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MOLTEN SALT ELECTRIC EXPERIMENT

PHASE II TEST PLAN

APRIL 30, 1984

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MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

MCDONNELL DOUGLAS CORPORATION

Molten Salt Electric Experiment

Phase II Test Plan

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FORWARD

This Phase II Test Plan is one of three documents that describe plans for Phase II of the MSEE project. These documents are:

MSEE Evaluation Plan
Plan to accomplish MSEE project objectives using Phase I and Phase II Test results, analysis and evaluation.

Phase II Test Plan
Plan for tests during Phase II which will provide data needed for evaluation.

Operator Training Plan
Plan to train four teams of utility operators and obtain their feedback on the MSEE system.

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SECTION 1
INTRODUCTION

1.1 BACKGROUND

Solar thermal central receiver systems have been under development since the early seventies. The first central receiver systems used water/steam as a heat transfer fluid in the receiver. Subsequent studies and test programs investigated molten salt, liquid sodium, and hot air as heat transfer fluids. They all possess certain advantages over water/steam, but many feel that molten nitrate salt is the most promising heat transfer fluid, particularly for utility-scale electric power plants with thermal storage.

A complete molten salt system experiment has been built at the Department of Energy (DOE) Central Receiver Test Facility (CRTF) located at Kirtland Air Force Base, Albuquerque, New Mexico. Two of the subsystems, the receiver and the thermal storage unit, have already been built and tested as subsystem research experiments, although the salt loop from the storage tanks to the receiver, consisting of a new boost pump, approximately 400 ft. of piping, valves, surge tanks and supporting instrumentation and control, is all new hardware. The tower and heliostat field are already available to concentrate solar energy onto the receiver. A molten salt steam generator has been designed and built specifically for this experiment. A 750 kW_e turbine/generator has been installed to convert thermal energy to electricity. This electricity will be fed into the local power grid. The heat rejection subsystem is part of the CRTF and has been used in previous test programs. The master control subsystem for the complete experiment is new.

This experiment is being conducted in two phases. Phase I, nearing completion, is a design, construction, installation, checkout, and verification effort. In Phase II, system characterization tests will be performed and the system will be operated and evaluated by utility personnel. The system, either as-is or modified to more closely simulate utility plants, may be run for an additional period in a potential third phase.

A consortium consisting of utilities, industries and the Electric Power Research Institute (EPRI), has helped construct and will support operation of the experiment. The consortium is supplying half of the project's funding through either cash contributions or donations of in-kind engineering services. The other half is supplied by the DOE, through Sandia, including engineering, experiment hardware, on-site labor and facility hardware.

1.2 SCOPE

The scope of this document is to define the specific tests to be conducted during Phase II. Each test is briefly described including the specific test objectives, test conditions, test sequence, the criteria for success and data requirements.

1.3 APPROACH

The Phase II test program is designed to provide the test information and operating opportunities to fulfill all major project objectives.

It is assumed that: (1) the Phase I test program has been completed at the initiation of Phase II; (2) all operating procedures required in Phase II have been written and verified during Phase I; and (3) CRTF personnel have been fully trained in operation of MSEE.

This plan is structured to sequentially develop engineering test results for MSEE evaluation and then provide training and operation of the MSEE by up to four teams of utility operators. The initial series of Phase II tests will thoroughly characterize the operation and performance of the MSEE including off-design conditions and operation through insolation transients. System integrity during transient tests with increasing power will be assured through: (1) controlling the receiver outlet temperature at less than the design value (1050^{o}F), (2) limiting the magnitude of the power increase, and (3) limiting the ramp rate. These limitations will be relaxed in successive tests, as indicated by test results, to determine the maximum sun-following capability of the system. Alternative overnight hold conditions will be tested to determine the most efficient mode and to help assess the value of a receiver door.

The results of the foregoing characterization of system operation and performance will be used to develop and verify an optimum operating strategy for the MSEE and to define system characteristics which would lead to improved operational availability and overall efficiency. The improved operating strategy/strategies will be demonstrated by the utility teams during their operation of the MSEE.

1.4 PHASE II SCHEDULE

The Phase II test program will begin upon completion of Phase I which is expected to occur about May 11, 1984. The engineering tests are scheduled to be completed by August 3, 1984. Training and operation by utility operators is planned to extend until about November 16, 1984.

1.5 RELATED DOCUMENTATION

The following documents are related to this Test Plan and the MSEE environment.

Number	Title
MCR-83-514	MSEE Configuration Management Plan
MCR-83-515	MSEE Phase I Test Plan
MCR-83-531	MSEE Hazards Analysis
MCR-83-538	MSEE Master Control Subsystem Requirements Specification
MCR-83-539	MSEE Steam Generator Subsystem Interface Control Document
MCR-83-541	MSEE System Specification
MCR-83-542	MSEE Receiver Subsystem Interface Control Document
MCR-83-543	MSEE Thermal Storage Subsystem Interface Control Document
MCR-83-544	MSEE Heat Rejection and Feedwater Subsystem Interface Control Document
MCR-83-545	MSEE Electric Power Generation Subsystem Interface Control Document
MCR-83-546	MSEE System Test Procedure
MCR-83-547	MSEE Receiver Testing Integrated Test Procedure
MCR-83-548	MSEE Steam Generation Acceptance Testing Integrated Test Procedure
MCR-83-549	MSEE Electric Power Generation Testing Integrated Test Procedure
MCR-83-550	MSEE Special Procurement List
MCR-83-551	MSEE Failure Modes and Effects Analysis
	MSEE Phase II Training Plan
	MSEE Phase II Evaluation Plan

Section 2

MSEE PROJECT OBJECTIVES

The overall objective of the MSEE program is to verify the system design, demonstrate its operation under all anticipated modes, characterize the system, and train utility operators to operate the system. The following objectives and goals were developed by the MSEE Technical Committee.

Phase II General Objectives:

a) Obtain, evaluate, and document performance data for each subsystem and total system interaction sufficient to verify design and identify uncertainties.

b) Define the operating range, flexibility and limitations of the system as installed.

c) Document performance results and evaluations that may be used for scaleup.

d) Identify and prioritize areas that need additional development.

e) Verify that equipment protection system functions properly in all modes of operation.

Specific Phase II Goals:

a) Demonstrate system performance:
    (1) Design operating conditions for all subsystems
    (2) Design control concept and subsystem interaction
    (3) Overall performance efficiency

b) Determine the response of the system to deviations (transients) from design conditions:
    (1) Naturally occurring including clouds and unanticipated outages.
    (2) Controlled to determine limits (cold and hot start-ups, shutdowns, etc.)

c) Develop the appropriate operating strategies to maximize solar energy utilization.

d) Collect thermal/hydraulic and thermal/mechanical design data to support design assumptions and to determine acceptable heat-up and cooldown rates.

e) Provide data to determine the mechanical reliability of individual components as used by:
   (1) Regular inspections (visual and non-destructive)
   (2) Post-failure examination
   (3) Provide input to a plan for post Phase II inspections of critical components for corrosion, erosion, cracking, etc.

f) Provide data to compare analytical and operational data and update the control models and the systems model where required.

g) Document results and actions via:
   (1) Interim quarterly presentations covering results, conclusions and action plans.
   (2) Final Phase II MSEE report

This test plan is designed to provide the test data necessary to accomplish these objectives and goals. Prioritization of the tests, hence goals and objectives, is given in Section 6.

Section 3
MSEE SYSTEM DESCRIPTION

The MSEE system is shown as an artist's concept in Figure 3.1. It is designed to demonstrate the conversion of solar energy to electricity using molten salt and water/steam as the working fluids. The molten salt is the energy transfer medium from the receiver through thermal storage to the steam generation subsystem and water/steam is the energy transfer medium from the steam generation subsystem to the electric power generation subsystem. The system schematic is shown in Figure 3.2. The receiver, located at the top of the CRTF tower, receives concentrated solar energy from the collector field. Molten salt from the cold storage tank, located at ground level, is pumped up the tower piping and through the receiver. In the experiment, cold salt is nominally defined to have a temperature of 306°C (580°F). The salt is heated from 310°C to 566°C (590°F to 1050°F) in the receiver, flows through a downcomer, and is throttled into the hot salt storage tank. Hot salt is defined to have a nominal temperature of 566°C (1050°F). Hot salt from storage is pumped through the steam generator superheater and evaporator, and is returned to the cold storage tank. An additional flow of cold salt is injected in the salt line between the superheater and evaporator to reduce the salt temperature entering the evaporator; this is to allow the use of low alloy steel in the evaporator. Main steam from the steam generator is used to drive a conventional steam turbine-generator. There are two principal advantages of this molten salt receiver system over a water/steam receiver system: the steam generator and turbine are decoupled from the receiver by the thermal storage subsystem; and, molten salt from the receiver is used directly as the thermal storage fluid, thus providing an inexpensive source of thermal storage and a constant temperature heat source for the steam generator.

The system is divided into the following subsystems:

a) Collector (CS)
b) Receiver (RS)
c) Thermal Storage (TSS)
d) Steam Generation (SGS)
e) Electric Power Generation (EPGS)
f) Heat Rejection and Feedwater (HRFS)
g) Master Control (MCS)
h) Data Acquisition (DAS)

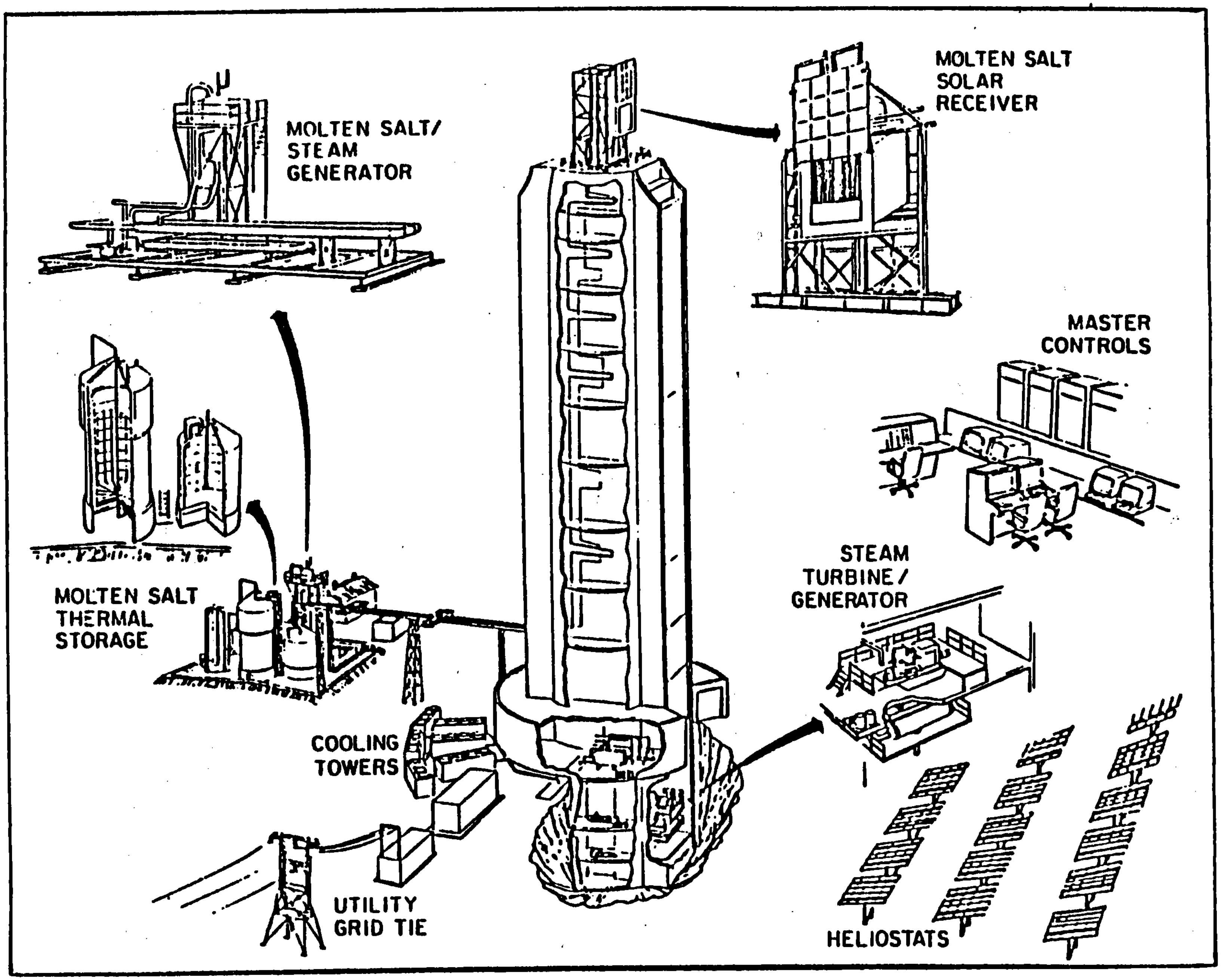

FIGURE 3.1 Artists Concept

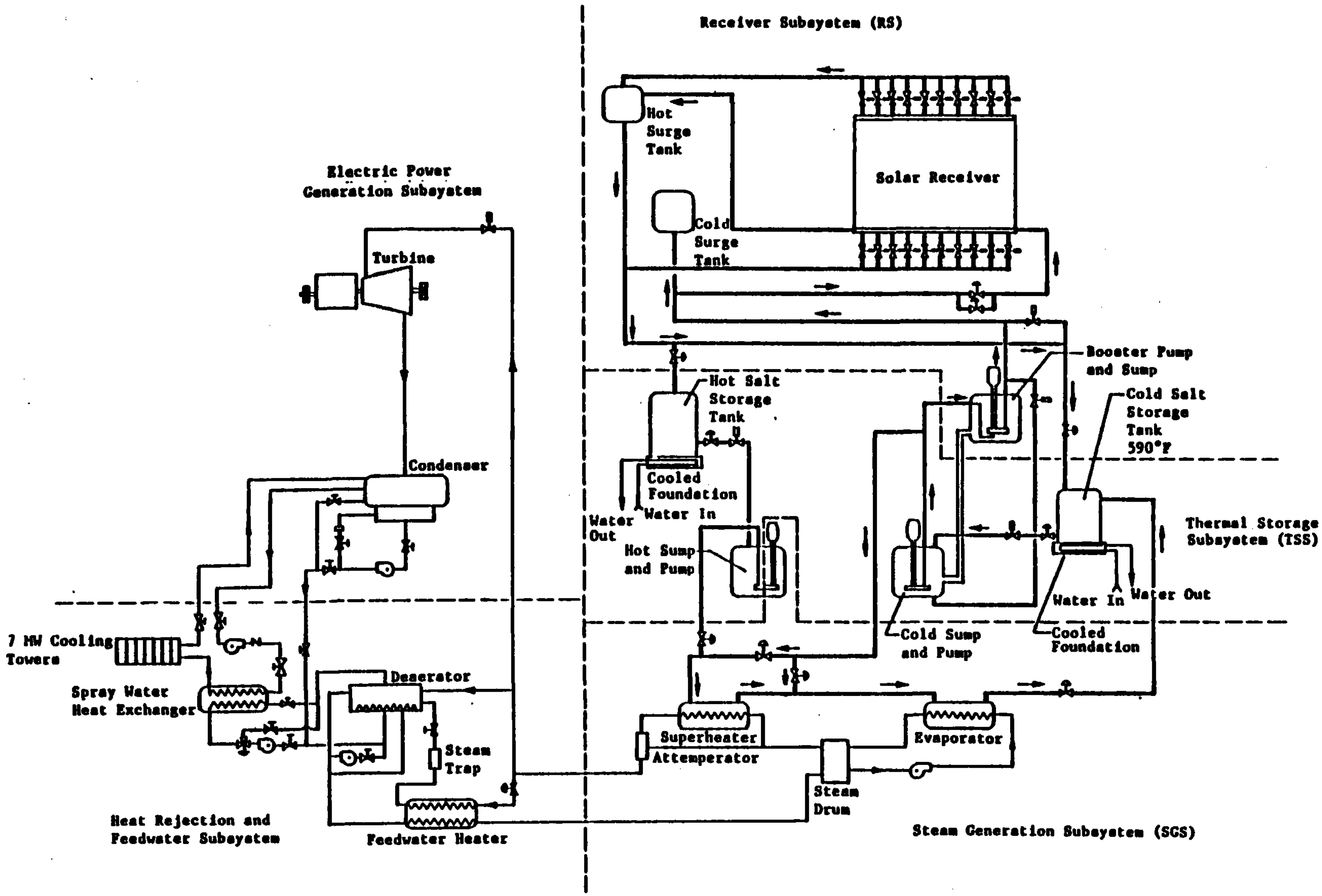

FIGURE 3.2 *MSEE Flow Schematic*

A tabulation of data describing the MSEE system is given on Table 3.1. A more detailed description of the MSEE subsystems is contained in the following subsections.

3.1 COLLECTOR SUBSYSTEM

The collector subsystem redirects, concentrates, and focuses solar radiation onto the tower-mounted receiver. The subsystem, which is already in place at the CRTF, consists of 221 two-axis tracking heliostats located north of the receiver tower, and its control system. Under optimum insolation and heliostat conditions, the heliostat field can concentrate approximately 5 MW_t onto the receiver.

Each heliostat has 25 individual mirror facets totaling 37.2 m^2 (400 ft^2) of reflective surface. The facets are mounted on a structure and individually adjusted to provide a concentration ratio of 25 to 1 on the receiver. The structure has motor-driven azimuth and elevation gimbals, which allow it to track the sun during the day.

The heliostats are operated from the control room by the CRTF collector control system. (The CRTF collector control system will be separate from the experiment master control subsystem.) The CRTF collector control system analyzes heliostat operating commands from a number of programmed test sequences or from the facility heliostat operator. Control signals are distributed to the heliostats through four heliostat array controllers and four heliostat interface modules. Each heliostat receives azimuth and elevation pointing information once every second and responds with its own status. Commands and data transmitted to the individual heliostats are received and executed by the heliostat control electronics. The electronics keep the drive motor power at the proper level until the gimbal axis encoders indicate that the desired position has been reached.

Table 3.1

MSEE Data

Location -- CRTF; on Kirtland Air Force Base, Albuquerque, NM

Heliostat Field -- Existing field of 221 heliostats each with 400 ft^2 of mirror surface.

Tower -- Existing concrete tower, 200 ft. high with internal lifting module

Master control -- EMCON D-2 distributed digital control system with central consoles; separate equipment protection system.

Receiver -- Refurbished from previous Subsystem Research Experiment.

- o Rating: 5 MW_{th}
- o Salt temperatures: in - 590^oF; out - 1050^oF
- o Configuration: cavity with door
- o Absorber: single panel of 3/4 in Incoloy 800 tubes (18 passes, 16 tubes per pass)
- o Peak flux: 630 kW/m^2 (200,000 Btu/hr - ft^2)

Thermal Storage -- Existing from previous Subsystem Research Experiment

- o Rating: 6.54 MW_{th} Hr when operating between 590^oF and 1050^oF
- o Type: 2-tank
  - Hot tank, internal insulation
  - Cold tank, external insulation

Steam Generator -- Supplied by Babcock and Wilcox

- o Type: Forced recirculation
- o 2 units: evaporator and superheater (both U-tube, U-shell) with steam drum separator
- o Rating: 11,000 lb/hr of steam at 940^oF and 1100 psi (3.13 MW_{th})
- o Prototypical of commercial design

Turbine Generator -- GE rebuilt unit

- o Marine turbine
- o 750 kW_e rating

Heat Rejection and Feedwater System -- existing at CRTF

- o Feedwater treatment only
- o 20,000 gallon demineralized water storage
- o Dry cooling, 7 MW_{th} capacity

3.2 RECEIVER SUBSYSTEM

The receiver subsystem (Figure 3.3) captures the insolation redirected from the heliostat field and converts it to thermal energy in the molten salt. The subsystem consists of the receiver absorber panel, cavity enclosure with one vertical aperture door, insulation, heat tracing, cold surge tank, booster pump, hot surge tank, overflow tank, instrumentation, and control valves. The receiver is located at the top of the CRTF tower.

The receiver was tested in a previous subsystem research experiment. Since the initial experiment, the receiver has been refurbished. This refurbishment included instrumentation and control system modifications, minor structural and piping changes, and the replacement of the two original horizontal cavity doors with one vertical aperture door.

The receiver absorber is a single panel with 18 vertical passes having 16 tubes per pass. The tubes are Incoloy 800 with 19 mm (0.75 in.) outside diameter. Purge and drain valves are provided for each pair of passes.

The receiver surge tanks are designed to dampen changes in the salt flow rate and to maintain salt flow through the receiver in the event of a cold salt pump outage. The cold surge tank is pressurized with facility-supplied instrument air to supply the necessary head to force the salt through the receiver in the event of a pump outage, and to provide a surge volume within the tank. The hot surge tank operates at atmospheric pressure, and is vented to an adjacent overflow tank in the event of a control problem in the salt downcomer throttle valve.

The cold salt booster pump takes its suction from the discharge of the cold salt pump and provides the necessary head for the salt as it travels up the tower and through the receiver.

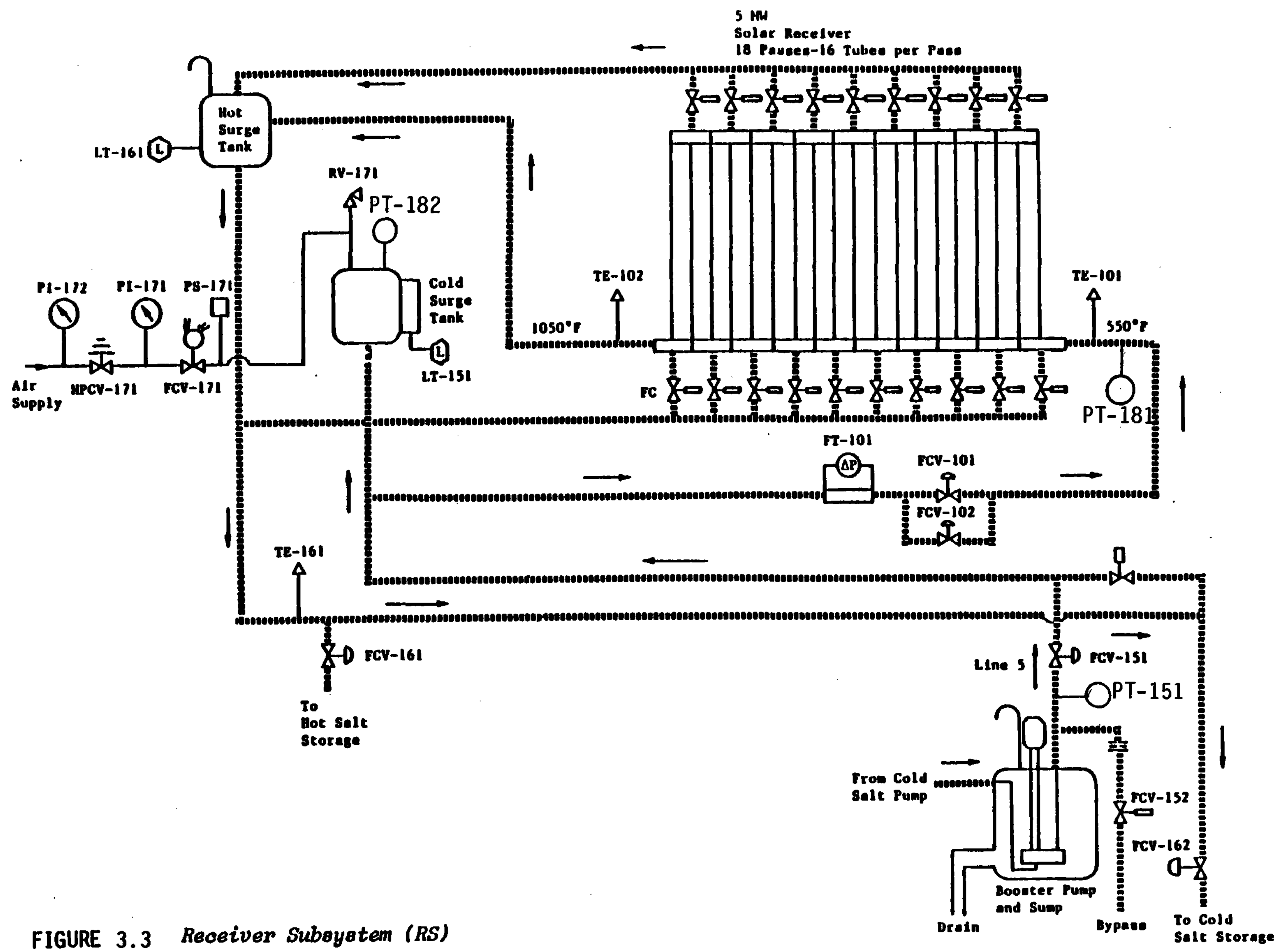

FIGURE 3.3 *Receiver Subsystem (RS)*

The cold salt line to the receiver starts at the booster pump, rises to the top of the hot storage tank, traverses the distance from the storage tanks to the receiver tower on an elevated pipe bridge, enters the tower, and runs up the east side of the tower in an existing pipe chase to the receiver. The hot salt line leaves the hot surge tank and traverses to the pipe chase. The hot salt downcomer carries the salt to the level of the pipe bridge. The hot salt line traverses the bridge, ending in a control valve which throttles the flow to the hot storage tank. The salt piping is inclined between the storage tanks and the tower to ensure that the piping system will completely drain. The salt piping is electrically heat traced and insulated with calcium silicate and aluminum sheathing.

3.3 THERMAL STORAGE SUBSYSTEM

The thermal storage subsystem provides a cold salt source for the receiver for daytime operation, and a hot salt source for the steam generator for day and early evening operation. The TSS can also furnish a source of thermal energy for overnight freeze protection of the receiver, steam generator, and salt piping and for early morning plant start-up. The subsystem includes the hot and cold salt storage tanks, propane-fired salt heater, cold salt pump and cold salt sump. The subsystem schematic is shown on Figure 3.4.

The salt pump is of a vertical cantilever design. The impeller and casing are suspended below the liquid level in a sump; the bearings are located above the liquid level and do not contact the salt.

The hot salt tank employs a unique design. To allow the use of carbon steel in the structural portions of the tank, an internal refractory insulation is used to limit the temperature of the walls, roof, and floor. A waffled Incoloy liner separates the salt and the internal insulation, and the tank foundation is cooled with circulating water to limit the floor temperature. The outside of the tank is insulated in the conventional manner with calcium silicate and aluminum sheathing. The cold salt tank is similar in design to the hot tank except that it does not require the internal insulation and liner due to its lower operating temperature. During the previous subsystem research experiment testing, the hot and cold tanks experienced only a limited number of temperature cycles.

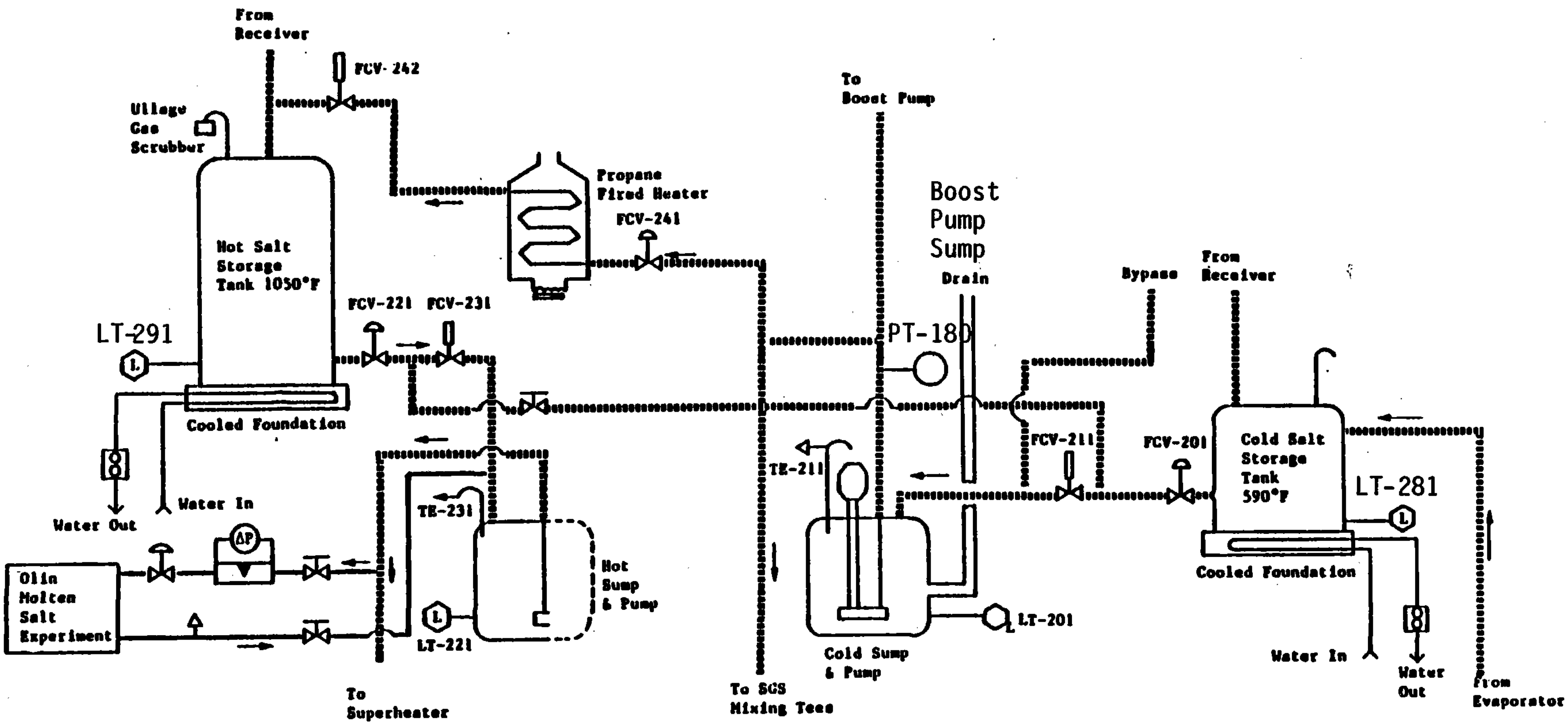

FIGURE 3.4 *Thermal Storage Subsystem (TSS)*

3.4 STEAM GENERATION SUBSYSTEM

The steam generation subsystem transfers sensible heat from the molten salt to produce superheated steam for the turbine-generator. The subsystem schematic is shown on Figure 3.5. The subsystem includes an evaporator, steam drum, boiler recirculation pump, superheater, and attemperator. The steam generator is the only major item of molten salt equipment which has not been tested in a subsystem research experiment.

The evaporator and superheater are U-tubes, U-shell heat exchangers, with low pressure salt on the shell side and high-pressure water and steam on the tube side. This shell and tube configuration has been selected to minimize thermal stresses, due to differential expansion, in the tubes and tubesheets.

A conventional steam drum, located above the evaporator, separates water droplets from the saturated steam before the latter enters the superheater, and receives feedwater from the feedwater heater. A forced recirculation design was selected, since it is preferred for power plants requiring daily start-up and shutdown.

The turbine requires a main steam temperature of 504^{o}C (940^{o}F); the steam outlet temperature from the superheater has been specified as 538^{o}C (1000^{o}F). The superheater outlet steam is attemperated by mixing with a small amount of saturated steam from the drum. The salt flow from the superheater to the evaporator is also attemperated, from 486^{o}C (906^{o}F) to 454^{o}C (850^{o}F), by mixing with salt flow from the cold tank. This allows chrome-moly piping and fittings, rather than stainless steel, to be used in the evaporator.

Warmup of the steam generation subsystem is accomplished by isolating the subsystem and preheating with the subsystem's electrical heater.

3.5 ELECTRIC POWER GENERATION SUBSYSTEM

The electric power generation subsystem converts the enthalpy in the main steam flow to electricity. The subsystem (Figure 3.6) includes the steam turbine, electric generator, electric power equipment, condenser, condensate pump and storage tank.

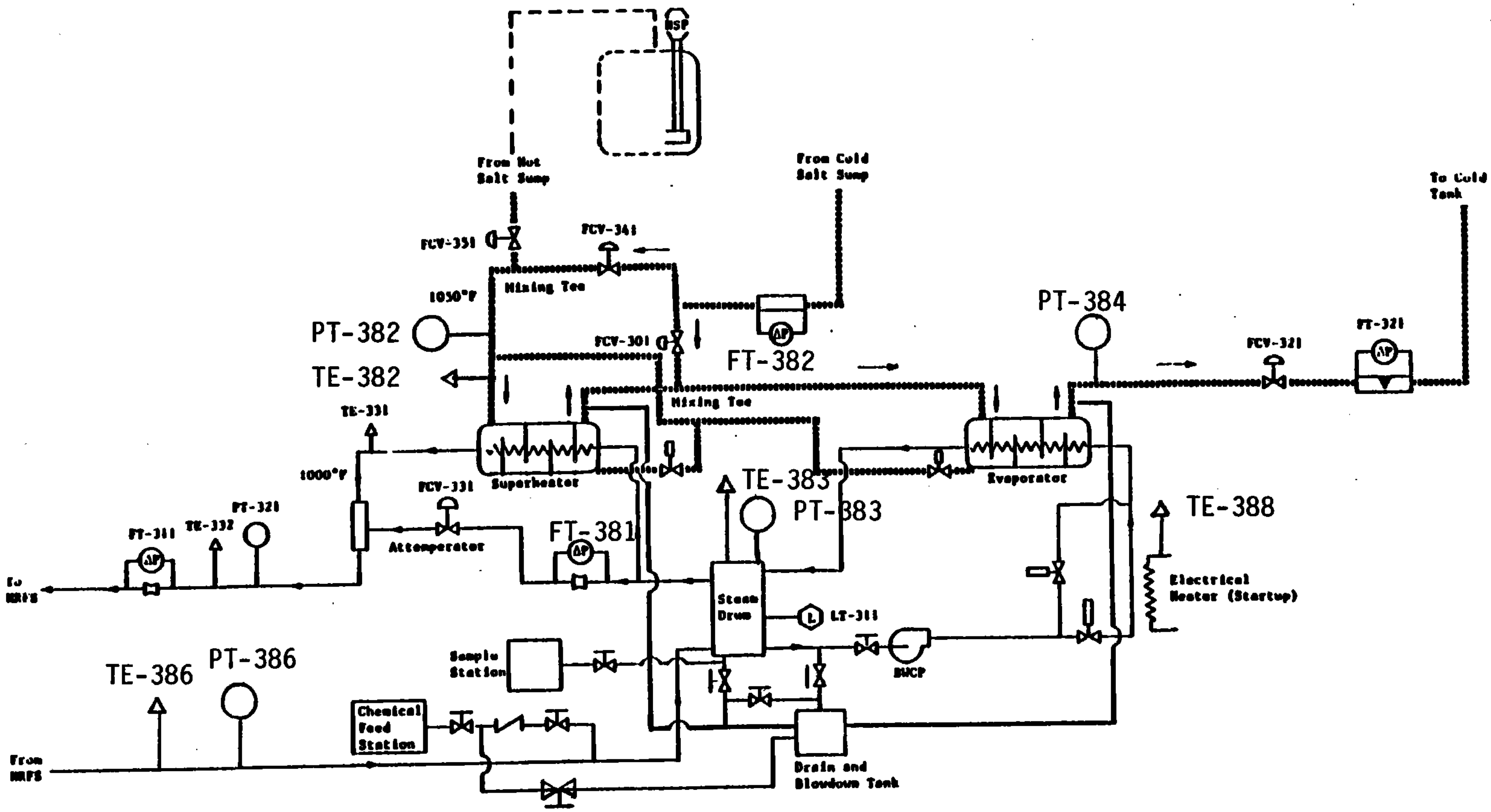

Figure 3.5 *Steam Generation Subsystem (SGS)*

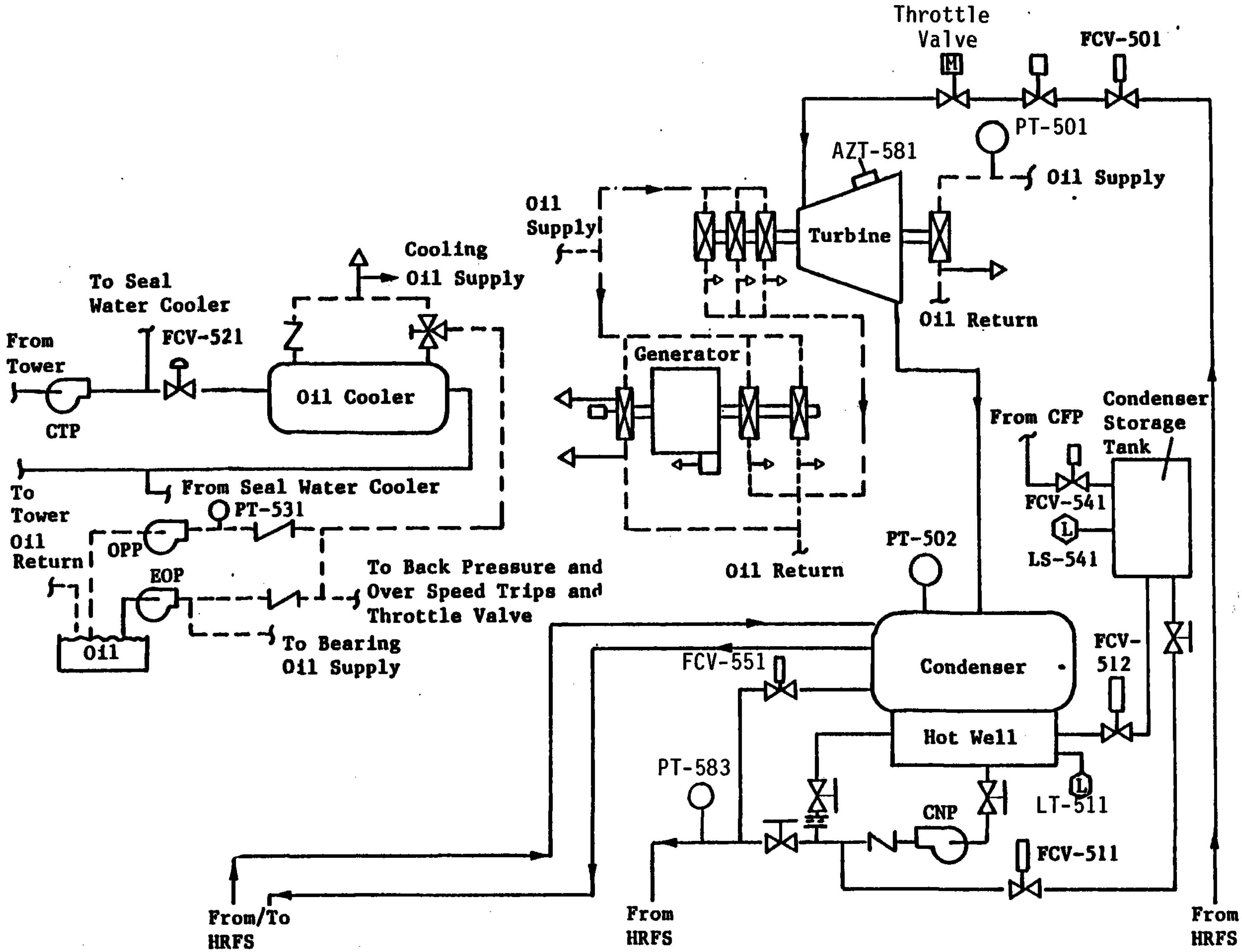

FIGURE 3.6 *Electric Power Generation Subsystem (EPGS)*

The turbine-generator set is a skid-mounted unit located at the north end of the receiver tower complex at the 80 ft. level (20 ft. below grade). This skid consists of a turbine, generator, and auxiliary equipment. The turbine is a seven-stage, single flow machine, operating at 17,400 rpm. Inlet steam conditions are 504°C (940°F) and 7.24 MPa (1050 psia). A single reduction gearbox reduces the turbine shaft speed to the generator speed of 1,200 rpm. The 750 kW_e generator operates at 480 V, and is cooled by circulating water through air cooling coils located above the generator. The turbine-generator auxiliaries include a lubricating oil pump, lube oil cooler, air ejection vacuum pump and mechanical-hydraulic governor. Discussions with General Electric Company indicate that the load on the turbine can be ramped up or down at least as quickly as the allowable rate of change in load on the steam generator. This design value is 10 percent per minute from 30 to 100 percent of rated capacity.

A shell and tube condenser, supported by a separate frame, will be located directly below the turbine. Access to the condenser is on the floor 40 ft. below ground. Condensate from the hot well of the condenser will be transferred to the deaerator when the water level in the deaerator requires makeup. Otherwise, the condensate is pumped to a storage tank. Condensate from this tank is piped back to the condenser hot well when the hot well level requires water.

Warmup of the turbine generator is accomplished by steam from the steam generation subsystem.

3.6 HEAT REJECTION AND FEEDWATER SUBSYSTEM

The heat rejection and feedwater subsystem rejects waste heat to the atmosphere, pressurizes and heats the condensate to the final feedwater temperature. The subsystem (Figure 3.7) includes the cooling towers, circulating water pump, deaerator, spray water heat exchanger, spray water pump, feedwater pump, feedwater heater, demineralizers, chemical feeders, water analyzers, and condensate makeup pump. These major pieces of equipment, except the recently purchased feedwater pump, were used during the tests of the 10 MW_e pilot plant water-steam receiver panel.

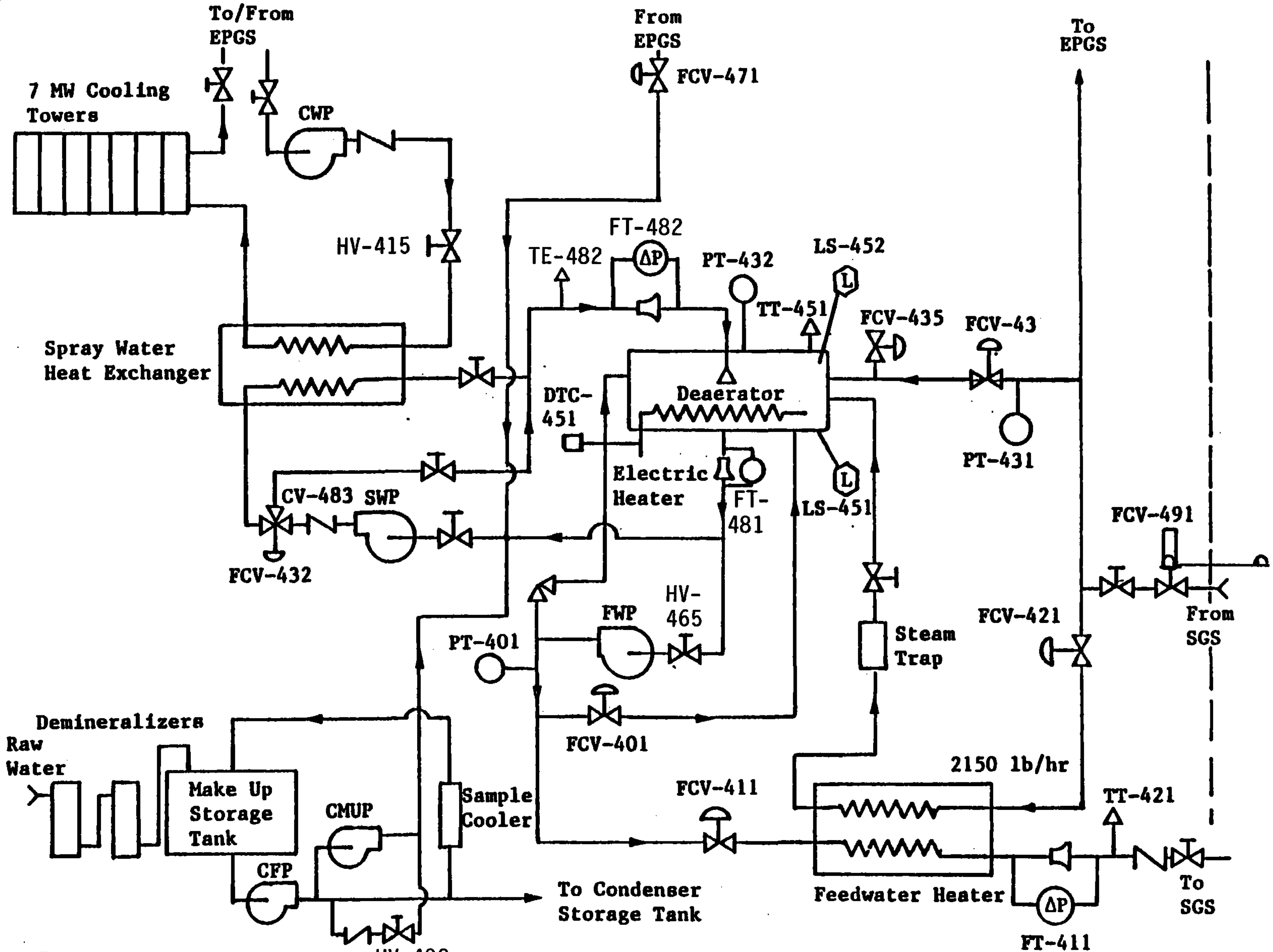

FIGURE 3.7
Heat Rejection and Feedwater Subsystem (HRFS)

The cooling towers consist of six forced-draft, finned-tube water-to-air heat exchangers. They originally were designed as Freon condensers for refrigeration systems. As designed for the 10 MW_e pilot plant panel test, the cooling towers had a duty of 7 MW_t (24×10^6 Btu/hr) when cooling water from 93°C to 71°C (200°F to 160°F) using air at the design point temperature of 34°C (94°F). The turbine condenser cooling load in the MSEE, however, is approximately 2.7 MW_t (8×10^6 Btu/hr), or about one-third the original duty. As a result, the cooling towers can provide cooling water temperatures closer to the design point air temperature.

The deaerator was originally designed as a direct contact condenser for the superheated steam from the 10 MW_e pilot plant panel test. In this test, the deaerator will be used to reject steam generated by the SGS. It is a horizontal, cylindrical pressure vessel, designed to operate at 1.7 MPa and 204°C (250 psia and 400°F). It includes a steam header with mixing spargers near the bottom of the tank, water spray nozzles across the top, and two immersion electric heaters. It will be used in the MSEE as a direct contact feedwater heater and deaerator. Feedwater, stored in the deaerator, is heated by steam from a branch off the SGS mainline to the turbine. The feedwater is circulated by a spray water pump at 400 gpm from the bottom of the deaerator to the spray nozzles in the vapor space at the top of the deaerator where the water condenses the steam and is thereby heated. Condensate from the turbine condenser, blended into this spray water, is also heated to 204°C (400°F) and deaerated.

A new high speed, single stage centrifugal feedwater pump has been purchased to replace the existing positive displacement pump, which has been prone to leaks.

The feedwater heater is a vertical, cylindrical pressure vessel with an internal steam condensing coil. Feedwater from the deaerator is heated on the tube side as steam from a branch of the SGS mainline condenses on the shell side. The saturated liquid from the coil is cascaded down to the deaerator through a steam trap. Main steam is used for feedwater heating in the feedwater heater and the deaerator because there are no external extraction points on the turbine.

3.7 MASTER CONTROL

The master control subsystem (Figure 3.8) consists of an EMCON-D2 for system control and a equipment protection system. A Bailey network 90-system will be used to directly control the SGS. Commands and set points will be provided by the EMCON master control subsystem to the Network 90 for SGS operation and control. The equipment protection system is an independent hardwired relay shutdown system. These relay trip devices will shut down the receiver or the power generation ends of the MSEE when critical parameters reach preset limit values. These relay units are independent of the EMCON and network 90 control systems. Additionally, an Accurex Data Logger will be used to collect and display all the temperature measurements relating to the heat tracing and data instrumentation.

The EMCON-D2 is a distributed digital control system consisting of two operator consoles, a host computer with its peripheral hardware, a communication control module, and three process control modules distributed among the subsystems. Two EMCON-D2 operator consoles are located in the CRTF main control room. The host computer is an existing DEC PDP 11/34 unit located in the control room. This computer links the operator with the process control modules, and analyzes data from the control modules for presentation on the operator consoles. The peripheral equipment includes two disk drives, an alarm system, and a data analysis system.

A communication control module links the host computer with the three field-located, process control modules. Each process control module is a small digital computer capable of monitoring a number of instrumentation points, and responding with a number of process control signals. Communications between the control modules and host computer will be primarily limited to direct operator commands from the console and critical operating information from the subsystems for console display. This distributed control system reduces the number of instrumentation and control links between the subsystems and control room.

The communication control module consists of a digital computer control unit, a multiplexer, an analog-to-digital converter, and a digital-to-analog converter. Analog signals from the process instrumentation are converted to

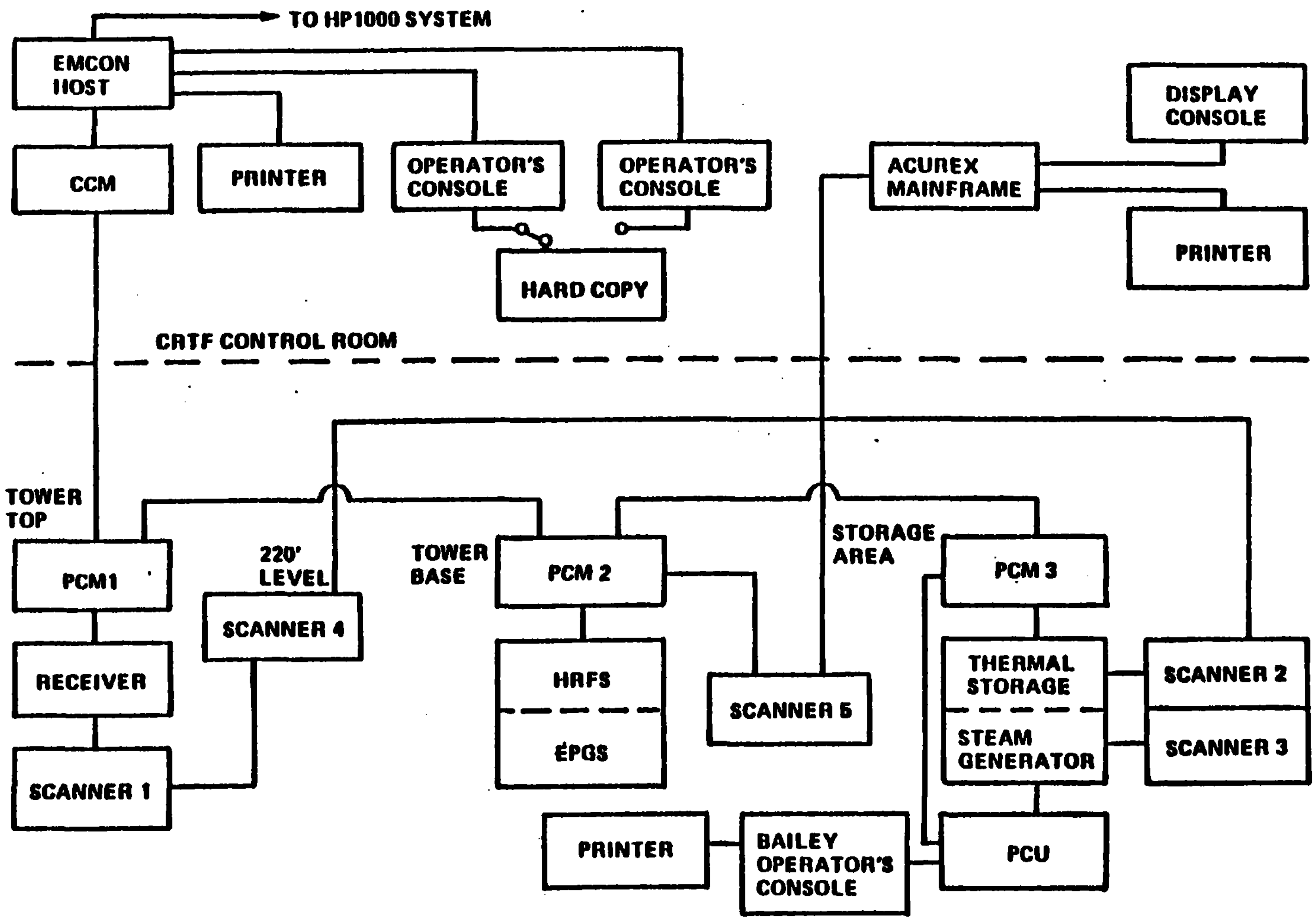

FIGURE 3.8 Master Control Subsystem

digital signals, selected in rotation by the multiplexer, and analyzed by the control unit. The module responds with an appropriate digital control signal which is passed through the multiplexer and sent to the appropriate controller. Each process control module is capable of monitoring 30 analog signals per second, monitoring 95 thermocouples, generating 20 analog control signals, and controlling over 100 on-off switches.

One process control module (PCM), located below the receiver in the tower elevator, will be dedicated to the control of the receiver. A second module, located at the base of the tower, will control the heat rejection and electric power generation subsystem. The third module, located in the control building adjacent to the salt storage tanks, will be used to control the thermal storage subsystem and to command the network 90 controlled steam generation subsystem.

The receiver subsystem PCM will modulate the salt flow rate to the receiver to maintain, as closely as possible, a constant outlet temperature of 566^{o}C (1050^{o}F). Individual thermocouples are located on the receiver to measure intermediate salt temperatures. From this information, the control module will estimate the flux on the receiver, and feed-forward a signal to the salt control valves at the receiver inlet. The control module will also control the receiver start-up and shutdown purge and drain valves.

Control of the thermal storage subsystem will involve the operation of the two salt downcomer flow control valves, cold salt pumps, salt storage tanks and piping heat tracing, and the propane-fired salt heater. The downcomer throttling valves will be controlled by the receiver control system to maintain a constant level in the receiver hot surge tank. Salt equipment heat trace temperatures will be monitored continuously by the Accurex Data Logger. The propane-fired salt heater will be operated intermittently, under manual control, during subsystem checkouts.

Automatic control of the heat rejection and electric power generation subsystem will involve the control of the steam and condensate flows to the deaerator, steam flow to the feedwater heater, and the operation of the cooling water, spray water condensate, and feedwater pumps. The EPGS condenser temperature, level and pressure will be monitored by the master control subsystem. The deaerator temperature will be maintained by controlling the steam flow from the main steam header. The final feedwater temperature is maintained by controlling the main steam flow to the feedwater heater.

Automatic control of the steam generation subsystem will primarily involve the control of steam pressure, steam temperature, drum water level, and the evaporator salt inlet temperature through the network 90 control system. The water level in the drum will be controlled by modulating the control valve downstream of the feedwater pump. Control of the main steam pressure will be accomplished by modulating the salt flow control valve downstream of the evaporator. Steam temperature is controlled using an attemperator to mix steam from the steam drum with the output of the superheater. The evaporator salt inlet temperature will be controlled by monitoring the inlet salt temperature, and modulating the cold salt control valve at the mixing tee between the superheater and evaporator.

The Bailey Network 90 Control System consists of two process control units (PCU) and one operation interface unit (OIU).

The PCU architecture is based on two key modules, the Controller Module (COM) and the Logic Master. Together, these modules provide a mix of both modulating and sequential control functions including: base, cascade, or ratio PID control, high/low and rate limiters, engineering units conversion, general function generator, square root, summation multiplication, lead/lag, and transfer select, or, and, not, time delay, and several others. The controller module can service up to four analog and three digital inputs and two analog and four digital outputs. The COM also provides A/D and D/A conversion, alarm limit checking (absolute and deviation) and notification, point quality checking and interlocking.

The Operator Interface Unit (OIU) provides the high level operator interface for the Network 90 system. The OIU consists of a color CRT-based table-top console, with functional keyboard, mass storage device, and console driver electronics.

In operation, the unit performs the system information display and control requirements. The OIU console includes a CRT keyboard and pushbutton hardware for process overview, alarm indicating, loop control, trending, tuning and configuration functions.

The OIU uses microprocessor, memory and I/O modules to support system functions. It furnishes monitoring, supervisory, recording and display capability at centralized or distributed locations, along with engineering functions.

3.8 DATA ACQUISITION SUBSYSTEM (DAS)

The DAS utilizes both the EMCON-D2 and an HP-1000. EMCON collects the data and HP-1000 stores and displays data. Data collected by the EMCON system is transmitted to the HP-1000 system on a terminal-to-terminal data link. The tag list for the data to be collected is in a file of 120 tags, which are divided into 4 groups or 30 tags. One group of 30 is transmitted every 15 seconds, giving a total update rate of once a minute. The data are then time tagged with day of the year, hour, minute, second, millisecond. Then the data are stored in a data file and/or displayed on one of six CRTs in a graphical form. Also, the data are transmitted in integer format, not floating point, but they are in engineering units. The data files are divided into eight-hour blocks, so if a test runs longer than eight hours, another eight-hour block is assigned to that test's file. Normally an 8-hour data block is stored in 19 tracks out of a maximum usable 1000 tracks.

The live data can be displayed on the 6 CRTs with 3 tags per screen, a time scale of 3 hours 20 minutes, and a Y-scale displayed of the first tag's display range. The other two tags are displayed using their respective ranges, but the scales are not shown on the plot. When the plot is full the plot scrolls left dropping the oldest 1/4 of the time scale data. This leaves 1/4 of the plot blank for new data. These plots can have hard copies made, but not automatically. The print is done by manual switch selection of each screen and a copy page switch.

Recovery of stored data can be done whenever live data files are not being made. These plots have a slightly different format, three being a maximum of five tags per plot, and the Y scale shown is that of the last tags range. These plots are not displayed on a CRT, but directly generated on the printer/plotter.

Section 4
PHASE II ROLES AND RESPONSIBILITIES

4.1 PHASE II CONTRACT MANAGER (The Electric Power Research Institute)

The Phase II Contract Manager will be responsible for the technical and contract control of the McDonnell Douglas Phase II activities. In addition, EPRI will solicit and coordinate, together with the Public Service Company of New Mexico, the participation of utility operating teams. The final report for the MSEE project will be published and distributed by EPRI.

4.2 MSEE PROJECT MANAGER (Sandia National Laboratories, Livermore)

The Project Manager will be responsible for the day-to-day coordination and management of all aspects of the project. The Project Manager will have the authority to plan and execute activities with the concurrence of the Executive Committee.

In addition, the Project Manager will perform the following test functions:

a) Review and approve the Phase II Test Plan
b) Review and approve the integrated test procedures (ITP)
c) Establish and maintain the program test schedule
d) Enter into contractual arrangements for any required supporting equipment or services

4.3 SITE MANAGER (The Central Receiver Test Facility)

The CRTF Site Manager will be responsible for the complete maintenance of MSEE equipment and the overall conduct of all tests. This will include the following:

a) Be responsible for MCS operation and maintenance
b) Maintain up-to-date file of all turnover records
c) Conduct configuration management change committee reviews
d) Review and approve all plans and procedures

e) Provide personnel for operations, maintenance and data acquisition and handling
f) Approve the test approach presented at pretest meetings
g) Final authority on test/maintenance activities and their scheduling
h) Maintain safety responsibility which includes the authority to shut down testing when hazardous conditions or unexpected test results occur
i) Maintain test procedures documentation

4.4 MSEE PHASE I SYSTEMS INTEGRATOR (Martin Marietta)

The Phase I Systems Integrator will be responsible for the turnover of the Phase I documentation test program results and of the MSEE. Specifically, the Systems Integrator shall be responsible for the following:

a) Provide red-lined test procedures from Phase I (as of April 6, completed)
b) Provide all Phase I documentation
c) Review significant changes to test procedures
d) Provide full-time controls/instrumentation engineer on-site through June 1984.
e) Review configuration management changes
f) Provide quick look analysis of Phase I test results
g) Provide Final Report on Phase I

4.5 TECHNICAL COMMITTEE

The Technical Committee will help guide the technical aspects of the Phase II tests including the following:

a) Establish Phase II objectives/priorities (accomplished)
b) Review and comment on test plan
c) Periodic review of Phase II test results

4.6 EQUIPMENT SUPPLIERS

a) Provide all documentation on equipment and Phase I checkout and testing
b) Identify any special data desired from Phase II tests
c) Consult on post-Phase II plan

4.7 HOST UTILITY (Public Service Company of New Mexico)

The host utility will coordinate, together with EPRI, the participation of operating teams from other utilities. Additionally, PNM will provide the first team of utility operators in Phase II.

4.8 UTILITY SPONSORS (APS, PG&E, and SCE)

All utility sponsors have agreed to provide either a full or partial operating team for Phase II. In addition, several other utilities can provide a single operator or engineer to participate in the Phase II test program.

Utility sponsors also participate on the Technical Committee (4.5) so those roles are also included.

4.9 MCDONNELL DOUGLAS ASTRONAUTICS COMPANY (MDAC)

MDAC will be responsible to define the testing required to meet the Phase II goals and objectives and specifically perform the following:

a) Provide Phase II test plan and schedule
b) Redline test procedures and participate in reviews
c) Conduct daily status meetings
   - Describe daily test activity, including test objectives, description and data required
   - If no testing, prioritize maintenance and repair
   - Update schedules
d) Maintain daily test log
e) Participate on configuration management review committee
f) Report weekly status to SNLL/EPRI
g) Provide system evaluation
h) Provide periodic progress reviews
i) Prepare final report

Section 5

TEST PROGRAM DESCRIPTION

5.1 GENERAL

Phase II tests, operating modes and transitions and pertinent Phase I Procedures are identified here.

5.1.1 Phase II Tests

Phase II tests are grouped into four categories. Part A tests will be used to generate the test data to be used to evaluate performance and functional capability of the MSEE. Part B contains training tests which will be used to train utility operator teams. Part C contains those tests that will be performed to evaluate the routine operation of MSEE as a utility power plant. They will be used to produce extended performance information using the optimum operating strategy developed in Part A tests. These tests will be conducted by the utility operator teams. Part D tests will be conducted throughout Phase II by Olin to obtain data on salt properties, stability and corrosion. These Phase II tests are listed below:

Part A - MSEE Characterization

II-1	Receiver Loop Performance
II-2	Power Production Subsystems Performance
II-3	Transient Response of Receiver Loop
II-4	Overnight Thermal Conditioning of the Receiver
II-5	Overnight Hold Conditions for the Steam Generator
II-6	Development of Optimum Operating Strategy

Part B - Training Tests

II-7	Receiver Loop Cold Flow
II-8	Receiver Loop Operation
II-9	Receiver Operation with Simulated (Slow) Cloud
II-10	Thermal Storage Charging with Propane Heater
II-11	Steam Generator and HRFS Operation
II-12	Operation of Full Electric Loop (TSS through EPGS)

Part C - Operation As A Utility Power Plant

II-13 System Operation from Receiver

II-14 System Operation with Fossil Fuel

Part D - Salt Characteristics

II-15 Salt Properties and Stability

II-16 Salt Corrosion

5.1.2 Modes of Operation and Transitions

The operating modes and transitions for each subsystem are described below:

Receiver Operating Modes

RS1	Receiver cold and drained
RS2	Receiver drained with trace heat on
RS3	Receiver drained with trace heat on and warm-up heliostats
RS4	Receiver cold flow with trace heat on and warm-up heliostats
RS5	Receiver cold flow with trace heat on, no warm-up heliostats and receiver door closed
RS6	Receiver operation, manual with flow control
RS7	Receiver operation, temperature control

Receiver Transitions

- o Start-up
  - RS1 to RS2 - Turn on trace heaters
  - RS2 to RS3 - Drained and warm to warm-up heliostats
  - RS3 to RS4 - Warm-up heliostats to cold flow through receiver
  - RS4 to RS5 - Cold flow through receiver with receiver door closed
  - to RS6 - To salt flow through receiver with flow control
  - to RS7 - To salt flow through receiver with temperature control
  - RS6 to RS7 - Salt flow with flow control to temperature control

- o Shutdown RS7 to RS6 - Salt flow with temperature control to flow control
  - to RS5 - Salt flow with temperature control to cold flow with door closed
  - to RS2 - Salt flow with temperature control to drained with trace heat on
  - RS6 to RS5 - Salt flow with flow control to cold flow with door closed
  - to RS2 - Salt flow with flow control to drained with trace heat on
  - RS5 to RS2 - Cold flow with door closed to drained with trace heat on
  - RS4 to RS2 - Cold flow with warm-up heliostats to drained with trace heat on
  - RS3 to RS2 - Drained with warm-up heliostats to drained with trace heat
  - RS2 to RS1 - Turn off trace heaters

Thermal Storage Operating Modes

TSS1	Hot tank drained and cold
TSS2	Hot and cold salt tanks warm and ready for operation
TSS3	Charging with propane heater

Thermal Storage Transitions

- o Start-up TSS1 to TSS2 - Pre-test check lists to pre-conditioning hot salt tank
  - TSS2 to TSS3 - Pre-test check lists to charging hot salt tank

- o Shutdown TSS3 to TSS2 - Charging hot salt tank to shutdown, salt in both tanks
  - TSS2 to TSS1 - Drain hot tank

Steam Generator Subsystem Operating Modes

SGS1	SGS cold and drained
SGS2	SGS warm and salt drained (diurnal shutdown)
SGS3	SGS warm standby (cold salt flow)
SGS4	SGS operating in boiler following mode
SGS5	SGS operating in turbine following mode

Steam Generator Transitions

o Start-up	SGS1 to SGS2 -	Pre-test check lists, pre-heat to diurnal shutdown
	SGS2 to SGS3 -	Diurnal shutdown to cold salt flow
	SGS3 to SGS4 -	Cold salt flow to boiler following mode
	SGS4 to SGS5 -	Boiler following to turbine following mode
o Shutdown	SGS5 to SGS4 -	Turbine following to boiler following mode
	SGS4 to SGS3 -	Boiler following mode to cold salt flow
	SGS3 to SGS2 -	Cold salt flow to diurnal shutdown
	SGS2 to SGS1 -	Diurnal shutdown to drained and cold

Electic Power Generation Subsystem Operating Modes

EPGS1	Shutdown
EPGS2	(Turbine standby) EPGS pumps on
EPGS3	EPGS standby (operating - offline)
EPGS 4	EPGS on-line (operating - synchronized)

Electric Power Generation Subsystem Transitions

o Start-up	EPGS 1 to EPGS 2 -	Pre-test check lists, pre-op and start-up pumps
	EPGS 2 to EPGS 3 -	Turbine standby to EPGS standby
	EPGS 3 to EPGS 4 -	EPGS standby to on-line
o Shutdown	EPGS 4 to EPGS 3 -	On-line to standby
	EPGS 3 to EPGS 2 -	EPGS standby to turbine standby
	EPGS 2 to EPGS 1 -	Turbine standby to shutdown

5.1.3 Application of Phase I Procedures

The procedures being developed in Phase I which will be utilized in the Phase II test program are described below:

Subsystem Transitions	Subsystem Procedures	System Procedures
Receiver Subsystem (RS)		
Start-up		
RS1 - RS2	Turn on trace heaters	Turn on trace heaters
RS2 - RS3	GROP #1, 1A, & 2 GSGP #1/1A	GSOP #1, 6, 7, 2 & 3
RS3 - RS4	GROP #2	GSOP #7
RS4 - RS5	GROP #2	GSOP #7
RS4 - RS6	GROP #2	GSOP #7
RS4 - RS7	GROP #2	GSOP #7
RS5 - RS6	GROP #2	GSOP #7
RS5 - RS7	GROP #2	GSOP #7
RS6 - RS7	GROP #2	GSOP #7
Shutdown		
RS7 - RS6	GROP #3	GSOP #8
RS7 - RS5	GROP #3	GSOP #8
RS7 - RS2	GROP #3 & 5 GSGP #6	GSOP #8, 10 & 12
RS6 - RS5	GROP #3	GSOP #8
RS6 - RS2	GROP #3 & 5 GSGP #6	GSOP #8, 10 & 12
RS5 - RS2	GROP #3 & 5 GSGP #6	GSOP #8, 10 & 12
RS4 - RS2	GROP #3 & 5 GSGP #6	GSOP #8, 10 & 12
RS3 - RS2	GROP #3 & 5 GSGP #6	GSOP #8, 10 & 12
RS2 - RS1	Turn off trace heaters	Turn off trace heaters

Subsystem Transitions	Subsystem Procedures	System Procedures
Thermal Storage Subsystem (TSS)		
Start-up		
TSS1 - TSS2	GROP #1A GSGP #1/1A & 4	GROP #6, 2 & 3
TSS2 - TSS3	GSGP #9 & 4	N/A
Shutdown		
TSS3 - TSS2	Allow hot tank to cool to 700°F	Allow hot tank to cool
TSS2 - TSS1	GSGP #9	N/A
Steam Generation Subsystem (SGS)		
Start-up		
SGS1 - SGS2	GSGP #1, 2 or 2A, APPENDIX C of GROP #1A	GSOP #2, 3, 7, 4 & 6
SGS2 - SGS3	GSGP #1A, 2 or 2A APPENDIX C of GROP #1A	GSOP #6, 7, 4
SGS3 - SGS4	GSGP #2 or 2A	GSOP #7
SGS4 - SGS5	GSGP #2 or 2A	GSOP #7
Shutdown		
SGS5 - SGS4	GSGP #3 or 3A	GSOP #8
SGS4 - SGS3	GSGP #3 or 3A	GSOP #8
SGS3 - SGS2	GSGP #3 or 3A, APPENDIX C of GROP #1A	GSOP #8, 13 & 6
SGS2 - SGS1	SGS Manual, Section 3.9	SGS Manual, Section 3.9
Electric Power Generation Subsystem (EPGS)		
Startup		
EPGS1 - EPGS2	GROP 1A, GEPGP #1, 1A & 2, APPENDICES A, B, and C	GSOP #6, 5, 7, 2, 3, & 4
EPGS2 - EPGS3	GEPGP #2	GSOP #7
EPGS3 - EPGS4	GEPGP #2	GSOP #7

Subsystem Transition	Subsystem Procedures	System Procedures
Shutdown		
EPGS4 - EPGS3	GEPGP #3	GSOP #8
EPGS3 - EPGS2	GEPGP #3	GSOP #8
EPGS2 - EPGS1	GEPGP #3 & 5, APPENDICES A, B, and C	GSOP #8, 14, 11, 12 & 13

5.2 TEST II-1 - RECEIVER LOOP PERFORMANCE

Description:

- o Calibrate receiver flow meter and receiver inlet and outlet thermocouples
- o Run receiver loop in cold flow conditions
- o Run receiver at various power levels with TSS, SGS, & HRFS operating

Objectives:

- o Determine receiver thermal loss rates at two temperatures
- o Determine steady state performance for full and part load operation
- o Verify receiver subsystem controllability under full and part load conditions

Pretest Conditions (Calibration and Thermal Loss Rate Tests):

- o RS2; receiver drained with trace heat on
- o TSS1; hot tank drained and cold or
  TSS2; hot and cold salt tanks warm and ready for operation
- o At least 70% of salt inventory in cold tank at one of the two temperatures listed under test matrix (below)
- o Insolation for receiver warm-up

Calibration

- o Receiver flow (FT-101) - Calibrate before testing; check calibration following tests
- o Receiver inlet and outlet temperature (TE-101 and TE-102) - Use data from receiver thermal loss tests, steps 4 through 8.

Test Matrix (Receiver Thermal Loss Tests)

Receiver Flow Rates (Klb/hr)	Receiver Salt Inlet Temperature (°F)
20	
40	Approx. 590
60	
80	Approx. 700
100	

Test Sequence - (Receiver thermal loss tests; conducted for both receiver inlet temperatures listed in the test matrix)

These tests may be conducted on different days except that each case covered by steps 4 through 8 and steps 9 through 13 must be completed under constant ambient conditions.

1. RS2 to RS3; receiver drained, add warmup heliostats
2. RS3 to RS4; receiver cold flow
3. RS4 to RS5; remove warmup heliostats, close receiver door
4. Establish receiver flow at 20 Klb/hr
5. Wait until flow and temperatures stabilize; record data
6. Repeat steps 4 and 5 for flow rates of 40K, 60K, 80K and 100K lb/hr substituted for 20 k lb/hr
7. Open Receiver door
8. Repeat steps 4, 5, and 6
9. Select one receiver flow condition from the test matrix.
10. Wait until flow and temperatures stabilize; record data
11. Open receiver door; repeat step 10
12. Add heliostats until receiver inlet (TE-101) and outlet (TE-102) temperatures become equal
13. Repeat step 10
14. Repeat steps 9 through 13 for the remaining receiver flows in the test matrix

Pretest Conditions (Receiver Performance Tests):

- o RS2; receiver drained with trace heat on
- o TSS2; hot and cold salt tanks warm and ready for operation
- o Temperature of salt in cold tank: approximately 590^{o}F
- o SGS2; SGS warm and salt drained (diurnal shutdown)
- o Clear day

Test Matrix (Receiver Performance Tests)

Receiver Power Level (% of Full Rating)	Receiver Outlet Temperature (^{o}F)
25	1050
50	1050
75	1050
100	1050
75	935
50	820

Test Sequence (Receiver Performance Tests):

1. SGS2 to SGS4; warm and salt drained to SGS operating in boiler following control mode at 30% of rated output
2. RS2 to RS3; pre-test checklists to warm-up heliostats
3. RS3 to RS4; warm-up heliostats to cold flow through receiver
4. Set receiver flow for one case in test matrix
5. RS4 to RS7; set receiver outlet salt temperature setpoint to value of test case from test matrix
6. Adjust SGS salt flow as required to maintain levels in hot and cold salt tanks and outlet salt temperature of 590°F
7. Wait until receiver flow and temperatures stabilize; record data
8. Repeat steps 4 through 7 for remaining cases in test matrix
9. RS7 to RS2; full flow temperature control to shutdown and drained
10. SGS4 to SGS2; SGS operating in boiler following mode to warm and salt drained

Success Criteria:

- o Successful operation of receiver throughout all tests
- o Instruments stay within calibration throughout test
- o Specified data collected and recorded

Primary Data Requirements:

- o Ambient air temperature, barometric pressure, relative humidity, wind speed and direction
- o Number of heliostats on target

RECORD DATA AT ONE-MINUTE INTERVALS FOR 10 MIN. AFTER STEADY STATE CONDITIONS ARE OBTAINED.

- o Pyroheliometer readings
- o Receiver salt inlet temperature (TE-101)
- o Receiver salt outlet temperature (TE-102)
- o Receiver salt flow rate (FT-101)
- o Receiver panel back tube temperatures (TE-103 through TE-120 and TE-131 through TE-148)
- o Cold surge tank pressure (PT-182)
- o Cold surge tank level (LT-151)
- o Receiver salt inlet pressure (PT-181)
- o Receiver subsystem heat trace circuit current readings

- Cold salt sump pump and cold salt boost pump current readings
- Hot salt surge tank level (LT-161)
- Cold salt storage tank heat trace current readings
- Cold salt storage tank temperatures
  (TE-281, TE-282 and TE-283)
- Cold salt storage tank level (LT-281)
- Hot salt storage tank temperatures
  (TE-291, TE-292 and TE-293)
- Hot salt storage tank level (LT-291)
- Cold salt pump and cold salt boost pump outlet pressures
  (PT-281 and PT-280)

5.3 TEST II-2 - POWER PRODUCTION SUBSYSTEMS PERFORMANCE

Description:

- o Run steam generator and turbine/generator at full and partial loads

Objectives:

- o Determine steady state performance for full and part load operation
- o Determine system responses and controllability at partial flow conditions

Calibration:

- o Calibrate FT-382 and FT-321 together
- o Check readings of FT-311 against FT-411 with constant drum level and pressures; remove and bench test both units if readings are different (more than 3%)

Pretest Conditions:

- o RS2; receiver drained with trace heat on
- o TSS2; hot and cold salt tanks warm and ready for operation (at least 50% salt inventory in hot tank at a temperature of 900^{o}F or above)
- o SGS2; SGS warm and salt drained (diurnal shutdown)
- o EPGS2; turbine standby - pumps on

Test Sequence:

1. SGS2 to SGS4; warm and salt drained to SGS operating in boiler-following control mode at 30% of rated output
2. EPGS2 to EPGS3; turbine standby to operating offline
3. EPGS3 to EPGS4; turbine generator operating offline to operating synchronized
4. Increase generator power to 225 kW_e at a rate of 75 kW_e per minute or less and stabilize
5. SGS4 to SGS5; SGS operating in boiler-following control mode to operating in turbine following mode
6. RS2 to RS7; set outlet temperature setpoint (TE-102) to 1050^{o}F
7. Adjust heliostat field to maintain levels in hot and cold salt tanks

ALTERNATE TO STEPS 6 AND 7: OPERATE PROPANE HEATER TO MAINTAIN HOT SALT INVENTORY

8. Wait until hot salt supplied to SGS is at least 1000^{o}F
9. Increase power to 250 kW_e at a rate of 75 kW_e per minute or less and stabilize; record data
10. Increase power to 500 kW_e at a rate of 75 kW_e per minute or less, repeat step 7 and stabilize; record data
11. Increase power to 750 kW_e at a rate of 75 kW_e per minute or less, repeat step 7 and stabilize; record data
12. Decrease power to 500 kW_e at a rate of 75 kW_e per minute or less, repeat step 7 and stabilize; record data
13. Decrease power to 250 kW_e at a rate of 75 kW_e per minute or less, repeat step 7 and stabilize; record data
14. SGS5 to SGS4; SGS operating in turbine following mode to operating in boiler-following mode
15. RS7 to RS2; shut down and drain receiver
16. EPGS4 to EPGS2; decrease power from generator to zero at a rate of 10% per minute or less
17. EPGS2 to EPGS1; turbine standby to shutdown
18. SGS4 to SGS2; SGS operating in boiler-following control mode to warm and salt drained

Success Criteria:

- o Successful operation of system at full and part load
- o Controls behavior acceptable
- o Specified data collected and recorded

Primary Data Requirements:

- o Ambient air temperature, barometric pressure, relative humidity, wind speed and direction

RECORD DATA AT ONE MIN. INTERVALS FOR 10 MIN. AFTER STEADY STATE CONDITIONS ARE REACHED;

- o Hot salt storage tank temperatures (TE-291, TE-292, and TE-293)
- o Cold salt storage tank temperatures (TE-281, TE-282, and TE-283)
- o Superheater salt inlet temperature (TE-382)
- o Superheater salt inlet pressure (PT-382)

- Evaporator salt inlet temperature (TE-301)
- Evaporator salt outlet temperature (TE-384)
- Evaporator salt outlet pressure (PT-384)
- SGS cold salt flow rate (FT-382)
- SGS total salt flow rate (FT-321)
- Feedwater inlet temperature (TE-386)
- Feedwater inlet pressure (PT-386)
- Feedwater inlet flow rate (FT-411)
- Steam drum water level (LT-311)
- Steam drum pressure (PT-383)
- Steam drum temperature (TE-383)
- Superheater outlet steam temperature (TE-331)
- Attemperator saturated steam flow rate (FT-381)
- SGS outlet steam temperature (TE-332)
- SGS outlet steam pressure (PT-321)
- SGS outlet steam flow rate (FT-311)
- Turbine inlet steam pressure (PT-581)
- Turbine inlet steam temperature (TE-583)
- Deaerator steam inlet temperature (TE-483)
- Deaerator steam inlet pressure (PT-431)
- Condensor steam inlet temperature (TI-581) (Record manually)
- Condensor steam pressure (PT-502)
- Hot well level (LT-511)
- Deaerator level (LT-471)
- Deaerator pressure (PT-432)
- Deaerator steam temperature (TE-481)
- Deaerator water temperature (TE-451)
- Deaerator outlet flow (FT-481)
- Feedwater heater outlet temperature (TE-421)
- Feedwater heater outlet pressure (PT-483)
- Generator speed (ST-582)
- Generator watt meter reading (JT-581)
- Generator voltage (ET-581)
- Generator current (IT-581)
- Generator VARS (VT-581)
- Generator power factor (PFT-581)
- All motor currents (Record manually)
- SGS heat trace currents

5.4 TEST II-3 - TRANSIENT RESPONSE OF RECEIVER LOOP

Description:

- o Operate receiver loop through progressively faster ramp increases in power

Objectives:

- o Develop map of system response to flux transients
- o Verify controls response to fast transients and adjust controllers if required
- o Develop limits of sun tracking through cloud passage
- o Develop minimum receiver start-up time

Pretest Conditions:

- o RS2; receiver drained with trace heat on
- o TSS2; hot and cold salt tanks warm and ready for operation (at least 70% salt inventory in cold tank)
- o SGS2; SGS warm and salt drained (diurnal shutdown)
- o EPGS; not applicable
- o Clear day

Test Sequence (Repeated from different initial conditions of salt flow rate, power and receiver outlet temperature and with different ramp rates in power and final power level; these test cases are given in Table 5-1)

1. RS2 to RS3; pre-test checklists to warm-up heliostats
2. RS3 to RS4; warm-up heliostats to cold flow through receiver
3. Establish salt flow through the receiver of 60,000 lb/hr
4. Bring all heliostats to be used for test case to near standby
5. RS4 to RS6; bring 25 percent of heliostat field onto the receiver
6. RS6 to RS7; set receiver outlet temperature control setpoint to value given in column A of Table 5-1. (Start with case 1)
7. Allow salt flow to stabilize and control at this outlet temperature
8. Add number of heliostats given in column B at the interval from column C for the particular test case

9. Monitor receiver temperatures
10. Monitor receiver control response
11. Allow receiver temperatures and salt flow rate to stabilize
12. Repeat previous four steps until the total number of increments given in column D have been added
13. Operate SGS and HRFS as necessary to reject heat and maintain cold salt inventory in cold storage tank

CRITERIA FOR SUCCESSFUL COMPLETION OF TEST AND PROGRESSION TO SUCCEEDING TEST CASE

A. Stable control of receiver outlet temperature as defined in MCS specification
B. Outlet temperature never exceeds $1070^{o}F$
C. Back tube temperatures stay within limits
D. Surge tank levels remain within limits.

14. Reduce number of heliostats on target to 25 percent of field
15. Repeat previous steps for next test case if criteria above have been successfully met.
16. RS7 to RS2; shut down and drain receiver
17. SGS (if operated) to SGS2

Success Criteria

- Successful determination of maximum transient capability of receiver
- Data system operational throughout tests and specified data recorded
- Controllability of receiver during flux transients

Primary Data Requirements;

- Ambient air temperature, barometric pressure, relative humidity, wind speed and direction

DATA ARE TO BE TAKEN CONTINUOUSLY THROUGH TESTING

- Number of heliostats on target
- Hot salt storage tank temperatures (TE-291, TE-292, and TE-293)
- Hot salt storage tank level (LT-291)

- o Riser heat trace current readings
- o Downcomer heat trace current readings
- o Receiver heat trace current readings
- o Cold salt sump pump, and cold salt boost pump current readings

THE FOLLOWING DATA ARE TO BE TAKEN AT MAXIMUM UPDATE RATE

- o Pyroheliometer readings
- o Receiver salt inlet temperature (TE-101)
- o Receiver salt outlet temperature (TE-102)
- o Receiver salt flow rate (FT-101)
- o Receiver back tube temperatures
  (TE-103 through TE-120 and TE-131 through TE-148)
- o Cold salt surge tank pressure (PT-182)
- o Cold salt surge tank level (LT-151)
- o Receiver salt inlet pressure (PT-181)
- o Hot surge tank level (LT-161)
- o Hot surge tank temperature (TE-183)
- o Downcomer exit salt temperature (TE-161)
- o Cold salt storage tank temperatures
  (TE-281, TE-282, TE-283)
- o Cold salt storage tank level (LT-281)
- o Cold salt storage tank heat trace current readings

Table 5-1

Description of Test Cases

Test Case No.	A Receiver Outlet Set Point (°F)	B Heliostat Increment Size (% of Field)	C Interval between Additions (sec)	D No. of Incre-ments	E Final Heliostats on Target (% of Field)
1	820	12.5	120	2	50
2	820	12.5	60	2	50
3	820	12.5	30	2	50
4	820	12.5	10	2	50
5	820	25	NA	1	50
6	940	12.5	120	4	75
7	940	12.5	60	4	75
8	940	12.5	30	4	75
9	940	12.5	10	4	75
10	940	25	30	2	75
11	940	25	10	2	75
12	940	50	NA	1	75
13	1050	12.5	120	6	100
14	1050	12.5	60	6	100
15	1050	12.5	30	6	100
16	1050	12.5	10	6	100
17	1050	25	30	3	100
18	1050	25	10	3	100
19	1050	50	30	2	100
20	1050	50	10	2	100
21	1050	75	NA	1	100

5.5 TEST II-4 - OVERNIGHT THERMAL CONDITIONING OF FILLED RECEIVER

Description:

- o Maintain filled receiver warm with the door closed by pulsing salt flow through the receiver from the cold surge tank and replenishing cold surge tank level, when required, with the pump.

Objectives:

- o Determine most efficient operations to maintain the receiver in the filled, warm condition overnight

Pretest Conditions:

- o RS2; receiver drained with trace heat on
- o TSS2; at least 40 percent of salt inventory in cold tank at temperature of 590°F or above
- o Sufficient insolation for warm-up heliostats

Test Sequence:

1. RS2 to RS3; receiver drained to warm up heliostats
2. RS3 to RS4; receiver cold flow
3. RS4 to RS5; receiver cold flow with door closed and heliostats off
4. Stop receiver salt flow (close FCV-101 and FCV-102); start timer and data recording
5. Verify cold tank level (LT-151) is at least 85 inches
6. Isolate cold surge tank (close FCV-151)
7. When minimum receiver temperature reaches 530°F, pulse flow through receiver from cold surge tank using FCV-101 or FCV-102 (vary size of pulse for different test cases)
8. Repeat step 7 until cold surge tank level (LT-151) reaches 20 inches
9. Fill cold surge tank with cold salt as required to replenish level to 85 inches by opening FCV-151
10. Repeat steps 8 through 10 for duration of test
11. RS5 to RS2; shut down and drain receiver

Success Criteria;

- o Salt-filled receiver maintained warm in a simulated overnight hold condition
- o Specified data collected and recorded

Primary Data Requirements:

- o Ambient air temperature, barometric pressure, relative humidity, wind speed and direction

DATA TO BE TAKEN THROUGHOUT TEST AT 1 MINUTE INTERVALS

- o Receiver salt inlet temperature (TE-101)
- o Receiver salt outlet temperature (TE-102)
- o Receiver back tube temperatures (TE-103 through TE-120 and TE-131 through TE-148
- o Receiver salt inlet pressure (PT-181)
- o Hot surge tank level (LT-161)
- o Hot surge tank temperature (TE-183)
- o Cold surge tank level (LT-151)
- o Cold surge tank pressure (PT-182)
- o Cold surge tank temperature (TE-182)
- o Receiver downcomer outlet temperature (TE-161)
- o Receiver and cold salt boost pump discharge pressure (PT-180)
- o Cold salt storage tank temperatures (TE-281, TE-282 and TE-283)

DATA TO BE TAKEN AT MAXIMUM UPDATE RATE OF ACUREX

- o Cold salt storage tank heat trace currents
- o Receiver heat trace currents
- o Riser and downcomer heat trace currents
- o Receiver hot and cold surge tank heat trace currents
- o Cold sump and cold salt boost pump heat trace currents
- o Receiver header temperatures

DATA TO BE RECORDED MANUALLY

- o Time, duration and current readings for salt pump operation

5.6 TEST II-5 - OVERNIGHT HOLD CONDITIONS FOR SGS

Description:

- o Hold SGS warm and filled with salt in diurnal shutdown condition

Objectives:

- o Compare diurnal hold using salt for thermal input with the baseline electrical heater

Pretest Conditions:

- o Receiver - NA
- o TSS2; at least 40 percent of salt inventory in cold tank at temperature of 590°F or above
- o EPGS - NA
- o SGS2; diurnal shutdown

Test Sequence:

1. SGS2 to SGS3; diurnal shutdown to cold salt flow
2. Establish drum level (LT-311) of 6 inches at drum pressure (PT-383) of 1200 psi
3. Isolate steam generator (shut FCV-341, FCV-411 and FCV-491), verify that FCV-301 is closed
4. Maintain bypass of electric heater (FCV-383 open, FCV-384 closed)
5. Monitor drum pressure (PT-383) and temperature (TE-383) and all salt loop temperatures on Acurex
6. Pulse salt flow through SGS by opening FCV-341 when any monitored Acurex temperature or TE-383 drops to 530°F (vary duration of pulse for different test runs)
7. Repeat step 6 for duration of test
8. SGS3 to SGS2; steam generator to normal diurnal shutdown

Success Criteria:

- o Maintained warm diurnal shutdown condition for at least 6 hours using pulsed salt flow
- o Collected specified data for comparison with baseline case

Primary Data Requirements:

- o Ambient air temperature, barometric pressure, relative humidity, wind speed and direction

FOLLOWING DATA WILL BE TAKEN CONTINUOUSLY THROUGH TEST AT 1 MIN. INTERVALS

- o SGS salt lines, valve, and equipment shell temperatures on Acurex data logger (channels 200 through 274)
- o Cold salt storage tank level (LT-281)
- o Cold salt storage tank temperatures (TE-281, TE-282, and TE-283)
- o Cold salt sump pump temperature (TE-286)
- o Cold salt sump pump level (LT-201)
- o Superheater salt inlet temperature (TE-382)
- o Superheater salt inlet pressure (PT-382)
- o Evaporator salt inlet temperature (TE-301)
- o Evaporator salt outlet temperature (TE-384)
- o Evaporator salt outlet pressure (PT-384)
- o Superheater outlet steam pressure (PT-321)
- o Steam drum temperature (TE-383)
- o Steam drum pressure (PT-383)
- o Steam drum level (LT-311)

DATA TO BE RECORDED MANUALLY

- o Time, duration and current readings for salt pump operation
- o All SGS heat trace current readings
- o Current reading for BWCP

5.7 TEST II-6 - OPTIMUM OPERATING STRATEGY DEVELOPMENT

Description:

- o Operate full MSEE to collect maximum net energy within the operating constraints identified in the preceding five tests

Objectives:

- o Develop operating strategy which maximizes net plant output
- o Develop data to be used to specify requirements for plant configuration, components and controls which would improve net plant output

Pretest Conditions:

- o To be determined from prior tests

Test Sequence:

- o To be determined from prior tests

Success Criteria:

- o Developed optimum operating strategy
- o Obtained data for improvement of plant output

Primary Data Requirements:

DATA TO BE RECORDED AT 1 MINUTE INTERVALS

- o Pyroheliometer readings
- o Receiver salt inlet temperature (TE-101)
- o Receiver salt outlet temperature (TE-102)
- o Receiver salt flow rate (FT-101)
- o Downcomer salt exit temperature (TE-161)
- o Hot salt storage tank level (LT-291)
- o Hot salt storage tank temperatures (TE-291, TE-292, and TE-293)
- o Cold salt storage tank level (LT-281)
- o Cold salt storage tank temperatures (TE-281, TE-282, and TE-283)
- o SGS cold salt flow rate (FT-382)

- SGS total salt flow rate (FT-321)
- Superheater salt inlet temperature (TE-382)
- Superheater salt inlet pressure (PT-382)
- Evaporator salt inlet temperature (TE-301)
- Evaporator salt outlet temperature (TE-384)
- Evaporator salt outlet pressure (PT-384)
- Feedwater flow rate (FT-411)
- Feedwater temperature (TE-386)
- Feedwater pressure (PT-386)
- SGS steam exit temperature (TE-332)
- SGS steam exit pressure (PT-321)
- SGS steam exit flow rate (FT-311)
- Turbine inlet steam temperature (TE-583)
- Turbine inlet steam pressure (PT-581)
- Condenser steam pressure (PT-502)
- Deaerator pressure (PT-432)
- Deaerator temperature (TE-451)
- Generator output voltage (ET-581)
- Generator speed (ST-582)
- Generator output wattage (JT-581)
- Generator current (IT-581)
- Generator VARS (VT-581)
- Generator power factor (PFT-581)

DATA TO BE RECORDED MANUALLY

- Pyroheliometer readings
- Ambient air temperature, barometric pressure, relative humidity, wind speed and direction
- Number of heliostats on target
- Receiver subsystem heat trace currents readings
- TSS heat trace currents readings
- SGS heat trace currents readings
- HRFS heater currents readings
- Receiver subsystem motor currents
- TSS motor currents
- SGS motor currents
- HRFS motor currents
- EPGS motor currents
- Turbine outlet steam temperature (TI-581)

5.8 TEST II-7 - RECEIVER COLD FLOW

Description:

- o Use warm-up heliostats on the receiver and flow cold salt through the receiver back to the cold salt tank.

Objectives:

- o Verify operation of receiver loop equipment, controls, and EPS
- o Confirm that surge tank provides emergency coolant to the receiver under all conditions.
- o Confirm procedures to accomplish start-up, shutdown, and emergency shutdown.
- o Confirm operation and interfaces of data system.

Pretest Conditions:

- o RS2; receiver drained with trace heat on
- o TSS2; hot and cold salt tanks warm and ready for operation
- o SGS not applicable
- o EPGS not applicable

Test Sequence:

1. RS2 to RS3; pre-test checklists to warm-up heliostats
2. RS3 to RS4; warm-up heliostats to cold flow through receiver
3. RS4 to RS5; cold flow through receiver with receiver door closed
4. Increase flow to 30%, stabilize and confirm level controls of hot and cold surge tanks
5. Increase flow to 50%, restabilize and reconfirm level controls
6. Increase flow to 100%, restabilize and reconfirm level controls
7. RS5 to RS2; cold flow through receiver to receiver drained, confirm shutdown
8. Repeat steps 1 and 2
9. Increase flow to 100%, stabilize and confirm level controls of hot and cold surge tanks
10. Initiate EPS trip by shutting off salt pumps. Confirm conditions of system following trip.
11. Complete transition to shutdown (RS2).

Success Criteria:

- o Successful operation of equipment and controls
- o Safe shutdown by EPS
- o Data system operational

Primary Data Requirements:

- o Ambient air temperature, barometric pressure, relative humidity, wind speed and direction
- o Number of heliostats on target

DATA TO BE LOGGED THROUGH TEST

- o Cold salt storage tank heat trace currents
- o Receiver heat trace currents
- o Receiver hot and cold surge tank heat trace currents
- o Riser and downcomer heat trace currents
- o Cold salt pump and cold salt booster pump heat trace currents

DATA TO BE RECORDED ON 2 MIN UPDATES

- o Pyroheliometer readings
- o Cold salt pump outlet pressure (PT-280)
- o Boost pump outlet pressure (PT-180)
- o Cold salt surge tank pressure (PT-182)
- o Receiver salt inlet pressure (PT-181)
- o Receiver salt inlet temperature (TE-101)
- o Receiver salt inlet flow rate (FT-101)
- o Receiver salt outlet temperature (TE-102)
- o Cold salt surge tank level (LT-151)
- o Hot salt surge tank level (LT-161)

5.9 TEST II-8 - RECEIVER STEADY STATE OPERATION

Description:

- o Focus heliostats on the receiver and heat salt from the cold tank through the receiver and return it to the hot salt tank

Objectives:

- o Verify operation of receiver loop equipment, controls, and EMCON alarms at rated receiver outlet temperature.
- o Confirm automatic switchover of TSS storage tanks accepting receiver outlet flow.

Pretest Conditions:

- o RS2; receiver drained with trace heat on
- o TSS2; hot and cold salt tanks warm and ready for operation (90% salt inventory in cold tank)
- o SGS not applicable
- o EPGS not applicable

Test Sequence:

1. RS2 to RS3; pre-test checklists to warm-up heliostats
2. RS3 to RS4; warm-up heliostats to cold flow through receiver
3. Increase flow to 50%
4. Set EMCON alarm on salt outlet temperature to 700°F
5. Increase heliostat field to 12.5% and stabilize
6. Reduce flow in 10% increments until salt outlet temperature exceeds 700°F
7. Confirm function of alarm
8. Reset EMCON alarm to 1060°F
9. Increase flow to 100%
10. RS4 to RS6; increase heliostat field to 25% in 12.5% increments
11. Stabilize and confirm salt outlet temperature
12. Reduce flow to 50%
13. Stabilize and confirm salt outlet temperature and flow switchover to hot tank

14. Increase flow back to 100%

15. Stabilize and confirm salt outlet temp and flow switchback to cold tank

16. Increase heliostat field to 50% in 12.5% increments

17. Stabilize and confirm salt outlet temperature and flow switchover to hot tank

18. RS6 to RS7; input receiver outlet salt temperature setpoint of 850^{O}F and stabilize

19. Increase setpoint to 950^{O}F and stabilize

20. Increase heliostat field to 75% in 12.5% increments and stabilize

21. Increase setpoint to 1050^{O}F and stabilize

22. Increase heliostat field to 100% in 12.5% increments and stabilize

23. RS7 to RS2; full flow temperature control to shutdown

Success Criteria:

- o Successful operation of equipment and controls
- o Successful automatic switchover of cold salt tank flow into hot salt tank flow
- o Confirmed functioning of receiver outlet temperature alarm

Primary Data Requirements:

- o Ambient air temperature, barometric pressure, relative humidity, wind speedf and direction

DATA TO BE LOGGED THROUGHOUT TEST

- o Number of heliostats on target
- o Receiver subsystem heat trace circuits currents
- o TSS heat trace circuits currents
- o Cold sump pump and cold salt boost pump currents

DATA TO BE CONTINUOUSLY RECORDED AT 2 MIN. INTERVALS

- o Pyroheliometer readings
- o Receiver salt inlet temperature (TE-101)
- o Receiver salt inlet pressure (PT-181)
- o Receiver salt outlet temperature (TE-102)

- Receiver back tube temperatures
  (TE-103 through TE-120, and TE-131 through TE-148)
- Cold salt surge tank pressure (PT-182)
- Cold salt surge tank temperature (TE-182)
- Cold salt surge tank level (LT-151)
- Hot salt surge tank temperature (TE-183)
- Hot salt surge tank level (LT-161)
- Downcomer salt exit temperature (TE-161)
- Cold salt storage tank level (LT-281)
- Cold salt storage tank temperatures
  (TE-281, TE-282, and TE-283)
- Hot salt storage tank level (LT-291)
- Hot salt storage tank temperatures
  (TE-291, TE-292, and TE-293)
- Cold salt pump outlet pressure (PT-281)
- Cold salt boost pump outlet pressure (PT-180)

5.10 TEST II - 9 - RECEIVER OPERATION WITH SIMULATED (SLOW) CLOUD

Description:

- o During receiver loop operation, ramp heliostats off of the receiver and back on.

Objectives:

- o Verify system operation through simulated cloud passage
- o Confirm control stability through transients

Pretest Conditions:

- o RS2; Receiver drained with trace heat on
- o TSS2; Hot and cold salt tanks warm and ready for operation (at least 70% salt inventory in cold tank)
- o SGS Not applicable
- o EPGS Not applicable

Test Sequence:

1. RS2 to RS3; pre-test checklists to warm-up heliostats
2. RS3 to RS4; warm-up heliostats to cold flow through receiver
3. Increase flow to 100%
4. RS4 to RS6; increase heliostat field to 50% in 12.5% increments
5. RS6 to RS7; input receiver outlet salt temperature setpoint to 950 °F and stabilize
6. Decrease heliostat field to 25% in two steps of 12.5% per two minutes and stabilize
7. Increase heliostat field to 50% in two steps of 12.5% per two minutes and stabilize
8. RS7 to RS6; increase flow to 100%
9. Increase heliostat field to 75% in increments of 12.5% per 2 minutes
10. RS6 to RS7; input receiver outlet salt temperature setpoint of 950 °F and stabilize
11. Decrease heliostat field to 25% in increments of 12.5% per two minutes and stabilize
12. Increase heliostat field back to 75% at 12.5% per two minutes and stabilize
13. RS7 to RS6; increase flow to 100%
14. Increase heliostat field to 100% in increments of 12.5% per two minutes

15. RS6 to RS7; input receiver outlet salt temperature setpoint of 1050 F and stabilize

16. Decrease heliostat field to 25% in increments of 12.5% per two minutes and stabilize

17. Increase heliostat field back to 100% at a rate of 12.5% per two minutes and stabilize

18. RS7 to RS2; full flow temperature control to shutdown

Success Criteria:

- o Successful operation of equipment
- o Maintains control stability through transient conditions

Primary Data Requirements:

THESE DATA SHOULD BE RECORDED AT 2 MIN. INTERVALS

- o Pyroheliometer readings
- o Receiver salt inlet temperature (TE-101)
- o Receiver salt inlet pressure (PT-181)
- o Receiver salt outlet temperature (TE-102)
- o Receiver back tube temperatures (TE-103 through TE-120 and TE-131 through TE-148)
- o Receiver salt flow control valve commanded position (IE-101, IE-102) and actual position (ZT-101, XT-102)
- o Receiver salt flow rate (FT-101)
- o Cold salt surge tank level (LT-151)
- o Riser salt flow control valve commanded position (IE-151) and actual position (ZT-151)
- o Hot salt surge tank level (LT-161)
- o Downcomer salt flow control valves commanded positions (IE-161, IE-162) and actual positions (ZT-161, ZT-162)
- o Downcomer salt exit temperature (TE-161)
- o Cold salt storage tank level (LT-281)
- o Cold salt storage tank temperatures (TE-281, TE-282, and TE-283)
- o Hot salt storage tank level (LT-291)

- Hot salt storage tank temperatures (TE-291, TE-292, and TE-293)
- Cold sump level (LT-201)
- Cold sump level control valve positions commanded (IE-201) and actual (ZT-201)

RECORD THESE DATA IN TABLES

- Number of heliostats on target
- Ambient air temperature, barometric pressure, relative humidity, wind speed and direction

5.11 TEST II-10 - THERMAL STORAGE CHARGING WITH PROPANE HEATER

Description:

- o Charge the hot salt tank with hot salt using the propane heater

Objectives:

- o Verify operation of propane heater loop to provide hot salt to TSS hot tank

Pretest Conditions:

- o RS not applicable (booster pump off, sump and lines warm and FCV-151 closed)
- o TSS2; hot and cold salt tanks warm and ready for operation (at least 50% salt inventory in cold tank)
- o SGS not applicable
- o EPGS not applicable

Test Sequence:

1. TSS2 to TSS3; pre-test checklists to charging hot salt tank using propane heater
2. Charge hot tank to selected level and temperature
3. TSS3 to TSS2; charging hot salt tank to shutdown

Success Criteria:

- o Successful operation of propane heater and controls
- o Salt flow from cold tank through heater to hot tank
- o Data system operational

Primary Data Requirements:

- o Record ambient air temperature, barometric pressure, relative humidity, wind speed and direction

DATA TO BE CONTINUOUSLY RECORDED AT 2 MIN. INTERVALS

- o Cold salt storage tank level (LT-281)
- o Cold salt storage tank temperatures (TE-281, TE-282, and TE-283)
- o Hot salt storage tank level (LT-291)
- o Hot salt storage tank temperatures (TE-291, TE-292, and TE-293)

5.12 TEST II-11- STEAM GENERATOR AND HRFS STEADY STATE OPERATIONS

Description:

- o Use hot salt from TSS hot tank to generate steam using SGS; reject through HRFS.

Objectives:

- o Verify operation of SGS using hot salt from TSS.
- o Verify operation of HRFS to provide feedwater to SGS and to reject heat
- o Verify controls of these operations.
- o Verify that EPS functions and safes the system.
- o Confirm procedures to accomplish start-up, shutdown and emergency shutdown
- o Confirm operation and interfaces of data system.

Pretest Conditions:

- o RS; Not applicable
- o TSS2; Hot and cold salt tanks warm and ready for operation (at least 60% salt inventory in hot tank and at least 30% in cold tank)
- o SGS2; SGS warm and salt drained (diurnal shutdown)
- o EPGS; Not applicable

Test Sequence:

1. SGS2 to SGS3; warm and salt drained to cold salt flow through SGS and stabilize
2. SGS3 to SGS4; warm standby to operating in boiler following mode
3. Stabilize at 30% of rated output

4 Adjust steam drum level set point to high-high level (to initiate EPS trip)

5 Confirm EPS trip and confirm condition of system

6 Restart HRFS feedwater pump

7 Restart SGS and stabilize at 30% of rated output

8. Increase to 60% of rated output and stabilize
9. Increase to 100% of rated output and stabilize
10. SGS4 to SGS2; SGS operating in boiler following control to diurnal shutdown

Success Criteria:

- o Successful operation of equipment and controls
- o Safe shutdown by EPS
- o Data system operational

Primary Data Requirements:

- o Record ambient air temperature, barometric pressure, relative humidity, wind speed and direction

DATA TO BE CONTINUOUSLY RECORDED AT 2 MIN. INTERVALS

- o Hot salt storage tank level (LT-291)
- o Hot salt storage tank temperatures (TE-291, TE-292, and TE-293)
- o Cold salt storage tank level (LT-281)
- o Cold salt storage tank temperatures (TE-281, TE-282, and TE-283)
- o Superheater salt inlet temperature (TE-382)
- o Superheater salt inlet pressure (PT-382)
- o Evaporator salt inlet temperature (TE-301)
- o Evaporator salt outlet temperature (TE-384)
- o Evaporator salt outlet pressure (PT-384)
- o SGS cold salt flow rate (FT-382)
- o SGS total salt flow rate (FT-321)
- o SGS feedwater inlet pressure (PT-386)
- o SGS feedwater inlet temperature (TE-386)
- o SGS feedwater inlet flow rate (FT-411)
- o SGS steam exit temperture (TE-332)
- o SGS steam exit pressure (PT-321)
- o SGS steam exit flow rate (FT-311)
- o Attemperator steam flow rate (FT-381)
- o Superheater exit steam temperature (TE-331)
- o Steam drum pressure (PT-385)
- o Steam drum temperature (TE-383)
- o Steam drum level (LT-311)

5.13 TEST II-12- OPERATION OF FULL ELECTRIC LOOP

Description:

- o Use hot salt from TSS to generate steam.
- o Flow steam through EPGS at various loads to generate electricity.

Objectives:

- o Verify operation of turbine using steam from SGS, heat rejection through HRFS, and all auxiliary circuits.
- o Verify synchronization of turbine generator with utility grid
- o Confirm procedures for all operations including emergency shutdown
- o Confirm operation at 110% of rated output

Pretest Conditions:

- o TSS2; hot and cold salt tanks warm and ready for operation (at least 60% salt inventory in hot tank at 950°F)
- o SGS2; SGS warm and salt drained (diurnal shutdown)
- o EPGS2; EPGS pumps on (turbine standby)

Test Sequence:

1. SGS2 to SGS4; diurnal shutdown to SGS operating in automatic boiler following mode at 30% of rated output
2. EPGS2 to EPGS3; EPGS pumps on to operating in EPGS standby
3. EPGS3 to EPGS4; operating EPGS standby to operating EPGS on-line
4. Increase power to 225 kW_e at a rate of 75 kW_e per minute
5. SGS4 to SGS5; SGS operating in auto boiler following mode to operating in turbine following
6. Increase power from generator to 750 kW_e at a rate of 75 kW_e per minute and stabilize
7. Increase power to 825 kW_e at a rate of 75 kW_e per minute
8. Decrease power to 225 kW_e at a rate of 75 kW_e per minute
9. SGS5 to SGS4; SGS operating in turbine following to operating in auto boiler following
10. EPGS4 to EPGS2; decrease electric power to zero at 75 kW_e per minute
11. SGS4 to SGS2; SGS operating in auto boiler following to diurnal
12. EPGS2 to EPGS1; EPGS pumps on to shutdown

Success Criteria:

- o Successful operation of equipment and control
- o Data system operational

Primary Data Requirements

DATA TO BE CONTINUOUSLY RECORDED AT 2 MIN. INTERVALS

- o Record air temperature, barometric pressure, relative humidity, wind speed and direction
- o Hot salt storage tank level (LT-291)
- o Hot salt storage tank temperatures (TE-291, TE-292, and TE-293)
- o Cold salt storage tank level (LT-281)
- o Cold salt storage tank temperatures (TE-281, TE-282, and TE-283)
- o Superheater salt inlet pressure (PT-382)
- o Superheater salt inlet temperature (TE-382)
- o Evaporator salt inlet temperature (TE-301)
- o Evaporator salt outlet pressure (PT-384)
- o Evaporator salt outlet temperature (TE-384)
- o SGS cold salt flow rate (FT-382)
- o SGS total salt flow rate (FT-321)
- o SGS feedwater flow rate (FT-411)
- o SGS feedwater temperature (TE-386)
- o SGS feedwater pressure (PT-386)
- o SGS outlet steam flow rate (FT311)
- o SGS outlet steam temperature (TE-332)
- o SGS outlet steam pressure (PT-321)
- o Steam drum level (LT-311)
- o Steam drum temperature (TE-383)
- o Steam drum pressure (PT-383)
- o Turbine steam inlet pressure (PT-581)
- o Turbine steam inlet temperature (TE-583)
- o Condensor steam pressure (PT-502)
- o Deaerator pressure (PT-432)

- o Deaerator temperature (TE-451)
- o Generator voltage (ET-581)
- o Generator output wattage (JT-581)
- o Generator current (IT-581)
- o Generator VARS (VT-581)
- o Generator power factor (PFT-581)
- o Generator speed (ST-582)

5.14 TEST II-13 - SYSTEM STEADY STATE OPERATION; (USING RECEIVER)

Descriptión:

- o With all subsystems operational and integrated, use full heliostat field to produce rated power in the receiver.
- o Use this hot salt to produce electricity.

Objectives:

- o Confirm operation of full system through normal start-up, steady state, and shutdown operations.
- o Confirm subsystem interactions and interfaces
- o Verify MCS interlock automatic procedures
- o Confirm utility type operations

Pretest Conditions:

- o RS2; receiver drained with trace heat on
- o TSS2;hot and cold salt tanks warm and ready for operation (at least 90% salt inventory in cold tank)
- o SGS2; SGS warm and salt drained (diurnal shutdown)
- o EPGS2; EPGS pumps on

Test Sequence:

1. RS2 to RS3; pre-test checklists to warm-up heliostats
2. RS3 to RS4; warm-up heliostats to cold flow through receiver
3. Increase flow to 100%
4. RS4 to RS6; increase heliostat field to 100% in increments of 12.5% per two minutes
5. RS6 to RS7; set receiver outlet salt temperature setpoint to 1050°F and stabilize
6. Charge hot salt tank
7. SGS2 to SGS4; diurnal shutdown to SGS operating in automatic boiler following mode at 30% of rated output
8. EPGS2 to EPGS3; EPGS pumps on to operating in EPGS standby
9. EPGS3 to EPGS4; operating EPGS standby to operating EPGS on-line
10. Increase power to 225 kW_e at a rate of 75 kW_e per minute
11. SGS4 to SGS5; SGS operating in boiler following mode to operating in turbine following mode

12. Increase power from generator to 750 kW_e at a rate of 75 kW_e per minute and stabilize
13. SGS5 to SGS4; SGS operating in turbine following to operating in auto boiler following
14. EPGS4 to EPGS2; decrease power from generator to zero at a rate of 75 kW_e per minute to turbine
15. SGS4 to SGS2; SGS operating in auto boiler following to diurnal shutdown
16. EPGS2 to EPGS1; EPGS pumps on to shutdown
17. RS7 to RS2; Full flow temperature control to shutdown

Success Criteria:

- o Successful operation of all subsystems
- o Data system operational

Primary Data Requirements:

- o Record ambient air temperature, barometric pressure, relative humidity, wind speed and direction

DATA TO BE CONTINUOUSLY RECORDED AT 2 MIN. INTERVALS

- o Pyroheliometer reading
- o Receiver salt inlet temperature (TE-101)
- o Receiver salt inlet pressure (PT-181)
- o Receiver salt outlet temperature (TE-102)
- o Receiver salt flow (FT-101)
- o Receiver salt flow control valve positions
  Commanded (IE-101, IE-102)
  Actual (ZT-101, ZT-102)
- o Cold salt surge tank temperature (TE-182)
- o Cold salt surge tank level (LT-151)
- o Cold salt surge tank pressure (PT-182)
- o Hot salt surge tank temperature (TE-183)
- o Hot salt surge tank level (LT-161)
- o Downcomer salt exit temperature (TE-161)
- o Hot salt storage tank level (LT-291)
- o Hot salt storage tank temperatures (TE-291, TE-292, and TE-293)

- Cold salt storage tank level (LT-281)
- Cold salt storage tank temperatures (TE-281, TE-282, and TE-283)
- Superheater salt inlet temperature (TE-382)
- Superheater salt inlet pressure (PT-382)
- Evaporator salt exit temperature (TE-384)
- Evaporator salt exit pressure (PT-384)
- SGS cold salt flow rate (FT-382)
- SGS total salt flow rate (FT-321)
- SGS feedwater inlet pressure (PT-386)
- SGS feedwater inlet temperature (TE-386)
- SGS feedwater inlet flow rate (FT-411)
- SGS steam exit pressure (PT-321)
- SGS steam exit temperature (TE-332)
- SGS steam exit flow rate (FT-381)
- Turbine steam inlet pressure (PT-581)
- Turbine steam inlet temperature (TE-583)
- Condensor steam pressure (PT-502)
- Deaerator pressure (PT-432)
- Deaerator temperature (TE-451)
- Generator voltage (ET-581)
- Generator output wattage (JT-581)
- Generator current (IE-581)
- Generator VARS (VT-581)
- Generator power factor (PFT-581)
- Generator speed (ST-582)

5.15 TEST II-14- HYBRID OPERATION (USING PROPANE HEATER)

Description:

- o With all subsystems operational and integrated, except no insolation for the receiver, use the propane heater to generate hot salt to the hot tank
- o Use this hot salt to produce electricity

Objectives:

- o Confirm operation of full system through normal start-up, steady state, and shutdown operations.
- o Confirm subsystem interactions and interfaces
- o Verify MCS interlock automatic procedures

Pretest Conditions:

- o RS not applicable
- o TSS2; hot and cold salt tanks warm and ready for operation (at least 90% salt inventory in cold tank)
- o SGS2; SGS warm and salt drained (diurnal shutdown)
- o EPGS2; turbine standby - pumps on

Test Sequence:

1. TSS2 to TSS3; Pre-test checklists to charging hot salt tank using propane heater
2. SGS2 to SGS3; diurnal shutdown to SGS operating in automatic boiler following mode at 30% of rated output
3. EPGS2 to EPGS3; EPGS pumps on to operating in EPGS standby
4. EPGS3 to EPGS4; operating EPGS standby to operating EPGS on-line
5. Increase power to 225 kW_e at a rate of 75 kW_e per minute
6. SGS4 to SGS5; SGS operating in auto boiler following mode to operating in turbine following
7. Increase power from generator to 750 kW_e at a rate of 75 kW_e per minute and stabilize

8. SGS5 to SGS4; SGS operating in turbine following to operating in auto boiler following

9. EPGS4 to EPGS2; decrease power from generator to zero at a rate of 75 kW_e per minute to turbine

10. SGS4 to SGS2; SGS operating in auto boiler following to diurnal shutdown

11. TSS3 to TSS2; charging hot salt tank to shutdown

12. EPGS2 to EPGS1; EPGS pumps on to shutdown

<u>Success Criteria:</u>

- o Successful operation of all subsystems
- o Data system operational

<u>Primary Data Requirements:</u>

- o Ambient air temperature, barometric pressure, relative humidity, wind speed and direction

DATA TO BE CONTINUOUSLY RECORDED AT 2 MIN. INTERVALS

- o Hot salt storage tank level (LT-291)
- o Hot salt storage tank temperatures (TE-291, TE-292, and TE-293)
- o Cold salt storage tank level (LT-281)
- o Cold salt storage tank temperatures (TE-291, TE-292, and TE-293)
- o Superheater salt inlet pressure (PT-382)
- o Superheater salt inlet temperature (TE-382)
- o Evaporator salt outlet pressure (PT-384)
- o Evaporator salt outlet temperature (TE-384)
- o SGS cold salt flow rate (FT-382)
- o SGS total salt flow rate (FT-321)
- o SGS feedwater flow rate (FT-411)
- o SGS feedwater temperature (TE-386)
- o SGS feedwater pressure (PT-386)
- o SGS outlet steam flow rate (FT-311)
- o SGS outlet steam temperature (TE-332)

- SGS outlet steam pressure (PT-321)
- Steam drum level (LT-311)
- Steam drum temperature (TE-383)
- Steam drum pressure (PT-383)
- Turbine steam inlet pressure (PT-581)
- Turbine steam inlet temperature (TE-583)
- Condensor steam pressure (PT-502)
- Deaerator pressure (PT-432)
- Deaerator temperature (TE-451)
- Generator voltage (ET-581)
- Generator output wattage (JT-581)
- Generator current (IT-581)
- Generator VARS (VT-581)
- Generator power factor (PFT-581)
- Generator speed (ST-582)

5.16 TEST II-15 - SALT PROPERTIES AND STABILITY (supplied by Olin)

<u>Description:</u>

During the MSEE molten salt will be sampled and analyzed to determine if the composition of the molten salt has been altered. Both hot salt (900-1000°F) and cold salt (590°F) samples will be analyzed on a monthly basis.

<u>Test Objectives</u>

The test objectives are:

a. Determine if the salt composition has been altered (i.e., sodium - potassium ratio changed).

b. Determine if new components are building up in the salt (i.e., corrosion products).

c. Determine if new components are being formed in the salt (i.e., carbonates and hydroxide).

Components to be analyzed:

Ni, Fe, Al, Mo, Cr^{+3}, Cr^{+6}, Ca, Mg, Si, Cl, SO_4 CO_3, OH, $NaNO_2$, $NaNO_3$, KNO_3, CU

<u>Test Description</u>

The salt sampling will be performed twice a month throughout Phase II. Two samples will be obtained of the salt, a hot salt sample of the Olin corrosion test loop, and a cold salt sample from the cold salt storage tank. The salt samples will be shipped to Olin for analysis. Results of the salt analysis will be reported at 6-month intervals.

To verify analysis of the molten salt, one set of samples will be sent to an independent laboratory.

5.17 TEST II -16 - SALT CORROSION (supplied by Olin)

Description

The corrosion loop has been placed in the salt loop to provide corrosion data of various metal alloys in molten salt service. The corrosion rates of the metal alloys with hot salt (900-10009F) will be tested.

Test Objectives

a. Determine the corrosion rate of various metal alloys in hot molten salt service (900-10009F).
b. Determine the effects of thermal cycling on the corrosion rate of the metal alloys.
c. Determine the effects of molten salt velocity on the corrosion rate of the metal alloys.

Alloys to be tested:

Stainless Steels 316L, 304L, 430
Incoloy 800
Inconel 600, 625, 690

Test Description

The corrosion test loop will operate throughout Phase II of the MSEE. The test loop is integrated with the hot salt pump so the loop will operate while the hot salt pump operates. During Phase II one corrosion box will be removed from the test loop and the metal samples analyzed.

Section 6

SCHEDULE AND PRIORITIES

The schedule for Phase II tests is shown on Figure 6-1. It is based on completing Phase I by May 14, 1984. In the event that Phase I completion is delayed, the Phase II program will be shifted accordingly.

The Phase II tests are scheduled so that all engineering tests are completed prior to operation by the utility operator teams. The Part A tests, MSEE characterization, are scheduled for 12 weeks assuming an equipmen availability of 0.5.(exclusive oif solar availability). Part B and Part C tests are then developed and used for a trial team of engineers from the sponsors. Part B and Part C tests, incorporating improvements from the trial session, are then repeated for each of the four utility operator teams. All utility team operations is scheduled to be completed by November 16, 1984.

The Part A tests are grouped to provide alternative tests in the event of cloudy weather where possible. The performance tests under II-1 and II-2 can be intermixed so that test II-1 would be performed on sunny days and II-2 on cloudy days. Similarly, the overnight conditioning tests can be adjusted to match the sun's availability.

Part D, Salt Characteristics, tests are conducted throughout Phase II.

Part A, MSEE Characteristics, and Part D, Salt Characteristics, have been given first priority in this test program. This is due to:

1. The need to develop data on the performance and operating capability of the MSEE to support the technology development program for utility-scale power plants utilizing molten salt.

2. The desire of the utility sponsors to see reasonably reliable, routine operation prior to committing operator teams.

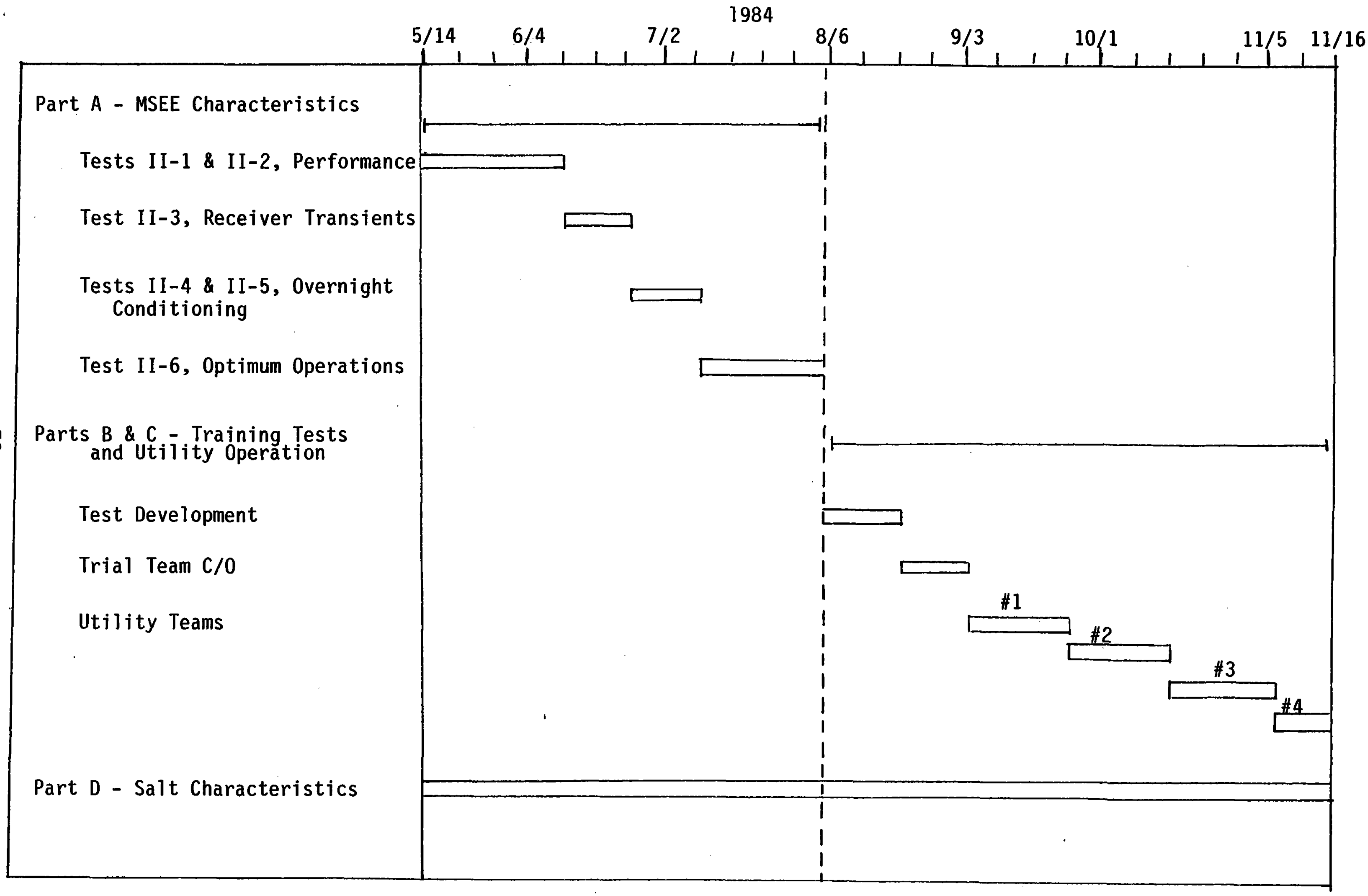

Figure 6-1. MSEE Phase II Test Schedule

Section 7
TEST DOCUMENTATION

7.1 TEST RECORDS AND DAILY LOG

The Test Conductor shall maintain a chronological and historical record of all significant events that transpire during the test. Events are to be recorded on the spot and later extracted to become part of the test report. The Test Conductor shall also keep a daily log with details of test progress, anomalies, deviations, significant results, etc. Log entries shall be made on a continual basis while tests are in progress, and daily during test downtime.

Each utility operator will keep a log of his daily activities which will be turned in to the Test Conductor at the end of each day.

7.2 PREPARATION OF TECHNICAL MEMORANDUM

A test report documenting the results of the tests shall be prepared and shall include, but not be limited to, the following:

A. Test hardware configuration

B. Test objectives

C. Description of test sequences

D. List of equipment used

E. Significant test data

F. Analysis of test data