 220 FT)	8 m x 8 m (25 FT x 25 FT)
CHARGING CYCLE					
FLUID	HELIUM	HELIUM	STEAM	STEAM	STEAM
CONDITION					
IN	3.5 MPa - 816 C (500 PSI - 1,500 F)	3.5 MPa - 816 C (500 PSI - 1,500 F)	9.9 MPa - 311 C (1,450 PSI - 592 F)	8.6 MPa - 511 C (1,250 PSI - 952 F)	343 C MAX (650 F MAX)
OUT	3.3 MPa - 538 C (480 PSI - 1,000 F)	3.3 MPa - 649 C (480 PSI - 1,200 F)	TBD*	8.3 MPa - 238 C (1,200 PSI - 460 F)	TBD*
FLOW RATE	3.6 KG/SEC (8 LB/SEC)	3.6 KG/SEC (8 LB/SEC)	0.18 KG/SEC (1,400 LB/HR)	2.0 KG/SEC (16,000 LB/HR)	0.1 to 1.0 MWt
DISCHARGING CYCLE					
FLUID	HELIUM	HELIUM	STEAM	STEAM	STEAM
CONDITION					
IN	3.6 MPa - 538 C (520 PSI - 1,000 F)	3.6 MPa - 427 C (520 PSI - 800 F)	TBD*	4.5 MPa - 204 C (650 PSI - 400 F)	TBD*
OUT	3.5 MPa - 816 C (500 PSI - 1,500 F)	3.5 MPa - 649 C (500 PSI - 1,200 F)	4.8 MPa - 262 C (700 PSI - 503 F)	4.1 MPa - 399 C (600 PSI - 750 F)	288 C MAX (550 F MAX)
FLOW RATE	3.6 KG/SEC (8 LB/SEC)	3.6 KG/SEC (8 LB/SEC)	0.66 KG/SEC (5,200 LB/HR)	2.0 KG/SEC (16,000 LB/HR)	0.1 to 1.0 MWt
INSTRUMENTS					
DATA ACQUISITION SYSTEM CHANNELS					
TEMPERATURE	50	30	25	TBD*	116
PRESSURE	8	10	6	TBD*	10
FLOW RATE	10	10	4	TBD*	6
OTHER	8 LIQUID LEVEL	30 STRAIN	HEAT FLOW	LIQUID LEVEL	35 STRAIN
RECORDER, HARD COPY, CHANNELS	30	31	10	20	20
CONTROLS	120 VAC	TBD*	0.02-0.1 MPa, 4-20 MA (3-15 PSIG)	0.02-0.1 MPa, 4-20 MA (3-15 PSIG)	TBD*
SUPPORT FACILITIES					
ENCLOSED TEST AREA	186 SQ m (2,000 SQ FT)	186 SQ m (2,000 SQ FT)	23 SQ m MIN 250 SQ FT MIN)	SMALL SHOP	30.5 m x 30.5 m x 7.6 m (100 FT x 100 FT x 25 FT)
OFFICES	27.9 SQ m (300 SQ FT)	27.9 SQ m (300 SQ FT)	1-2.4 m x 3.1 m (1-8 FT x 10 FT)	3	92.9 SQ m (1,000 SQ FT)
STORAGE					
OUTSIDE	92.9 SQ m (1,000 SQ FT)	92.9 SQ m (1,000 SQ FT)	TBD*	61 m x 76 m (200 FT x 250 FT)	46.5 SQ m (500 SQ FT)
INDOOR	92.9 SQ m (1,000 SQ FT)	92.9 SQ m (1,000 SQ FT)	YES	46 SQ m (500 SQ FT)	46.5 SQ m (500 SQ FT)
MOBILE CRANE CAPACITY	45,360 KG (50 TONS)	45,360 KG (50 TONS)	36,287 KG (40 TONS)	31, 750 KG (35 TONS)	9,072 KG (10 TONS)
SAFETY					
FLUID	SULFUR TRIOXIDE FLUID	FUSIBLE SALT	MOLTEN SALT FLUID	HYDROCARBON OIL	PETROLEUM-BASED FLUID
PROVISIONS	DIKE AROUND TANKS EMER. SHOWERS AND EYEWASH PROTECTIVE CLOTHING	DIKE AROUND TANK LIQUID METAL BURN PROTECTION	DIKE AROUND TANK	DIKE AROUND TANKS FIRE PROTECTION EQUIP.	DIKE AROUND TANK FIRE PROTECTION EQUIP.

* TO BE DETERMINED

SUMMARY OF CONTRACTOR RESPONSES TO
FACILITY REQUIREMENTS FOR SRE HELIOSTATS

ITEM	BOEING	HONEYWELL	MARTIN MARIETTA	MCDONNELL DOUGLAS
HELIOSTATS				
FOUNDATION	PEDESTAL 0.11 m DIA (4.5 IN DIA)	(2) PEDESTALS 1.2 m SQ (4 FT SQ)	PEDESTAL 0.6 m DIA (2 FT DIA)	PEDESTAL 2.1 m DIA (7 FT DIA)
LOAD				
STATIC	48.6 KG (107 LB)	3,855 KG (8,500 LB)	AXIAL - 2,721 KG (6,000 LB) SHEAR - 2,948 KG (6,500 LB)	1,506 KG (3,320 LB)
WIND	LIFT - 1,360 KG (3,000 LB) DRAG - 272 KG (600 LB)	LIFT - 136 KG (300 LB) DRAG - 181 KG (400 LB)	11,680 KG-m MAX (84,500 FT-LB MAX)	2,544 KG (5,610 LB)
TOPOGRAPHY	FLAT	LESS THAN 0.3 m/4.6 m (1 FT/15 FT)	FLAT	FLAT
ARRAY				
NUMBER	3	3	11	5
SPACING	1.5 m MIN (5 FT MIN)	45% GROUND COVER	SAMPLE POSITIONS IN 439 m x 439 m (1,440 FT x 1,440 FT)	9 m (29.5 FT) NORTH-TO-LINE-OF-SIGHT 10 m (33 FT) PARALLEL
CONTROLS	BOEING SUPPLIED	COMPUTER WITH CONTRACTOR SOFTWARE	PDP-11 COMPUTER	DIGITAL DATA BUS-MANCHESTER FORMAT 2 KH$_2$
SOLAR IMAGE				
SIZE	6.7 m (263 IN.) @ 152 m (500 FT) 8.8 m (348 IN.) @ 305 m (1,000 FT)	3.1 m x 3.1 m @ 92.9 m (10 FT x 10 FT @ 1,000 FT)	DIA (m) = .0122 D + 1.22 DIA (FT) = .0122 D + 4	DIA (m) = 3.05 + 0.0113 D DIA (FT) = 10 + 0.0113 D
FLUX	547 W/m^2 @ 312 m 580 W/m^2 @ 212 m	TBD*	$q/A\ (W/m^2) = 1.017 \times 10^7 \div D^2$ $q/A\ (Btu/hr\ ft^2) = 1.06 \times 10^7 \div D^2$ D = SLANT RANGE	$q/A\ (W/m^2) = \frac{20.5}{\pi[0.153\ (3.05 + 0.0113\ D)]^2}$ $q/A\ (Btu/hr\ ft^2) = \frac{70}{\pi[0.153\ (10 + 0.0113\ D)]^2}$ D = SLANT RANGE
SUPPORT FACILITIES				
ENCLOSED TEST AREA	92.9 SQ m (1,000 SQ FT)	139 SQ m (1,500 SQ FT)	SMALL SHOP	(12 m x 18 m x 6.7 m H) (40 FT x 60 FT x 22 FT H) TWO 1,814 KG (4,000 LB) HOISTS
OFFICE	37.2 SQ m (400 SQ FT)	37.2 SQ m (400 SQ FT)	3 OFFICES	139.4 SQ m (1,500 SQ FT)
STORAGE	74.3 SQ m (800 SQ FT)	56 SQ m (600 SQ FT)	152 m x 152 m (500 FT x 500 FT)	83.6 SQ m (900 SQ FT)
MOBILE CRANE	136 KG (300 LB) @ 12.2 m (40 FT) H	1,134 KG (2,500 LB)	4,536 KG (10,000 LB)	4,536 KG (10,000 LB)

* TO BE DETERMINED

APPENDIX B

CHECKLIST RESPONSES OF CONTRACTORS

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5 MW SOLAR THERMAL TEST FACILITY

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT RECEIVERS

Contractor HONEYWELL

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Target Surface

1.1.1.1 Size Annulus, 10.6' dia x 6' dia x 4.2' high

1.1.1.2 Orientation Relative to Heliostat Field Centered in heliostat field. Annulus "fare" 30° from vertical.

1.1.1.3 Flux Distribution at Surface Not germane to concept: probably Gaussian in vertical, nearly flat in azmuth with anomalies at supports.

1.1.2 Receiver Dimensions

1.1.2.1 Width ________

1.1.2.2 Depth ________

1.1.2.3 Diameter 16' outside

1.1.2.4 Height 28'

1.1.2.5 Service Platform Requirements 24' dia.

1.2 Weight

1.2.1 Total 60,000 lbs.

1.2.2 Load Pattern on Service Platform

1.2.2.1 Distributed Loading

____

____

1.2.2.2 Concentrated Loading and Locations

3 corbels at 20,000 lbs. each

1.3 Special Requirements Support adapter to rate receiver to tower.

2.0 Cycle

2.1 Working Fluid

2.1.1 Water-Steam Yes

2.1.2 Other

2.1.3 Quality Very high

2.2 Power Cycle-Rankine

2.2.1 Inlet Fluid Conditions

2.2.1.1 Pressure 1700 psig

2.2.1.2 Temperature 520°F

2.2.2 Outlet Fluid Conditions

2.2.2.1 Pressure 1500 psig

2.2.2.2 Temperature 955°F

2.2.3 Fluid Flow Rate Range 15,300 lbs/hr/1530 lbs/hr

2.2.4 Special Requirements Pump located near receiver. Steam and water lines to pump and from pump to receiver.

2.3 Quantity of Water in Receiver 8000 lbs.

3.0 Solar Flux

3.1 Density

3.1.1 Operating ______ 400 KW/M^2 ______

3.1.2 Maximum Permissible 450 KW/M^2 ______

3.2 Heliostat Field

3.2.1 Field Design Configuration

3.2.1.1 30° ______

3.2.1.2 90° ______

3.2.1.3 360° Yes--with dead region in center

3.2.1.4 Other ______

3.2.2 Angular Distribution Requirements of Incident Radiation on Target Surfaces

3.2.2.1 Horizontal 360° ______

3.2.2.2 Vertical 43 degrees included angle
20 degrees from vertical
27 degrees from horizontal

4.0 Auxiliary Equipment Requirements during Transient Solar Flux

Heliostat controller and spray attemperator

5.0 Instrumentation

5.1 Data Acquisition System Preferred for Your Evaluation of Test Results.

5.1.1 Magnetic Tape Yes

5.1.2 Multiplexer Yes

5.1.3 Analog Display Yes

5.1.4 Digital Printout Yes

5.1.5 Other Real time, digital computer with real time readout and CRT

5.2 Parametric Data Signals (Maximum Values and Number of Channels - volts, millivolts, milliamperes, etc.) for Data Acquisition System

	Max Values	Channels
5.2.1 Temperature	10 MW	250
5.2.2 Pressure	10 V	10
5.2.3 Flow Rates	10 V	10
5.2.4 Heat Flux	10 MW	10
5.2.5 Strain	10 MW	10
5.2.6 Other		

5.3 Recorders (Hard Copy)

5.3.1 Channels None

5.3.2 Signals (Maximum Values and Types)

5.4 Optical Monitoring (Remote)

5.4.1 Closed Circuit Television Yes--3 channels

5.4.2 Line Photography Record only

5.4.3 Pyrometry None

5.4.4 Still Photography Yes

5.5 Chemical Analysis

5.5.1 pH Meter Yes

5.5.2 Dissolved Oxygen Yes

5.5.3 Residual Hydrazine Yes

5.5.4 Conductivity Yes

5.5.5 Others Fe, ppm
Cu, ppm
Total hardness, ppm
SiOz, ppm
Organic solids, ppm

6.0 Controls

6.1 Type

6.1.1 Pneumatic, 3 to 15 psig Yes

6.1.2 Electronic, 4 to 20 ma Yes

6.1.3 Other Electnc, Hydraulic

6.2 Others TBD

7.0 Support Facilities

7.1 Dedicated Space for Contractor (Floor Area and Ceiling Height)

7.1.1 Enclosed Test Preparation Area 8000 ft^2 x50 ft

7.1.2 Office Areas 1200 ft^2 x8'

7.1.3 Equipment Storage Area 1500 ft^2

7.1.4 Materials and Supplies Storage Area 1000 ft^2

7.2 Technicians to Assist Vendor

7.2.1 Receiver Installation 2

7.2.2 Instrumentation and Controls Checkout 2

7.2.3 Special Requirements 2

7.3 Tower Facilities at Top

7.3.1 Space for Auxiliary Equipment

7.3.1.1 Room Size 10'x10'x8' high

7.3.1.2 Utilities

7.3.1.2.1 Power 480V, 3Ø/220,110V, 1Ø

7.3.1.2.2 Water Yes

7.3.1.2.3 Compressed Air Yes

7.3.1.2.4 Other Gases No

7.3.1.2.5 Vacuum Yes

7.3.2 Field Crane Capacity 30 Ton

7.3.3 Personnel and Materials Elevator

7.3.3.1 Size 6 x 6

7.3.3.2 Capacity 4000

7.3.4 Monorail Hoist Capacity 10 Ton

7.4 Mobile Crane Capacity 5 Ton

8.0 Number of Your Field Crew Expected to be Present During Testing 4

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5 MW SOLAR THERMAL TEST FACILITY

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT RECEIVERS

Contractor Martin Marietta Corporation

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Target or Apperture Surface

1.1.1.1 Size 8.75 ft x 8.75 ft (Square)

1.1.1.2 Orientation Relative to Heliostat Field 20° Off of vertical.

1.1.1.3 Flux Distribution at Surface ____

1.1.2 Receiver Dimensions

1.1.2.1 Width 30 ft

1.1.2.2 Depth 25 ft

1.1.2.3 Diameter ____

1.1.2.4 Height 50 ft

1.1.2.5 Service Platform Requirements Yes.

1.2 Weight

1.2.1 Total 70 Tons

1.2.2 Load Pattern on Service Platform

1.2.2.1 Distributed Loading

Standard Design

1.2.2.2 Concentrated Loading and Locations

TBD

1.3 Special Requirements

2.0 Cycle

2.1 Working Fluid

2.1.1 Water-Steam Yes

2.1.2 Other

2.1.3 Quality Demineralized

2.2 Power Cycle-Rankine

2.2.1 Inlet Fluid Conditions

2.2.1.1 Pressure 1450 psig

2.2.1.2 Temperature 350°F

2.2.2 Outlet Fluid Conditions

2.2.2.1 Pressure 1325 psig

2.2.2.2 Temperature 960°F

2.2.3 Fluid Flow Rate Range 0 - 20,000 lbm/hr

2.2.4 Special Requirements Cooling tower, water treatment.

2.3 Quantity of Water in Receiver 900 Gallons; Makeup = 1.5 GPM

3.0 Solar Flux

3.1 Density

3.1.1 Operating 0 to 225,000 Btu hr/ft^2

3.1.2 Maximum Permissible 225,000 (on boiler)

3.2 Heliostat Field

3.2.1 Field Design Configuration

3.2.1.1 30° ____________________

3.2.1.2 90° Rectangular, on north side of tower.

3.2.1.3 360° ____________________

3.2.1.4 Other ____________________

3.2.2 Angular Distribution Requirements of Incident Radiation on Target or Apperture Surfaces

3.2.2.1 Horizontal 90° Included Angle

3.2.2.2 Vertical 45° Included Angle

4.0 Auxiliary Equipment Requirements during Transient Solar Flux

____

____

5.0 Instrumentation

5.1 Data Acquisition System Preferred for Your Evaluation of Test Results.

5.1.1 Magnetic Tape ____X____

5.1.2 Multiplexer ____X____

5.1.3 Analog Display ____X____

5.1.4 Digital Printout ____X____

5.1.5 Other ________

5.2 Parametric Data Signals (Maximum Values and Number of Channels - volts, millivolts, milliamperes, etc.) for Data Acquisition System

150 Channels 5.2.1 Temperature 0 to 1200^{o}F and ________

20 Channels 5.2.2 Pressure 0 to 1800 psig and ________

20 Channels 5.2.3 Flow Rates 0 to 20,000 lbm/hr and ________

25 Channels 5.2.4 Heat Flux 0 to 200,000 Btu/hr/ft^{2} and ________

100 Channels 5.2.5 Strain ________ and ________

20 Channels 5.2.6 Other Deflection

5.3 Recorders (Hard Copy)

5.3.1 Channels 20

5.3.2 Signals (Maximum Values and Types)

10 Temperature (1200^{o}F)

10 Pressure (1800 psig)

5.4 Optical Monitoring (Remote)

5.4.1 Closed Circuit Television 2 Channels.

5.4.2 Line Photography ______

5.4.3 Pyrometry ___X___

5.5 Chemical Analysis

5.5.1 pH Meter ___X___

5.5.2 Dissolved Oxygen ___X___

5.5.3 Residual Hydrazine ___X___

5.5.4 Conductivity ___X___

5.5.5 Others Sodium Content, Silica Content, Total Dissolved Solids

6.0 Controls

6.1 Type

6.1.1 Pneumatic, 3 to 15 psig ___X___

6.1.2 Electronic, 4 to 20 ma ___X___

6.1.3 Other ______

6.2 Others ______

______

7.0 Support Facilities

7.1 Dedicated Space for Contractor (Floor Area and Ceiling Height)

7.1.1 Enclosed Test Preparation Area 4000 ft^2 X 50 ft height

7.1.2 Office Areas 1000 ft^2 (2 or 3 Offices)

7.1.3 Equipment Storage Area 1000 ft^2

7.1.4 Materials and Supplies Storage Area ---

7.2 Technicians to Assist Vendor

7.2.1 Receiver Installation Yes.

7.2.2 Instrumentation and Controls Checkout Yes.

7.2.3 Special Requirements Hydrostatic Test - Yes.
Acid & Aklaline Cleaning - Yes.

7.3 Tower Facilities at Top

7.3.1 Space for Auxiliary Equipment

7.3.1.1 Room Size 10' x 10' x 6'

7.3.1.2 Utilities

7.3.1.2.1 Power X

7.3.1.2.2 Water X

7.3.1.2.3 Compressed Air X

7.3.1.2.4 Other Gases ______

7.3.1.2.5 Vacuum X

7.3.2 Field Crane Capacity 50 Tons

7.3.3 Personnel and Materials Elevator

7.3.3.1 Size Normal

7.3.3.2 Capacity Normal

7.3.4 Monorail Hoist Capacity 10 Tons.

7.4 Mobile Crane Capacity ______

8.0 Number of Your Field Crew Expected to be Present During Testing ______

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5 MW SOLAR THERMAL TEST FACILITY

FACILITY REQUIREMENTS FOR TESTING

RESEARCH EXPERIMENT RECEIVERS

Contractor McDonnell Douglas Astronautics Company

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Target or Apperture Surface

1.1.1.1 Size 1 x 17m (3.3 x 56 feet)

1.1.1.2 Orientation Relative to Heliostat Field vertical or canted and elevated above field

1.1.1.3 Flux Distribution at Surface .4 MW/m^2 Max

1.1.2 Receiver Dimensions

1.1.2.1 Width 1 meter (3.3 ft)

1.1.2.2 Depth 4 meters (13.2 ft)

1.1.2.3 Diameter --

1.1.2.4 Height 17 meters (56 ft)

1.1.2.5 Service Platform Requirements At top and bottom of panel. Temporary access along full length.

1.2 Weight

1.2.1 Total 2700 Kg (6000 lbs including valves, piping, etc)

1.2.2 Load Pattern on Service Platform

1.2.2.1 Distributed Loading

For 2-3 people simultaneous access

1.2.2.2 Concentrated Loading and Locations

Panel supported from upper end. Support for valves and control assemblies on top and bottom access platforms (max point load 300 lbs).

1.3 Special Requirements

Intermediate lateral support along total length of panel.

2.0 Cycle

2.1 Working Fluid

2.1.1 Water-Steam X

2.1.2 Other —

2.1.3 Quality See below

2.2 Power Cycle-Rankine

2.2.1 Inlet Fluid Conditions

2.2.1.1 Pressure 13.8 ± .35 MN/m^2 (2000 ± 50 psia)

2.2.1.2 Temperature 104/204 ± 14°C (220/400 ± 25°F)

2.2.2 Outlet Fluid Conditions

2.2.2.1 Pressure 10.4 MN/m^2 (1500 psia)

2.2.2.2 Temperature 343/477°C (650/890°F)

2.2.3 Fluid Flow Rate Range 2.25/.25 Kg/sec (5/.6 lbs/sec)

2.2.4 Special Requirements Water quality as per standard boiler requirements.

Dissolved solids 20-50 PPB; Ph = 9.5 nominal

2.3 Quantity of Water in Receiver .6 m^3 (2 ft^3); 57 Kg (125 lbs)

3.0 Solar Flux

3.1 Density

3.1.1 Operating .4 MW/m^2

3.1.2 Maximum Permissible .45 MW/m^2

3.2 Heliostat Field

3.2.1 Field Design Configuration

3.2.1.1 30° ________________

3.2.1.2 90°+ ✓

3.2.1.3 360° ________________

3.2.1.4 Other ________________

3.2.2 Angular Distribution Requirements of Incident Radiation on Target or Apperture Surfaces

3.2.2.1 Horizontal No requirement

3.2.2.2 Vertical > 20° from panel surface

4.0 Auxiliary Equipment Requirements during Transient Solar Flux

N/A

5.0 Instrumentation

5.1 Data Acquisition System Preferred for Your Evaluation of Test Results.

5.1.1 Magnetic Tape ✓

5.1.2 Multiplexer —

5.1.3 Analog Display ✓

5.1.4 Digital Printout ✓

5.1.5 Other —

5.2 Parametric Data Signals (Maximum Values and Number of Channels - volts, millivolts, milliamperes, etc.) for Data Acquisition System

5.2.1 Temperature 797°C (1500°F) and 100 channels

5.2.2 Pressure 17.3 MN/m^2 (2500 psia) and 10 channels

5.2.3 Flow Rates 2.25 Kg/sec (5 lbs/sec) and 2 channels

5.2.4 Heat Flux .5 MW/m^2 and 2 channels

5.2.5 Strain 10 micro-inches/inch and 5 channels

5.2.6 Other Panel valve positions 30 channels

—

5.3 Recorders (Hard Copy)

5.3.1 Channels 20 channels

5.3.2 Signals (Maximum Values and Types)

0-5 VDC

5.4 Optical Monitoring (Remote)

5.4.1 Closed Circuit Television 2 cameras

5.4.2 Line Photography —

5.4.3 Pyrometry ✓

5.5 Chemical Analysis

5.5.1 pH Meter ✓

5.5.2 Dissolved Oxygen ✓

5.5.3 Residual Hydrazine ✓

5.5.4 Conductivity ✓

5.5.5 Others —

6.0 Controls

6.1 Type

6.1.1 Pneumatic, 3 to 15 psig ✓

6.1.2 Electronic, 4 to 20 ma ✓

6.1.3 Other —

6.2 Others —

7.0 Support Facilities

7.1 Dedicated Space for Contractor (Floor Area and Ceiling Height)

7.1.1 Enclosed Test Preparation Area 100 x 100 x 25 feet

7.1.2 Office Areas 1,000 ft^2

7.1.3 Equipment Storage Area 500 ft^2

7.1.4 Materials and Supplies Storage Area 500 ft^2

7.2 Technicians to Assist Vendor

7.2.1 Receiver Installation (1) crane operator; (2) riggers

7.2.2 Instrumentation and Controls Checkout meterology tech

7.2.3 Special Requirements --

7.3 Tower Facilities at Top

7.3.1 Space for Auxiliary Equipment

7.3.1.1 Room Size 10 x 10 x 8 ft high

7.3.1.2 Utilities

7.3.1.2.1 Power 110 VAC, 1 KW; 0-28 VDC

7.3.1.2.2 Water As noted

7.3.1.2.3 Compressed Air 150 psi, 20 SCFM

7.3.1.2.4 Other Gases GN_2, 1000 psi, 20 SCFM

7.3.1.2.5 Vacuum 0.1 atmosphere

7.3.2 Field Crane Capacity 3 tons

7.3.3 Personnel and Materials Elevator

7.3.3.1 Size TBD

7.3.3.2 Capacity 1/2 ton

7.3.4 Monorail Hoist Capacity 1/4 ton

7.4 Mobile Crane Capacity 3 tons

8.0 Number of Your Field Crew Expected to be Present During Testing 7

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5 MW SOLAR THERMAL TEST FACILITY

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT RECEIVERS

Contractor Martin Marietta Corporation (1 MWth Receiver)

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Target or Apperture Surface

1.1.1.1 Size 3.35 ft x 3.35 ft

1.1.1.2 Orientation Relative to Heliostat Field
20^{o} Off Vertical (Downward)

1.1.1.3 Flux Distribution at Surface 0 to 155,000 Btu/Hr-ft^2 on Boiler; 0 to 45,000 Btu/hr^2-ft^2 on Superheater

1.1.2 Receiver Dimensions

1.1.2.1 Width 10 ft

1.1.2.2 Depth 10 ft

1.1.2.3 Diameter ____

1.1.2.4 Height 10 ft

1.1.2.5 Service Platform Requirements 3 ft Wide Service Platforms All Around

1.2 Weight

1.2.1 Total 8 Tons

1.2.2 Load Pattern on Service Platform

1.2.2.1 Distributed Loading

____

____

1.2.2.2 Concentrated Loading and Locations

Load on four points. Maximum will not exceed 5000 lbs.

1.3 Special Requirements The test article is a welded assembly. It is very desirable to handle it in a single assembly.

2.0 Cycle

2.1 Working Fluid

2.1.1 Water-Steam X

2.1.2 Other

2.1.3 Quality Boiler Feedwater

2.2 Power Cycle-Rankine

2.2.1 Inlet Fluid Conditions

2.2.1.1 Pressure 1500 psig

2.2.1.2 Temperature 350 to 450°F (Steady State)

2.2.2 Outlet Fluid Conditions

2.2.2.1 Pressure 1300 psig

2.2.2.2 Temperature 955°F

2.2.3 Fluid Flow Rate Range 0 to 3000 lbs/hr

2.2.4 Special Requirements All support equipment required to cool, condense, and pump the working fluid can be supplied with the test article, if desired.

2.3 Quantity of Water in Receiver 600 lbs

3.0 Solar Flux

3.1 Density

3.1.1 Operating 0 to 150,000 Btu/Hr-ft^2

3.1.2 Maximum Permissible 150,000 Btu/Hr-ft^2

3.2 Heliostat Field

3.2.1 Field Design Configuration

3.2.1.1 30° ________________

3.2.1.2 90° Rectangular, on north side of tower.

3.2.1.3 360° ________________

3.2.1.4 Other ________________

3.2.2 Angular Distribution Requirements of Incident Radiation on Target or Apperture Surfaces

3.2.2.1 Horizontal 90° Included Angle

3.2.2.2 Vertical 45° Included Angle

4.0 Auxiliary Equipment Requirements during Transient Solar Flux

It will be necessary to sequence heliostats on in a manner which will protect the superheater. It is estimated that the sequence might require as few as 10 heliostats at a time be turned on.

5.0 Instrumentation

5.1 Data Acquisition System Preferred for Your Evaluation of Test Results.

5.1.1 Magnetic Tape X

5.1.2 Multiplexer X

5.1.3 Analog Display X

5.1.4 Digital Printout X

5.1.5 Other ______

5.2 Parametric Data Signals (Maximum Values and Number of Channels - volts, millivolts, milliamperes, etc.) for Data Acquisition System

100 Channels	5.2.1 Temperature	0 to 1200°F	and	
10 Channels	5.2.2 Pressure	0 to 1800 psig	and	
10 Channels	5.2.3 Flow Rates	0 to 20,000 lbm/hr	and	
25 Channels	5.2.4 Heat Flux	0 to 200,000 Btu hr/ft^2	and	
20 Channels	5.2.5 Strain		and	
10 Channels	5.2.6 Other	Deflection		

5.3 Recorders (Hard Copy)

5.3.1 Channels 20

5.3.2 Signals (Maximum Values and Types)

10 Temperature (1200° F)

10 Pressure (1800 psig)

5.4 Optical Monitoring (Remote)

5.4.1 Closed Circuit Television 2 Channels.

5.4.2 Line Photography ____________

5.4.3 Pyrometry ______ X ______

5.5 Chemical Analysis

5.5.1 pH Meter ______ X ______

5.5.2 Dissolved Oxygen ______ X ______

5.5.3 Residual Hydrazine ______ X ______

5.5.4 Conductivity ______ X ______

5.5.5 Others Sodium Content, Silica Content, Total Dissolved Solids

6.0 Controls

6.1 Type

6.1.1 Pneumatic, 3 to 15 psig ______ X ______

6.1.2 Electronic, 4 to 20 ma ______ X ______

6.1.3 Other ____________

6.2 Others Complete control and instrumentation system available with test article.

7.0 Support Facilities

7.1 Dedicated Space for Contractor (Floor Area and Ceiling Height)

7.1.1 Enclosed Test Preparation Area 400 ft^2 x 15 ft height.

7.1.2 Office Areas 200 ft^2

7.1.3 Equipment Storage Area 200 ft^2

7.1.4 Materials and Supplies Storage Area --

7.2 Technicians to Assist Vendor

7.2.1 Receiver Installation Yes (2)

7.2.2 Instrumentation and Controls Checkout Yes (2)

7.2.3 Special Requirements Hydrostatic Test - Yes.
Acid & Alkaline Cleaning - Yes.

7.3 Tower Facilities at Top

7.3.1 Space for Auxiliary Equipment

7.3.1.1 Room Size 10' x 10' x 10'

7.3.1.2 Utilities

7.3.1.2.1 Power X

7.3.1.2.2 Water X

7.3.1.2.3 Compressed Air X

7.3.1.2.4 Other Gases ______

7.3.1.2.5 Vacuum ______

7.3.2 Field Crane Capacity 10 Tons

7.3.3 Personnel and Materials Elevator

7.3.3.1 Size Normal

7.3.3.2 Capacity Normal

7.3.4 Monorail Hoist Capacity 10 Tons

7.4 Mobile Crane Capacity ______

8.0 Number of Your Field Crew Expected to be Present During Testing 3

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5 MW SOLAR THERMAL TEST FACILITY

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT RECEIVERS

Contractor BLACK & VEATCH 1 MWt Gas-cooled Receiver.

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Target or Apperture Surface

1.1.1.1 Size 1.0 m Square

1.1.1.2 Orientation Relative to Heliostat Field Vertical

1.1.1.3 Flux Distribution at Surface Heliostats Aimed At Center of Aperture

1.1.2 Receiver Dimensions

1.1.2.1 Width 4 m

1.1.2.2 Depth 4 m

1.1.2.3 Diameter Not applicable

1.1.2.4 Height 3 m

1.1.2.5 Service Platform Requirements Can use 1 MWt test platform.

1.2 Weight

1.2.1 Total 3.5 Ton

1.2.2 Load Pattern on Service Platform

1.2.2.1 Distributed Loading

1.2.2.2 Concentrated Loading and Locations

____

____

____

1.3 Special Requirements ____________________

____

____

2.0 Cycle

2.1 Working Fluid

2.1.1 Water-Steam __________

2.1.2 Other Air

2.1.3 Quality __________

2.2 Power Cycle-Rankine

2.2.1 Inlet Fluid Conditions

2.2.1.1 Pressure 120 psia

2.2.1.2 Temperature 800 ^{o}F

2.2.2 Outlet Fluid Conditions

2.2.2.1 Pressure 120 psia

2.2.2.2 Temperature 1600-1800 ^{o}F

2.2.3 Fluid Flow Rate Range 1-3 LB/SEC

2.2.4 Special Requirements Small air compressor at test platform or base of tower to supply inlet air to receiver on test platform and 1 MBTUH electric preheater.

2.3 Quantity of Water in Receiver None

3.0 Solar Flux

3.1 Density

3.1.1 Operating $1.0\ MWt/m^2$ (Average)

3.1.2 Maximum Permissible TBD

3.2 Heliostat Field

3.2.1 Field Design Configuration

3.2.1.1 30° ________

3.2.1.2 90° YES

3.2.1.3 360° ________

3.2.1.4 Other ________

3.2.2 Angular Distribution Requirements of Incident Radiation on Target or Apperture Surfaces

3.2.2.1 Horizontal ________

3.2.2.2 Vertical ________

3.2.2.3 Heliostats Aimed at Center of Aperture

4.0 Auxiliary Equipment Requirements during Transient Solar Flux

TBD

5.0 Instrumentation

5.1 Data Acquisition System Preferred for Your Evaluation of Test Results.

5.1.1 Magnetic Tape YES

5.1.2 Multiplexer YES

5.1.3 Analog Display YES

5.1.4 Digital Printout YES

5.1.5 Other ______

5.2 Parametric Data Signals (Maximum Values and Number of Channels - volts, millivolts, milliamperes, etc.) for Data Acquisition System

5.2.1 Temperature 2500 ^{o}F and 50 Channels

5.2.2 Pressure 200 psi and 10 Channels

5.2.3 Flow Rates 5 lb/sec and 4 Channels

5.2.4 Heat Flux 1 Mw/m^2 and 2 Channels

5.2.5 Strain ______ and ______

5.2.6 Other TBD

5.3 Recorders (Hard Copy)

5.3.1 Channels TBD

5.3.2 Signals (Maximum Values and Types)

TBD

5.4 Optical Monitoring (Remote)

5.4.1 Closed Circuit Television YES

5.4.2 Line Photography ______________________

5.4.3 Pyrometry ______ YES ______

5.5 Chemical Analysis

5.5.1 pH Meter ______ N/A ______

5.5.2 Dissolved Oxygen ______ N/A ______

5.5.3 Residual Hydrazine ______ N/A ______

5.5.4 Conductivity ______ N/A ______

5.5.5 Others ______ N/A ______

6.0 Controls

6.1 Type

6.1.1 Pneumatic, 3 to 15 psig ______________________

6.1.2 Electronic, 4 to 20 ma ______________________

6.1.3 Other ______ TBD ______

6.2 Others ______________________________________

____

7.0 Support Facilities

7.1 Dedicated Space for Contractor (Floor Area and Ceiling Height)

7.1.1 Enclosed Test Preparation Area 30 x 30 Feet

7.1.2 Office Areas ______ 800 Ft^2 ______

7.1.3 Equipment Storage Area 1000 Ft^2 ______

7.1.4 Materials and Supplies Storage Area TBD

7.2 Technicians to Assist Vendor

7.2.1 Receiver Installation ____TBD____

7.2.2 Instrumentation and Controls Checkout ____TBD____

7.2.3 Special Requirements ____TBD____

7.3 Tower Facilities at Top

7.3.1 Space for Auxiliary Equipment

7.3.1.1 Room Size ____TBD____

7.3.1.2 Utilities

7.3.1.2.1 Power ____TBD____

7.3.1.2.2 Water ____NONE____

7.3.1.2.3 Compressed Air ____150 psi, 3600 scfm____

7.3.1.2.4 Other Gases ____NONE____

7.3.1.2.5 Vacuum ____NONE____

7.3.2 Field Crane Capacity ____TBD____

7.3.3 Personnel and Materials Elevator

7.3.3.1 Size ____TBD____

7.3.3.2 Capacity ____TBD____

7.3.4 Monorail Hoist Capacity ____TBD____

7.4 Mobile Crane Capacity ____TBD____

8.0 Number of Your Field Crew Expected to be Present During Testing ____3-5 People____

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BLACK & VEATCH

5 MW SOLAR THERMAL TEST FACILITY

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT RECEIVERS

(Revised 9/30/75)

Contractor Boeing Engineering and Construction

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Target or Apperture Surface

1.1.1.1 Size 1 m radius

1.1.1.2 Orientation Relative to Heliostat Field Aperture horizontal and centered in field.

1.1.1.3 Flux Distribution at Surface Heliostats aimed at center of aperture

1.1.2 Receiver Dimensions

1.1.2.1 Width N/A

1.1.2.2 Depth N/A

1.1.2.3 Diameter 5 m

1.1.2.4 Height 5 m

1.1.2.5 Service Platform Requirements 2 meter working zone around receiver R

1.2 Weight

1.2.1 Total 40 tons R

1.2.2 Load Pattern on Service Platform

1.2.2.1 Distributed Loading

1.2.2.2 Concentrated Loading and Locations

1.3 Special Requirements

2.0 Cycle

2.1 Working Fluid

2.1.1 Water-Steam N/A

2.1.2 Other Helium

2.1.3 Quality N/A

2.2 Power Cycle-Rankine

2.2.1 Inlet Fluid Conditions

2.2.1.1 Pressure 500 psi

2.2.1.2 Temperature 800 - 1200°F

2.2.2 Outlet Fluid Conditions

2.2.2.1 Pressure 500 psi

2.2.2.2 Temperature 1200 - 1600°F

2.2.3 Fluid Flow Rate Range 1-10 lb/sec

2.2.4 Special Requirements Pressure loss in receiver circuit (.2 to .5) (Mass Flow Rate)^2 ~ psi

2.3 Quantity of Water in Receiver N/A

3.0 Solar Flux

3.1 Density

3.1.1 Operating 1.5 MW/m^2 (average over aperture)

3.1.2 Maximum Permissible TBD

3.2 Heliostat Field

3.2.1 Field Design Configuration

3.2.1.1 30° ______

3.2.1.2 90° ______

3.2.1.3 360° Yes

3.2.1.4 Other Vertical angle of field approximately 60°.

3.2.2 Angular Distribution Requirements of Incident Radiation on Target or Apperture Surfaces

3.2.2.1 Horizontal Approximately uniform

3.2.2.2 Vertical Heliostats aimed at center of aperture

4.0 Auxiliary Equipment Requirements during Transient Solar Flux

TBD

5.0 Instrumentation

5.1 Data Acquisition System Preferred for Your Evaluation of Test Results.

5.1.1 Magnetic Tape Yes

5.1.2 Multiplexer Yes

5.1.3 Analog Display Yes

5.1.4 Digital Printout Yes

5.1.5 Other TBD

5.2 Parametric Data Signals (Maximum Values and Number of Channels - volts, millivolts, milliamperes, etc.) for Data Acquisition System

5.2.1 Temperature 2000°F and 250 channels R

5.2.2 Pressure 700 psi and 50 channels

5.2.3 Flow Rates 10 lb/sec and 50 channels

5.2.4 Heat Flux 0.5 MW/m^2 and 40 channels

5.2.5 Strain ____ and 100 channels

5.2.6 Other TBD

5.3 Recorders (Hard Copy)

5.3.1 Channels TBD

5.3.2 Signals (Maximum Values and Types)

TBD

5.4 Optical Monitoring (Remote)

5.4.1 Closed Circuit Television Yes

5.4.2 Line Photography ______

5.4.3 Pyrometry Yes

5.5 Chemical Analysis

5.5.1 pH Meter ______

5.5.2 Dissolved Oxygen ______

5.5.3 Residual Hydrazine ______

5.5.4 Conductivity ______

5.5.5 Others Gas Analysis

6.0 Controls

6.1 Type

6.1.1 Pneumatic, 3 to 15 psig ______

6.1.2 Electronic, 4 to 20 ma ______

6.1.3 Other (50) 1 Amp 120 V AC 1 Ø valves

6.2 Others ______

7.0 Support Facilities

7.1 Dedicated Space for Contractor (Floor Area and Ceiling Height)

7.1.1 Enclosed Test Preparation Area 4000 ft^2, 40 ft ceiling R

7.1.2 Office Areas 1000 ft^2

7.1.3 Equipment Storage Area 1000 ft^2

7.1.4 Materials and Supplies Storage Area TBD

7.2 Technicians to Assist Vendor

7.2.1 Receiver Installation 2-4 R

7.2.2 Instrumentation and Controls Checkout 4 R

7.2.3 Special Requirements ______

7.3 Tower Facilities at Top

7.3.1 Space for Auxiliary Equipment

7.3.1.1 Room Size ______

7.3.1.2 Utilities

7.3.1.2.1 Power Yes

7.3.1.2.2 Water Yes

7.3.1.2.3 Compressed Air Yes

7.3.1.2.4 Other Gases Helium, nitrogen

7.3.1.2.5 Vacuum Yes

7.3.2 Field Crane Capacity ______

7.3.3 Personnel and Materials Elevator

7.3.3.1 Size ______

7.3.3.2 Capacity ______

7.3.4 Monorail Hoist Capacity ______

7.4 Mobile Crane Capacity ______

8.0 Number of Your Field Crew Expected to be Present During Testing 3 to 10

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5 MW SOLAR THERMAL TEST FACILITY

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT HELIOSTATS

Contractor Boeing Engineering & Construction

Check List (Please check appropriate spaces and list related parameters)

1.0 Configuration

1.1 Foundation Geometry

1.1.1 Mounting Technique

1.1.1.1 Pedestal 4.5 in. Dia. by 7.2 Ft. High

1.1.1.2 Concrete Float Not applicable

1.1.1.3 Rotating Pad 17 Ft. Dia.

1.1.2 Foundation Contact Area

1.1.2.1 Distributed Area 170 Sq. Ft.

1.1.2.2 Concentrated Areas 12.6 Ft^2 at Center of Pad

1.2 Heliostat-Mount Loads

1.2.1 Maximum Static Enclosure Wt. is about 50 lb excluding Ring Foundation Reflector/Pedestal is about 300 lb Excluding Foundation

1.2.2 Maximum Dynamic Enclosure Windloads: Lift = 3000 lbs. drag = 600 lb.

1.3 Field Deployment

1.3.1 Site Topography Overall heliostat field is flat. Base excavations required for individual heliostats, 4.0 ft. deep.

1.3.1.1 Flat

1.3.1.2 Terraced Profile No

1.3.2 Number of Heliostats in Test Array 3

1.3.3 Recommended Spacing 5 ft. minimum spacing between domes

2.0 Controls

2.1 Power Requirements for Heliostat Tracking and Guidance Drives
2-10 Watt D. C. Stepper Motors per heliostat, 6 steps per minute. Electronics - to be determined

2.2 Master Control Signal Requirements for Compatability with Heliostat Controls Boeing will provide master control simulator to operate heliostats

3.0 Instrumentation

3.1 Data Acquisition System for Data from Sensors at Heliostats

3.1.1 Magnetic Tape X No. of Channels 100

3.1.2 Multiplexer ______ No. of Channels ______

3.1.3 Analog Display ______ No. of Channels ______

3.1.4 Digital Printout ______ No. of Channels ______

3.1.5 Other 5 strip chart records

3.2 Redirected Flux

3.1.1 Maximum Solar Image Size as Function of Distance
263 in. at 500 ft. and 348 in. at 1000 ft.

3.1.2 Maximum Flux Intensity from One Heliostat as Function of Distance

547 watts / sq. m. at 312 m and 580 watts/sq.m at 212 m

3.3 Other ______________________________

4.0 Support Facilities

4.1 Dedicated Space for Contractor

4.1.1 Enclosed Test Preparation Area 1000 sq. ft.

4.1.2 Office Area 400 sq. ft.

4.1.3 Equipment Storage Area 800 sq. ft.

4.1.4 Materials and Supplies Storage Area 400 sq. ft.

4.2 Technicians to Assist Contractor

4.2.1 Heliostat Installation 3

4.2.2 Instrumentation and Controls Checkout 2

4.2.3 Special Requirements May need to install concrete pad, electrical conduits, and signal wires.

4.3 Mobile Crane Capacity 2 ton - 300 lbs. at 40 ft. maximum height

5.0 Number of Your Field Crew Expected to be Present During Testing 5

5 MW SOLAR THERMAL TEST FACILITY

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT HELIOSTATS

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Contractor Honeywell, Inc.

Check List (Please check appropriate spaces and list related parameters)

1.0 Configuration

1.1 Foundation Geometry

1.1.1 Mounting Technique

1.1.1.1 Pedestals (2) 4' x 4' foundations with 3' to 6' steel piers

1.1.1.2 Concrete Float (2) 1' x 1' pads

1.1.1.3 Rotating Pad ________

1.1.2 Foundation Contact Area

1.1.2.1 Distributed Area 34 ft^2

1.1.2.2 Concentrated Areas ________

1.2 Heliostat-Mount Loads

1.2.1 Maximum Static 8500 lbs. at concrete/earth interface (250 lb/ft^2)

1.2.2 Maximum Dynamic 300 lb. vertical component and 400 lb. horizontal component at 30 mph wind gust

1.3 Field Deployment

1.3.1 Site Topography

1.3.1.1 Flat less than 12"/15'

1.3.1.2 Terraced Profile ________

____

1.3.2 Number of Heliostats in Test Array 3

1.3.3 Recommended Spacing 45% ground cover (rectilinear)

East/West -- 28.4' North/South -- 15.4'

____

2.0 Controls

2.1 Power Requirements for Heliostat Tracking and Guidance 120 v rms, 60HZ, 1Ø, 12.5W Average, 30W Peak (Discharged battery) (per heliostat)

2.2 Master Control Signal Requirements for Compatability with Heliostat Controls Simplex serial digital data bus using two 8 bit bytes at a rate of 4800 band.

3.0 Instrumentation

3.1 Data Acquisition System for Data from Sensors at Heliostats

3.1.1 Magnetic Tape yes No. of Channels TBD

3.1.2 Multiplexer TBD No. of Channels TBD

3.1.3 Analog Display yes No. of Channels TBD

3.1.4 Digital Printout yes No. of Channels TBD

3.1.5 Other TBD

3.2 Redirected Flux

3.1.1 Maximum Solar Image Size as Function of Distance

10' x 10' at 1000'

3.1.2 Maximum Flux Intensity from One Heliostat as Function of Distance

TBD

3.3 Other TBD

4.0 Support Facilities

4.1 Dedicated Space for Contractor

4.1.1 Enclosed Test Preparation Area 1500 ft^2

4.1.2 Office Area 400 ft^2

4.1.3 Equipment Storage Area 600 ft^2

4.1.4 Materials and Supplies Storage Area 1200 ft^2

4.2 Technicians to Assist Contractor

4.2.1 Heliostat Installation 3

4.2.2 Instrumentation and Controls Checkout 3

4.2.3 Special Requirements TBD

4.3 Mobile Crane Capacity 2500 lbs.

5.0 Number of Your Field Crew Expected to be Present During Testing 5

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5 MW SOLAR THERMAL TEST FACILITY
FACILITY REQUIREMENTS FOR TESTING OF RESEARCH EXPERIMENT HELIOSTATS

Contractor Martin Marietta Corporation

Check List (Please check appropriate spaces and list related parameters)

1.0 Configuration

1.1 Foundation Geometry

1.1.1 Mounting Technique

1.1.1.1 Pedestal 2' Dia. Caisson with 6 - 12" Shaft, 3' Long.

1.1.1.2 Concrete Float --

1.1.1.3 Rotating Pad --

1.1.2 Foundation Contact Area

1.1.2.1 Distributed Area 2 ft Dia. - Depth TBD.

1.1.2.2 Concentrated Areas --

1.2 Heliostat-Mount Loads

1.2.1 Maximum Static Axial Load 6000 lbs
Shear Load 6500 lbs
Bending Moment 84,500 ft-lbs Maximum.

1.2.2 Maximum Dynamic Not Available Now.

1.3 Field Deployment

1.3.1 Site Topography

1.3.1.1 Flat X

1.3.1.2 Terraced Profile (Simulated)

1.3.2 Number of Heliostats in Test Array 11

1.3.3 Recommended Spacing Sample positions within 1440 x 1440 ft square field.

2.0 Controls

2.1 Power Requirements for Heliostat Tracking and Guidance Voltage 117 V, Single Phase, 2 Wire, Range 112 to 126V; Current - 22 Amperes Max.

2.2 Master Control Signal Requirements for Compatability with Heliostat Controls Compatible with PDP-11 Computer for Executive Control.

3.0 Instrumentation

3.1 Data Acquisition System for Data from Sensors at Heliostats

3.1.1 Magnetic Tape X No. of Channels ______

3.1.2 Multiplexer ______ No. of Channels ______

3.1.3 Analog Display X No. of Channels ______

3.1.4 Digital Printout X No. of Channels ______

3.1.5 Other ______

3.2 Redirected Flux

3.1.1 Maximum Solar Image Size as Function of Distance

Diameter = (.0122) (Distance) + 4 feet

3.1.2 Maximum Flux Intensity from One Heliostat as Function of Distance

$$70 \times \left\{ 0.153 \; [3m(10 \; ft) + 0.113 \times \text{slant range}] \right\}^{-2} / \pi$$

3.3 Other ______

______

4.0 Support Facilities

4.1 Dedicated Space for Contractor

4.1.1 Enclosed Test Preparation Area 40' x 60' with 22' overhead clearance. 16' high by 22' wide door. Two 2-ton overhead cranes

4.1.2 Office Area 1500 ft^2

4.1.3 Equipment Storage Area 900 ft^2

4.1.4 Materials and Supplies Storage Area 400 ft^2

4.1.5 Loading Dock, Loading Equipment

4.2 Technicians to Assist Contractor

4.2.1 Heliostat Installation 1 crane operator, 1 driver 1 to 2 (mechanical, electrical technicians)

4.2.2 Instrumentation and Controls Checkout 1

4.2.3 Special Requirements General Electronics, circuitry background

4.3 Mobile Crane Capacity 5 Ton

5.0 Number of Your Field Crew Expected to be Present During Testing 5

5 MW SOLAR THERMAL TEST FACILITY

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT HELIOSTATS

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Contractor McDonnell Douglas Astronautics Company

Check List (Please check appropriate spaces and list related parameters)

1.0 Configuration

1.1 Foundation Geometry

1.1.1 Mounting Technique

1.1.1.1 Pedestal 2.1m (84") dia. concrete pad

1.1.1.2 Concrete Float ______

1.1.1.3 Rotating Pad ______

1.1.2 Foundation Contact Area

1.1.2.1 Distributed Area X

1.1.2.2 Concentrated Areas ______

1.2 Heliostat-Mount Loads

1.2.1 Maximum Static ± 14.8 KN (3320 lbs)

1.2.2 Maximum Dynamic ± 25 KN (5610 lbs)

1.3 Field Deployment

1.3.1 Site Topography

1.3.1.1 Flat X

1.3.1.2 Terraced Profile ______

1.3.2 Number of Heliostats in Test Array 5

1.3.3 Recommended Spacing 9m (29.5 ft) normal to line of sight to tower, 10m (33 ft) parallel

2.0 Controls

2.1 Power Requirements for Heliostat Tracking and Guidançe ______

1 KW AC 220V

2.2 Master Control Signal Requirements for Compatability with Heliostat Controls Digital data bus - Manchester Format - 2 KHz

3.0 Instrumentation

3.1 Data Acquisition System for Data from Sensors at Heliostats

3.1.1 Magnetic Tape ✓ No. of Channels 2 Channels

3.1.2 Multiplexer ✓ No. of Channels 80 1 sps / 40 20 sps

3.1.3 Analog Display ✓ No. of Channels 20 Channels

3.1.4 Digital Printout ✓ No. of Channels ______

3.1.5 Other Strip charts - 20 channels

3.2 Redirected Flux

3.1.1 Maximum Solar Image Size as Function of Distance

3m (10 ft) + 0.0113 x slant range

3.1.2 Maximum Flux Intensity from One Heliostat as Function of Distance

$$(q/A)\ \text{Max.} = \frac{1.06 \times 10^7}{(\text{DISTANCE})^2}$$

Btu hr/ft^2 feet

3.3 Other ______________________

____

4.0 Support Facilities

4.1 Dedicated Space for Contractor

4.1.1 Enclosed Test Preparation Area Small Shop/Assembly Area

4.1.2 Office Area 3 Offices

4.1.3 Equipment Storage Area 500' x 500'

4.1.4 Materials and Supplies Storage Area 20' x 30'

4.2 Technicians to Assist Contractor

4.2.1 Heliostat Installation

4.2.2 Instrumentation and Controls Checkout 3

4.2.3 Special Requirements ______________________

____

4.3 Mobile Crane Capacity 5 Tons

5.0 Number of Your Field Crew Expected to be Present During Testing ______________________

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5 MW SOLAR THERMAL TEST

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT THERMAL STORAGE

Contractor Boeing (Chemical Energy Storage)

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Storage Tank

	SO_3	SO_2	O_2
1.1.1.1 Dimensions	ft	ft	ft
1.1.1.2 Horizontal	3x10	3x12	2x30
1.1.1.3 Vertical	3	3	2
1.1.2 Array of Storage Tanks			
1.1.2.1 Number of Tanks	4	4	6 = 1 stack of 6
1.1.2.2 Spacing (ft)	10	10	6 ft between stacks
1.1.2.3 Total Land Area(ft^2)	400	500	300

1.2 Weight

1.2.1 Total 40,000 lbs

1.2.2 Load Pattern

1.2.2.1 Distributed Loading Yes

1.2.2.2 Concentrated Loading and Location ______

1.3 Special Installation Requirements Interface with helium cycle fluid and cooling water

Turbine
2.0 Cycle

2.1 Charging Fluid

2.1.1 Helium

2.1.2 ______

2.1.3 ______

2.2 Discharging Fluid

2.2.1 Helium

2.2.2 ______

2.2.3 ______

2.3 Operating Conditions

2.3.1 Inlet Charging Fluid Conditions

2.3.1.1 Pressure 500 psi, 480 psi*

2.3.1.2 Temperature 1500°F, 1000°F*

2.3.2 Outlet Discharging Fluid Conditions

2.3.2.1 Pressure 500 psi, 520 psi**

2.3.2.2 Temperature 1500°F, 1000°F **

2.3.3 Fluid Flow Rate

2.3.3.1 Charging Cycle 8 lb/s

2.3.3.2 Discharging Cycle 8 lb/s

2.3.4 Special Requirements ______

______

______

* Outlet charging
** Inlet discharging

3.0 Instrumentation

3.1 Data Acquisition System Preferred for Your Evaluation of Test Results

3.1.1 Magnetic Tape Yes

3.1.2 Multiplexer Yes

3.1.3 Analog Display Same as 3.2.1

3.1.4 Digital Printout Yes

3.1.5 Other ______

3.2 Recorder (Hard Copy)

3.2.1 Channels 30 = 15 Stripchart Recorders

3.2.2 Signals (Maximum Values and Types) Analog 10 V
Digital 0.5 V

3.3 Parametric Data Sensors and Maximum Signal Values

3.3.1 Temperature 50 Thermocouples

3.3.2 Pressure 8 Pressure transducers

3.3.3 Flow Rates 10 flow rates

3.3.4 Other 8 Liquid Level gauges

3.4 Chemical Analysis

3.4.1 pH Meter None

3.4.2 Dissolved Oxygen None

3.4.3 Residual Hydrazine None

3.4.4 Other: a) Sensor for SO_2 or SO_3 leakage into helium stream

3.4.4 Others (continued)

b) Gas Chromatograph with digital integrator

(BEC to provide)

4.0 Controls

4.1 Type

4.1.1 Pneumatic, 3 to 15 psig None

4.1.2 Electronic, 4 to 20 ma None

4.1.3 Other (20) 1 AMP 120 V AC 1 0/ valves

4.2 Other

5.0 Support Facilities

5.1 Dedicated Space for Contractor (Areas)

5.1.1 Enclosed Test Preparation 2000 ft^2

5.1.2 Office 300 ft^2

5.1.3 Equipment, Materials, and Supplies Storage

5.1.3.1 Outside and Unprotected 1000 ft^2

5.1.3.2 Indoors 1000 ft^2

5.2 Technicians to Assist Vendor

5.2.1 Thermal Storage Installation 3

5.2.2 Instrumentation and Controls Checkout 1

5.2.3 Special Requirements

5.3 Mobile Crane Capacity 50 tons

5.4 Utilities

5.4.1 Power As required for 3.0, 110 V AC

5.4.2 Water Yes

5.4.3 Compressed Air Yes

5.4.4 Other Gases None

5.4.5 Vacuum Yes, startup only

6.0 Safety

6.1 Handling of Thermal Storage Material Sulfur trioxide in hermitically sealed system

6.2 Venting of Equipment None

6.3 Emergency Procedures Lime slurry applied through fire truck

6.4 Special Requirements Acid-proof clothing during fluid transfer (loading) operations. Respirators available on standby. Emergency showers and eye wash fountains every 50 feet.

5 MW SOLAR THERMAL TEST

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT THERMAL STORAGE

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Contractor Boeing (Fusible Salt)

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Storage Tank

1.1.1.1 Dimensions 6' x 12'

1.1.1.2 Horizontal 12'

1.1.1.3 Vertical 6'

1.1.2 Array of Storage Tanks

1.1.2.1 Number of Tanks 1

1.1.2.2 Spacing DNA

1.1.2.3 Total Land Area 200 ft^2

1.2 Weight

1.2.1 Total 75,000 lbs.

1.2.2 Load Pattern

1.2.2.1 Distributed Loading No

1.2.2.2 Concentrated Loading and Location Yes
Heater heads

1.3 Special Installation Requirements Quality interface with cycle fluid flow.

2.0 Cycle

2.1 Charging Fluid

2.1.1 Water-Steam: NA

2.1.2 Other: Helium

2.1.3 Quality: NA

2.2 Discharging Fluid

2.2.1 Water-Steam: NA

2.2.2 Other: Helium

2.2.3 Quality: NA

2.3 Operating Conditions

2.3.1 Inlet Charging Fluid Conditions

2.3.1.1 Pressure: 500 psi, 480 psi*

2.3.1.2 Temperature: 1500°F, 1200°F*

2.3.2 Outlet Discharging Fluid Conditions

2.3.2.1 Pressure: 500 psi, 520 psi**

2.3.2.2 Temperature: 1200°F, 800°F**

2.3.3 Fluid Flow Rate

2.3.3.1 Charging Cycle: 8 lb/sec

2.3.3.2 Discharging Cycle: 8 lb/sec

2.3.4 Special Requirements: ______

*Outlet charging
**Inlet discharging

3.0 Instrumentation

3.1 Data Acquisition System Preferred for Your Evaluation of Test Results

3.1.1 Magnetic Tape Yes

3.1.2 Multiplexer Yes

3.1.3 Analog Display Yes

3.1.4 Digital Printout Yes

3.1.5 Other Scope

3.2 Recorder (Hard Copy)

3.2.1 Channels 31

3.2.2 Signals (Maximum Values and Types) See 3.3

3.3 Parametric Data Sensors and Maximum Signal Values

3.3.1 Temperature (30) 1650°F

3.3.2 Pressure (10) 550 psi

3.3.3 Flow Rates (10) 10 lb/sec

3.3.4 Other Strain gages (30) 10,000 psi

3.4 Chemical Analysis

3.4.1 pH Meter None

3.4.2 Dissolved Oxygen None

3.4.3 Residual Hydrazine None

3.4.4 Other: Residual chemical contaminants in helium from molten salt chemical leaks

3.4.4 Others ______________________

____

____

4.0 Controls

4.1 Type

4.1.1 Pneumatic, 3 to 15 psig TBD

4.1.2 Electronic, 4 to 20 ma TBD

4.1.3 Other ______________________

4.2 Other ______________________

____

5.0 Support Facilities

5.1 Dedicated Space for Contractor (Areas)

5.1.1 Enclosed Test Preparation 2000 sq.ft.

5.1.2 Office 300 sq. ft.

5.1.3 Equipment, Materials, and Supplies Storage

5.1.3.1 Outside and Unprotected 1000 sq.ft.

5.1.3.2 Indoors 1000 sq.ft.

5.2 Technicians to Assist Vendor

5.2.1 Thermal Storage Installation ___3___

5.2.2 Instrumentation and Controls Checkout ___1___

5.2.3 Special Requirements ______

5.3 Mobile Crane Capacity ___50 tons___

5.4 Utilities

5.4.1 Power ___As required per 3.0___

5.4.2 Water ___Yes___

5.4.3 Compressed Air ___Yes___

5.4.4 Other Gases ___NO___

5.4.5 Vacuum ___No___

6.0 Safety

6.1 Handling of Thermal Storage Material ___All pre-encapsulated thermal salt___

6.2 Venting of Equipment ___None___

6.3 Emergency Procedures ___Normal liquid metal burn treatment required in case of catastrophic failure___

6.4 Special Requirements ______

TO: John Myers, MMC-Denver, ext. 2332, Sept. 18, 1975, page 1 of 6.
FROM: Steve Bomar, Georgia Tech

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3 DEC 1975
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5 MW SOLAR THERMAL TEST

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT THERMAL STORAGE

Contractor Martin Marietta Corporation

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Storage Tank

1.1.1.1 Dimensions
2 Tanks (6' dia. x 12')
4 Tanks (10' dia. x 31' 3")
1 Tank (8' dia. x 16' 9")

1.1.1.2 Horizontal ______

1.1.1.3 Vertical ______

1.1.2 Array of Storage Tanks

1.1.2.1 Number of Tanks 7 Tanks

1.1.2.2 Spacing See Attached Sheet

1.1.2.3 Total Land Area 120' x 220' (see note below)

1.2 Weight

1.2.1 Total 500,000 lbs.

1.2.2 Load Pattern

1.2.2.1 Distributed Loading Load associated with tanks (see enclosed schematic)

1.2.2.2 Concentrated Loading and Location ______

1.3 Special Installation Requirements ______

This land area exceeds minimum NFPA land requirements.

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2.0 Cycle

2.1 Charging Fluid

2.1.1 Water-Steam 952^{0} F, 1250 psig steam in; water out at 460^{0} F, 1200 psig

2.1.2 Other ______

2.1.3 Quality ______

2.2 Discharging Fluid

2.2.1 Water-Steam Water in at 400^{0} F (650 psig) Steam out at 750^{0} F (600 psig)

2.2.2 Other ______

2.2.3 Quality ______

2.3 Operating Conditions

2.3.1 Inlet Charging Fluid Conditions

2.3.1.1 Pressure 1250 psig

2.3.1.2 Temperature 950^{0} F

2.3.2 Outlet Discharging Fluid Conditions

2.3.2.1 Pressure 600 psig

2.3.2.2 Temperature 750^{0} F

2.3.3 Fluid Flow Rate

2.3.3.1 Charging Cycle 16,000 lb/hr, 12,800 lbs Total

2.3.3.2 Discharging Cycle 16,000 lb/hr, 12,800 lbs Total

2.3.4 Special Requirements ______

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J. [illegible]
C1

3.0 Instrumentation

3.1 Data Acquisition System Preferred for Your Evaluation of Test Results

3.1.1 Magnetic Tape X

3.1.2 Multiplexer ______

3.1.3 Analog Display X

3.1.4 Digital Printout X

3.1.5 Other ______

3.2 Recorder (Hard Copy)

3.2.1 Channels 20

3.2.2 Signals (Maximum Values and Types) 20 MV Max

Requirement not defined.

3.3 Parametric Data Sensors and Maximum Signal Values (No. of Channels).

3.3.1 Temperature 0 to 1000^{0} F and ______

3.3.2 Pressure 0 to 1500 psi and ______

3.3.3 Flow Rates 0 to 17,000 lb/hr and ______

3.3.4 Other Liquid level sensor

3.4 Chemical Analysis

3.4.1 pH Meter X

3.4.2 Dissolved Oxygen X

3.4.3 Residual Hydrazine X

3.4.4 Others ______________________

____

____

4.0 Controls

4.1 Type

4.1.1 Pneumatic, 3 to 15 psig X

4.1.2 Electronic, 4 to 20 ma X

4.1.3 Other ______________________

4.2 Other ______________________

____

5.0 Support Facilities

5.1 Dedicated Space for Contractor (Areas)

5.1.1 Enclosed Test Preparation small shop, assembly area

5.1.2 Office 3 standard offices

5.1.3 Equipment, Materials, and Supplies Storage

5.1.3.1 Outside and Unprotected 200' x 250'

5.1.3.2 Indoors 500 square ft.

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7/18/75
J. Conrad Mackey
C.

5.2 Technicians to Assist Vendor

5.2.1 Thermal Storage Installation 4

5.2.2 Instrumentation and Controls Checkout 3

5.2.3 Special Requirements (shop technician -2)

5.3 Mobile Crane Capacity 70,000 lbs.

5.4 Utilities

5.4.1 Power Yes

5.4.2 Water Yes

5.4.3 Compressed Air Yes

5.4.4 Other Gases N_2

5.4.5 Vacuum No

6.0 Safety

6.1 Handling of Thermal Storage Fluids Diking or drainage ditches - fire control equipment for hydrocarbon oil.

6.2 Venting of Equipment Venting of steam required - maximum flow rate = 16,000 lbs/hr.

6.3 Emergency Procedures Standard Industrial Practices.

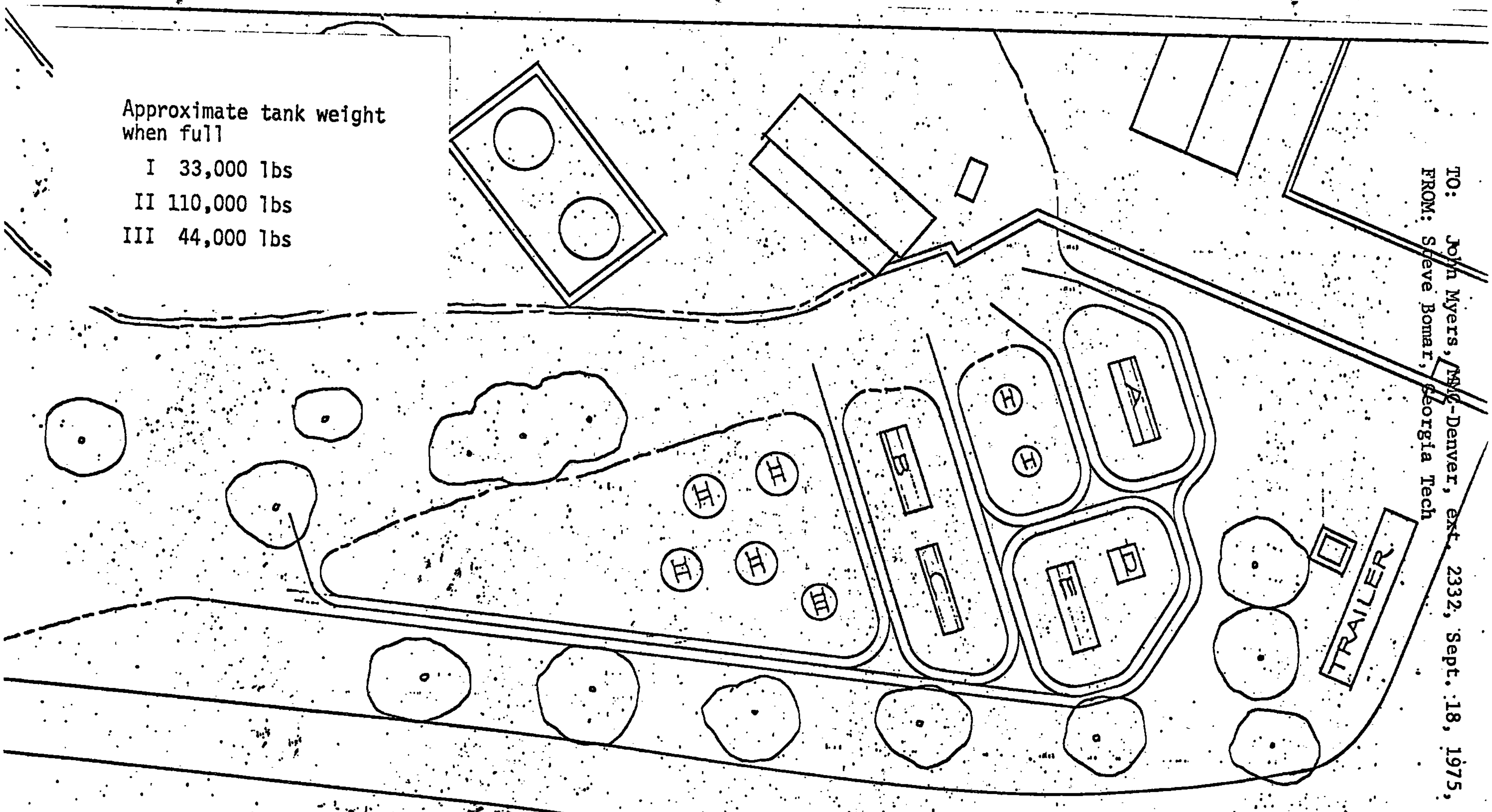
6.4 Special Requirements Not yet defined

7.0 Number of Your Field Crew Expected to be Present During Testing 8

TO: John Myers, MMC-Denver, ext. 2332, Sept. 18, 1975, page 2 of 6.
FROM: Steve Bomar, Georgia Tech

Approximate tank weight when full

I	33,000 lbs
II	110,000 lbs
III	44,000 lbs



NOTES

(1) Tree outlines shown represent existing pecan trees which must be preserved.

(2) A = Energy Transfer Module A, inclusive of Heat Exchangers for Stage I (HITEC)
B = Energy Transfer Module B, inclusive of Heat Exchanger for Stage II (HYDROCARBON OIL)
C = Energy Transfer Module C, inclusive of Heat Exchanger for Stage III (HYDROCARBON OIL)
D = Dummy Load or Discharge Silencer (TBD).
E = Cooler for Feed and Discharge Water.

(3) Energy Storage Unit sizes including 12-inches of insulation.
I = 6' Diameter x 12' High
II = 10' Diameter x 31'-3" High
III = 12' Diameter x 29' Long
IV = 8' Diameter x 16'-9" High

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4 DEC 1975
BLACK & VEATCH

5 MW SOLAR THERMAL TEST

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT THERMAL STORAGE

Contractor Honeywell Inc.

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Storage Tank

1.1.1.1 Dimensions 12' x 6' x 8' (lxbxh)

without insulation 14' x 8' x 10' overall

1.1.1.2 Horizontal ______

1.1.1.3 Vertical ______

1.1.2 Array of Storage Tanks

1.1.2.1 Number of Tanks one

1.1.2.2 Spacing ______

1.1.2.3 Total Land Area 250 sq. ft. (18'x 14')

1.2 Weight

1.2.1 Total 70,000 lb gross

1.2.2 Load Pattern

1.2.2.1 Distributed Loading 7-10 psi

maximum ______

1.2.2.2 Concentrated Loading and Location ______

______

1.3 Special Installation Requirements Requires retaining wall around tank to hold 400 ft^3 of molten salt.

2.0 Cycle

2.1 Charging Fluid

2.1.1 Water-Steam Sat'd steam @ 1450 psi

2.1.2 Other ______

2.1.3 Quality Saturated

2.2 Discharging Fluid

2.2.1 Water-Steam Water @ 335°F

2.2.2 Other Pressurised to 800 psi

2.2.3 Quality Saturated

2.3 Operating Conditions

2.3.1 Inlet Charging Fluid Conditions

2.3.1.1 Pressure 1450 psi

2.3.1.2 Temperature 592°F

2.3.2 Outlet Discharging Fluid Conditions

2.3.2.1 Pressure 700 psi

2.3.2.2 Temperature 503°F

2.3.3 Fluid Flow Rate

2.3.3.1 Charging Cycle 1400 lb/hr steam

2.3.3.2 Discharging Cycle 5200 lb/hr water

2.3.4 Special Requirements Forced-circulation for discharging cycle with steam drum and recirculation pump.

2.4 Phase Change Material

Ternary eutectic salt	NaCl	6% wt.
	$NaNO_3$	85% wt.
	Na_2SO_4	9% wt.

Temperature 549°F

3.0 Instrumentation

3.1 Data Acquisition System Preferred for Your Evaluation of Test Results

3.1.1 Magnetic Tape -- Yes

3.1.2 Multiplexer --

3.1.3 Analog Display -- Yes

3.1.4 Digital Printout -- Yes

3.1.5 Other --

3.2 Recorder (Hard Copy)

3.2.1 Channels 10

3.2.2 Signals (Maximum Values and Types) ± 10V

3.3 Parametric Data Sensors and Maximum Signal Values (No. of Channels).

3.3.1 Temperature 1-10 mv and 25

3.3.2 Pressure 1-10 mv and 6

3.3.3 Flow Rates 1-100 mv and 4

3.3.4 Other Heat flow - 0.1-1.0 mv

3.4 Chemical Analysis

3.4.1 pH Meter

3.4.2 Dissolved Oxygen

3.4.3 Residual Hydrazine

3.4.4 Others Salt concentrations ullage vapors

4.0 Controls

4.1 Type

4.1.1 Pneumatic, 3 to 15 psig 5

4.1.2 Electronic, 4 to 20 ma 10

4.1.3 Other

4.2 Other

5.0 Support Facilities

5.1 Dedicated Space for Contractor (Areas)

5.1.1 Enclosed Test Preparation 250 ft^2 min + retaining wall

5.1.2 Office 1- 8 x 10

5.1.3 Equipment, Materials, and Supplies Storage

5.1.3.1 Outside and Unprotected

5.1.3.2 Indoors Yes

5.2 Technicians to Assist Vendor

5.2.1 Thermal Storage Installation ______________

5.2.2 Instrumentation and Controls Checkout ______________

5.2.3 Special Requirements Brick masons to prepare firebrick courses for tank foundation.

5.3 Mobile Crane Capacity 40 ton

5.4 Utilities

5.4.1 Power 220 VAC 10KVA

5.4.2 Water feedwater

5.4.3 Compressed Air 40 psi

5.4.4 Other Gases N_2 & steam at 1450 psig

5.4.5 Vacuum none

6.0 Safety

6.1 Handling of Thermal Storage Fluids Molten salt handling procedures required.

6.2 Venting of Equipment Salt tank vented with periodic N_2 purge required.

6.3 Emergency Procedures Catastrophic tank rupture, steam line rupture, salt into water system - procedures required.

6.4 Special Requirements Working with molten salts

7.0 Number of Your Field Crew Expected to be Present During Testing 4

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5 MW SOLAR THERMAL TEST

FACILITY REQUIREMENTS FOR TESTING OF

RESEARCH EXPERIMENT THERMAL STORAGE

Contractor McDonnell Douglas Astronautics Company

Check List (Please check appropriate spaces and list related parameters).

1.0 Configuration

1.1 Geometry

1.1.1 Storage Tank

1.1.1.1 Dimensions 3.2m (10.5 ft) diameter x 13.3m (43.7 ft) high

1.1.1.2 Horizontal (Test Site) 8m x 8m (25' x 25')

1.1.1.3 Vertical (Test Site) 20m (66 ft)

1.1.2 Array of Storage Tanks

1.1.2.1 Number of Tanks 1

1.1.2.2 Spacing N/A

1.1.2.3 Total Land Area $58m^2$ ($625 ft^2$)

1.2 Weight

1.2.1 Total Tank = 5450 Kg (12,000 lbs); oil = 20,900 Kg (46,000 lbs); Rock = 209,000 Kg (458,000 lbs)

1.2.2 Load Pattern

1.2.2.1 Distributed Loading Uniform On 4m (13 ft) diameter concrete pad

1.2.2.2 Concentrated Loading and Location N/A

1.3 Special Installation Requirements None

2.0 Cycle

2.1 Charging Fluid (Other than Thermal Storage Fluid)

2.1.1 Water-Steam ✓

2.1.2 Other ______

2.1.3 Quality Saturated

2.2 Discharging Fluid

2.2.1 Water-Steam ✓

2.2.2 Other ______

2.2.3 Quality Superheated

2.3 Operating Conditions

2.3.1 Inlet Charging Fluid Conditions

2.3.1.1 Pressure (See 2.3.3.1)

2.3.1.2 Temperature 343°C (650°F) Max

2.3.2 Outlet Discharging Fluid Conditions

2.3.2.1 Pressure (See 2.3.3.2)

2.3.2.2 Temperature 288°C (550°F) Max

2.3.3 Fluid Flow Rate

2.3.3.1 Charging Cycle (0.1 to 1.0 MW_{th})

2.3.3.2 Discharging Cycle (0.1 to 1.0 MW_{th})

2.3.4 Special Requirements Inlet and outlet heat exchangers required between steam and TSS Fluid (HT-43). High temp pumps for TSS (HT-43) to achieve charging and discharging rates of 2.3.3.1 and 2.3.3.2. [Approx 10 Kg/sec (22 lbs/sec) at 0.3 MN/m^2 (44 psi)]

3.0 Instrumentation

3.1 Data Acquisition System Preferred for Your Evaluation of Test Results

3.1.1 Magnetic Tape ✓

3.1.2 Multiplexer ________

3.1.3 Analog Display ✓

3.1.4 Digital Printout ✓

3.1.5 Other ________

3.2 Recorder (Hard Copy)

3.2.1 Channels 20

3.2.2 Signals (Maximum Values and Types) 0-5 VDC

3.3 Parametric Data Sensors and Maximum Signal Values (No. of Channels).

3.3.1 Temperature 370°C (700°F) and 116 Channels

3.3.2 Pressure 3.45 MN/m^2 (500 psia) and 10 Channels

3.3.3 Flow Rates 10 Kg/sec (22 lbs/sec) and 6 Channels

3.3.4 Other 35 strain gages; 10 micro inches/inch

3.4 Chemical Analysis (As required by test site steam generators)

3.4.1 pH Meter (Noted)

3.4.2 Dissolved Oxygen (Noted)

3.4.3 Residual Hydrazine (Noted)

3.4.4 Others Analysis of heat transfer fluid samples; particulates; vacuum distillation; Ph; chemical composition

4.0 Controls

4.1 Type

4.1.1 Pneumatic, 3 to 15 psig None

4.1.2 Electronic, 4 to 20 ma TBD

4.1.3 Other Solenoid valve control

4.2 Other Pump and valve controllers; detail requirements TBD.

5.0 Support Facilities

5.1 Dedicated Space for Contractor (Areas)

5.1.1 Enclosed Test Preparation 100 x 100 x 25 feet

5.1.2 Office 1000 ft^2

5.1.3 Equipment, Materials, and Supplies Storage

5.1.3.1 Outside and Unprotected 500 ft^2

5.1.3.2 Indoors 500 ft^2

5.2 Technicians to Assist Vendor

5.2.1 Thermal Storage Installation Crane operator

5.2.2 Instrumentation and Controls Checkout None

5.2.3 Special Requirements Chemical analyses tech

5.3 Mobile Crane Capacity 10 tons

5.4 Utilities

5.4.1 Power 110 VAC lighting & support; 0-28 VDC instrument & control; 30 KW--440 VAC

5.4.2 Water For steam generators and fire support

5.4.3 Compressed Air Controls requirements TBD

5.4.4 Other Gases GN_2, 180 SCFH

5.4.5 Vacuum N/A

6.0 Safety

6.1 Handling of Thermal Storage Fluids Petroleum based heat transfer fluid

6.2 Venting of Equipment To flame arrestor vent

6.3 Emergency Procedures Standard for petroleum based fluids.

6.4 Special Requirements Dike around tank to hold 150% of thermal storage fluid; fire protection.

7.0 Number of Your Field Crew Expected to be Present During Testing 5