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Molten Salt Electric Experiment Steam Generator Subsystem Final Report

Babcock & Wilcox
Nuclear Equipment Division
Barberton, Ohio

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MOLTEN SALT ELECTRIC EXPERIMENT
STEAM GENERATOR SUBSYSTEM
FINAL REPORT

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ABSTRACT

The Molten Salt Electric Experiment (MSEE) is a full-system demonstration of a solar central receiver power generation plant which uses molten nitrate salt as the primary heat transfer fluid and also as the thermal storage medium. The MSEE receiver has a thermal capacity of 5 MWt, and the turbine-generator is rated at 750 kWe. The system has a two-tank thermal storage subsystem with a capacity of 6 MW-hours, and a steam generator rated at 3.1 MWt. The MSEE began in mid-1982, and testing was completed in July 1985 at the Central Receiver Test Facility in Albuquerque, New Mexico. Babcock and Wilcox was awarded the contract to supply a steam generator for the MSEE capable of producing superheated steam using molten salt as a heat source. This report covers the design, fabrication, installation, and testing of the Steam Generation Subsytem beginning in September 1982 and ending in June 1984.

SOLAR THERMAL TECHNOLOGY
FOREWORD

The research and development described in this document was conducted within the U.S. Department of Energy's (DOE) Solar Thermal Technology Program. The goal of the Solar Thermal Technology Program is to advance the engineering and scientific understanding of solar thermal technology, and to establish the technology base from which private industry can develop solar thermal power production options for introduction into the competitive energy market.

Solar thermal technology concentrates solar radiation by means of tracking mirrors or lenses onto a receiver where the solar energy is absorbed as heat and converted into electricity or incorporated into products as process heat. The two primary solar thermal technologies, central receivers and distributed receivers, employ various point and line-focus optics to concentrate sunlight. Current central receiver systems use fields of heliostats (two-axis tracking mirrors) to focus the sun's radiant energy onto a single tower-mounted receiver. Parabolic dishes up to 17 meters in diameter track the sun in two axes and use mirrors or Fresnel lenses to focus radiant energy onto a receiver. Troughs and bowls are line-focus tracking reflectors that concentrate sunlight onto receiver tubes along their focal lines. Concentrating collector modules can be used alone or in a multi-module system. The concentrated radiant energy absorbed by the solar thermal receiver is transported to the conversion process by a circulating working fluid. Receiver temperatures range from 100°C in low-temperature troughs to over 1500°C in dish and central receiver systems.

The Solar Thermal Technology Program is directing efforts to advance and improve promising system concepts through the research and development of solar thermal materials, components, and subsystems, and the testing and performance evaluation of subsystems and systems. These efforts are carried out through the technical direction of DOE and its network of national laboratories who work with private industry. Together they have established a comprehensive, goal directed program to improve performance and provide technically proven options for eventual incorporation into the Nation's energy supply.

To be successful in contributing to an adequate national energy supply at reasonable cost, solar thermal energy must eventually be economically competitive with a variety of other energy sources. Components and system-level performance targets have been developed as quantitative program goals. The performance targets are used in planning research and development activities, measuring progress, assessing alternative technology options, and making optimal component developments. These targets will be pursued vigorously to insure a successful program.

The work described in this report falls under Task 11, System Experiments, of the Solar Thermal Technology Program. This report covers the design, fabrication, installation, and testing of the Steam Generator Subsystem of the Molten Salt Electric Experiment. This steam generator uses molten nitrate salt as a heat source to produce 3.1 MW of superheated steam to drive a conventional turbine-generator. The Molten Salt Electric Experiment is a full-system demonstration of a central receiver power plant that uses molten nitrate salt as both the primary heat transfer fluid and as the thermal storage medium. It is an important step toward the commercialization of solar thermal technology.

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1.0 INTRODUCTION AND SUMMARY

The objective of the Steam Generator Subsystem program for the Molten Salt Electric Experiment is to provide a reliable subsystem to generate superheated steam, using energy input from molten nitrate salt, for the purpose of verifying the feasibility of a molten salt central receiver electric system. An additional objective is to provide a control system for the Steam Generator Subsystem which can be integrated with the existing test facility control system such that automatic control for the entire Molten Salt Electric Experiment can be developed by Martin-Marietta Corporation and Sandia National Laboratories.

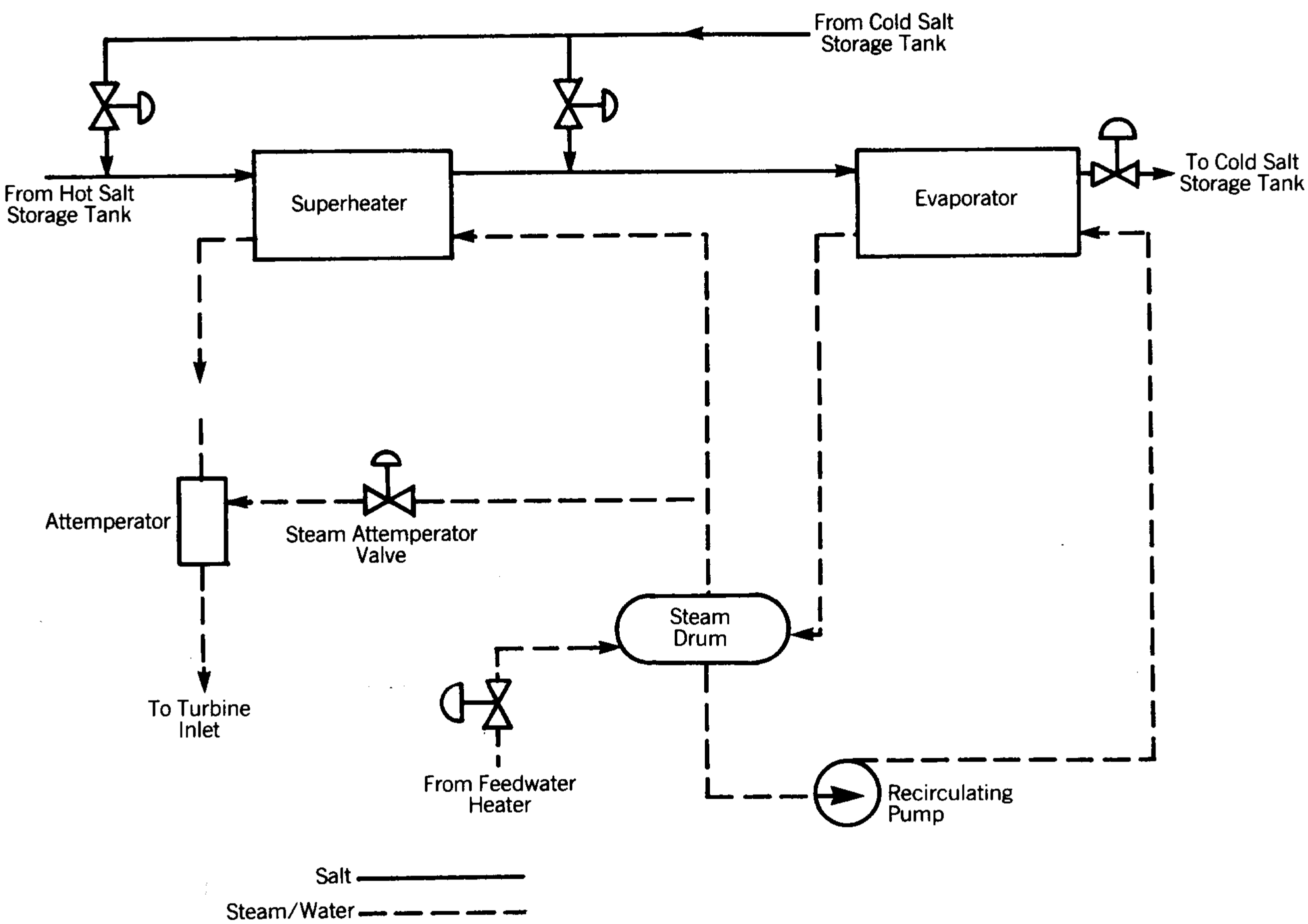
The design, material procurement, and fabrication of the Steam Generator Subsystem (SGS) took place between September of 1982 and May of 1983. The SGS is a skid mounted assembly which was shop-fabricated to the maximum extent possible prior to shipment to The Department of Energy's Central Receiver Test Facility (CRTF) in Albuquerque, New Mexico in May of 1983. Erection of the SGS, including all interface piping and wiring connections, and pre-operational checkout of the SGS took place from May of 1983 through August of 1983. Operational checkout testing and acceptance testing in accordance with SNL specification requirements were conducted between September of 1983 and May of 1984.

A simplified flow schematic of the Steam Generator Subsystem is shown on Figure 1.0-1. The SGS produces superheated steam at 1100 psig (7584 kPa) and 950°F (510°C) for delivery to the turbine in the Electric Power Generation Subsystem by a transfer of energy from molten salt flowing through the SGS superheater and evaporator. Molten salt entering the SGS at 1050°F (566°C) is pumped through the superheater, evaporator, and associated salt pumping, exiting the SGS at 580°F (304°C).

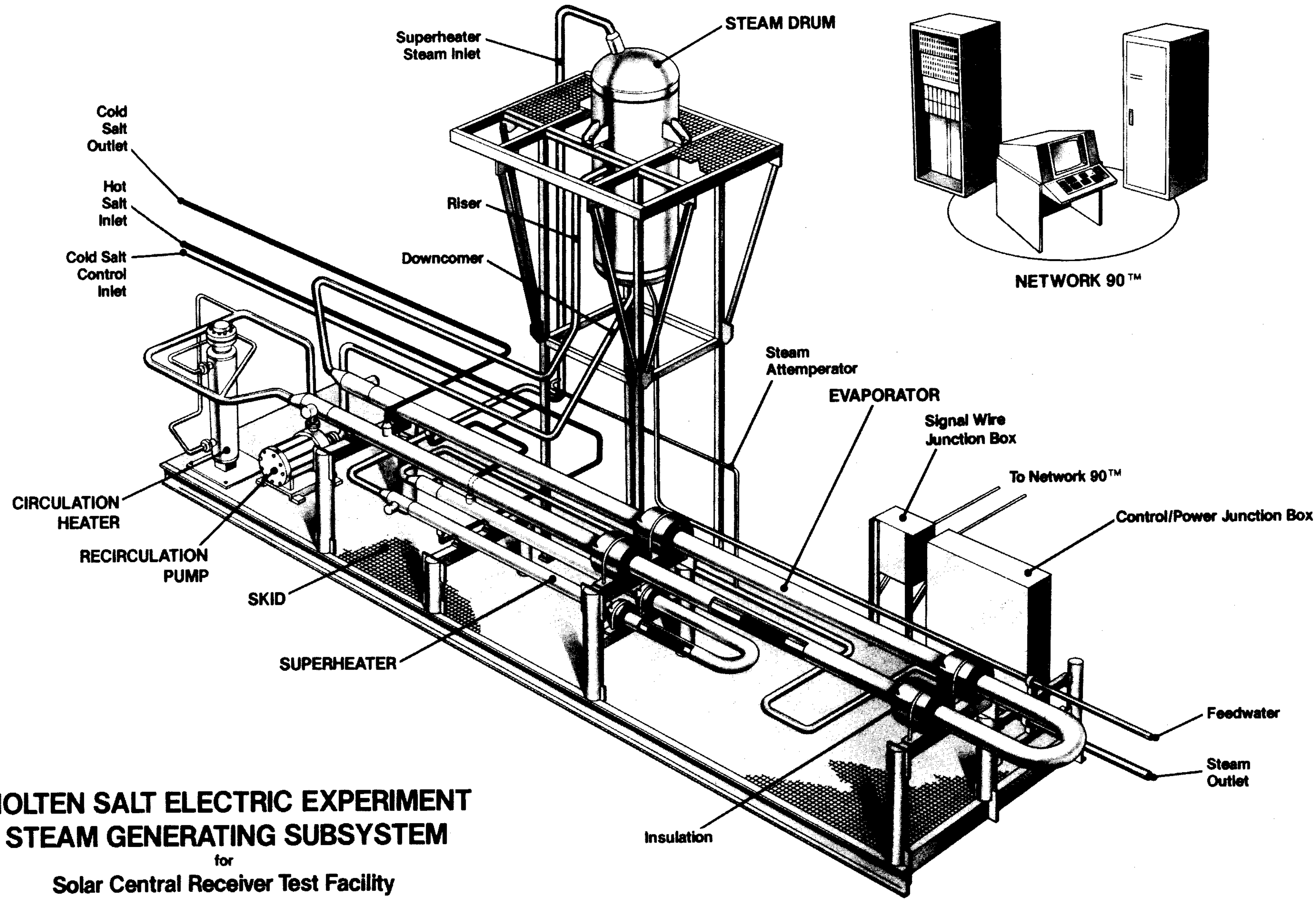
The flow of molten salt through the SGS is regulated to maintain the required steam delivery pressure. Salt from the cold salt storage tank is mixed with salt exiting from the superheater to control the evaporator salt inlet temperature to 850^{o}F (454^{o}C). Subcooled water from the steam drum is circulated by the boiler water circulation pump into the evaporator. The steam-water mixture generated in the evaporator flows to the steam drum. The dry saturated steam removed from the mixture by the steam drum separation equipment flows to the superheater where it is superheated to approximately 1000^{o}F (538^{o}C). Final adjustment of the superheated steam temperature flowing to the turbine to 950^{o}F (510^{o}C) is made by the steam attemperator which mixes saturated steam with the superheated steam exiting the superheater. Feedwater from the Heat Rejection and Feedwater Subsystem is added to the steam drum at a rate equal to steam flow to maintain a constant steam drum water level. An artist's rendering of the SGS showing the overall arrangement of the major subsystem components and piping is shown on Figure 1.0-2.

The Steam Generator Subsystem has performed well as an integral part of the Molten Salt Electric Experiment. The SGS successfully completed all steady-state and transient acceptance tests. Subsystem rated heat load has been exceeded by 8% at design steam delivery temperature and pressure. The SGS Network 90 control system has maintained the subsystem set point parameters constant during steady-state and power change transients. The Network 90 interfaces well with the CRTF EMCON control system, allowing operation of the SGS from either the Network 90 control console or the EMCON console.

This final report provides a review of the major phases of SGS activity: design, fabrication, installation, pre-operational checkout, operational checkout, and acceptance testing. This report also discusses the performance of the SGS and compares that performance to specification requirements.



Steam Generator Flow Schematic
Figure 1.0-1



MOLTEN SALT ELECTRIC EXPERIMENT
STEAM GENERATING SUBSYSTEM
for
Solar Central Receiver Test Facility

Babcock&Wilcox
a McDermott company

Figure 1.0-2

2.0 SGS DESIGN

2.1 General Description

The Steam Generator Subsystem has been designed in accordance with Sandia National Laboratories Document 81-5100 (Reference 1) to be an integral part of the Molten Salt Electric Experiment (MSEE) system. The complete system experiment has the objectives of verifying the feasibility of a molten salt central receiver system to produce electric power and developing the automatic controls for this system. The function of the Steam Generator Subsystem (SGS) is to generate superheated steam as required for operation of the MSEE system. The energy required to generate this steam is supplied by molten nitrate salt flowing through the SGS.

In addition to the SGS, the MSEE system consists of the following subsystems:

- Receiver Subsystem (RS)
- Thermal Storage Subsystem (TSS)
- Heat Rejection and Feedwater Subsystem (HRFS)
- Electric Power Generation Subsystem (EPGS)
- Master Control Subsystem (MCS)
- Collector Subsystem (CS)

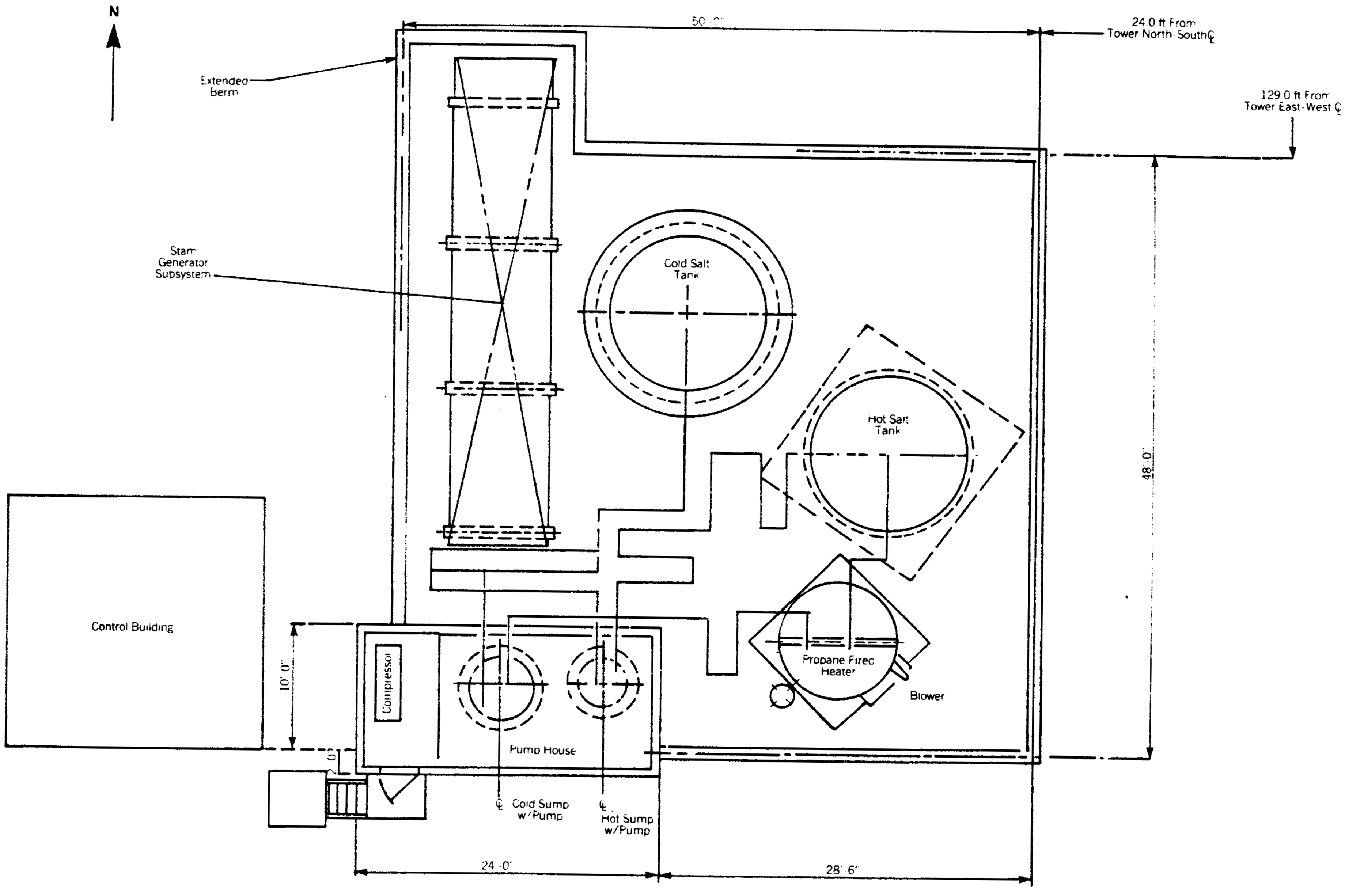
With the exception of the turbine-generator set portion of the EPGS, each of these subsystems was in place at the Central Receiver Test Facility in Albuquerque, New Mexico from previous experimental work. The addition of the SGS, together with changes to the existing subsystems, has upgraded the CRTF capability to perform the Molten Salt Electric Experiment.

The SGS consists of a superheater, evaporator, steam drum, salt and water/steam piping and valves, a boiler water circulation pump, a circulation heater, heat tracing, controls and instrumentation, and electrical equipment mounted on a structural steel skid assembly. The skid assembly is located within the berm of the thermal storage area at the CRTF. A general location plan is shown on Figure 2.1-1. The overall arrangement of the skid assembly is shown on B&W drawings 405331E, 405332E, 405333E, 405338E, and 405345E. The SGS is supplied with a Bailey Controls Company Network 90 control system. This system provides for direct control of the steam generator subsystem from either the Network 90 Operation Interface Unit (OIU) or from the EMCON control console in the CRTF main control room.

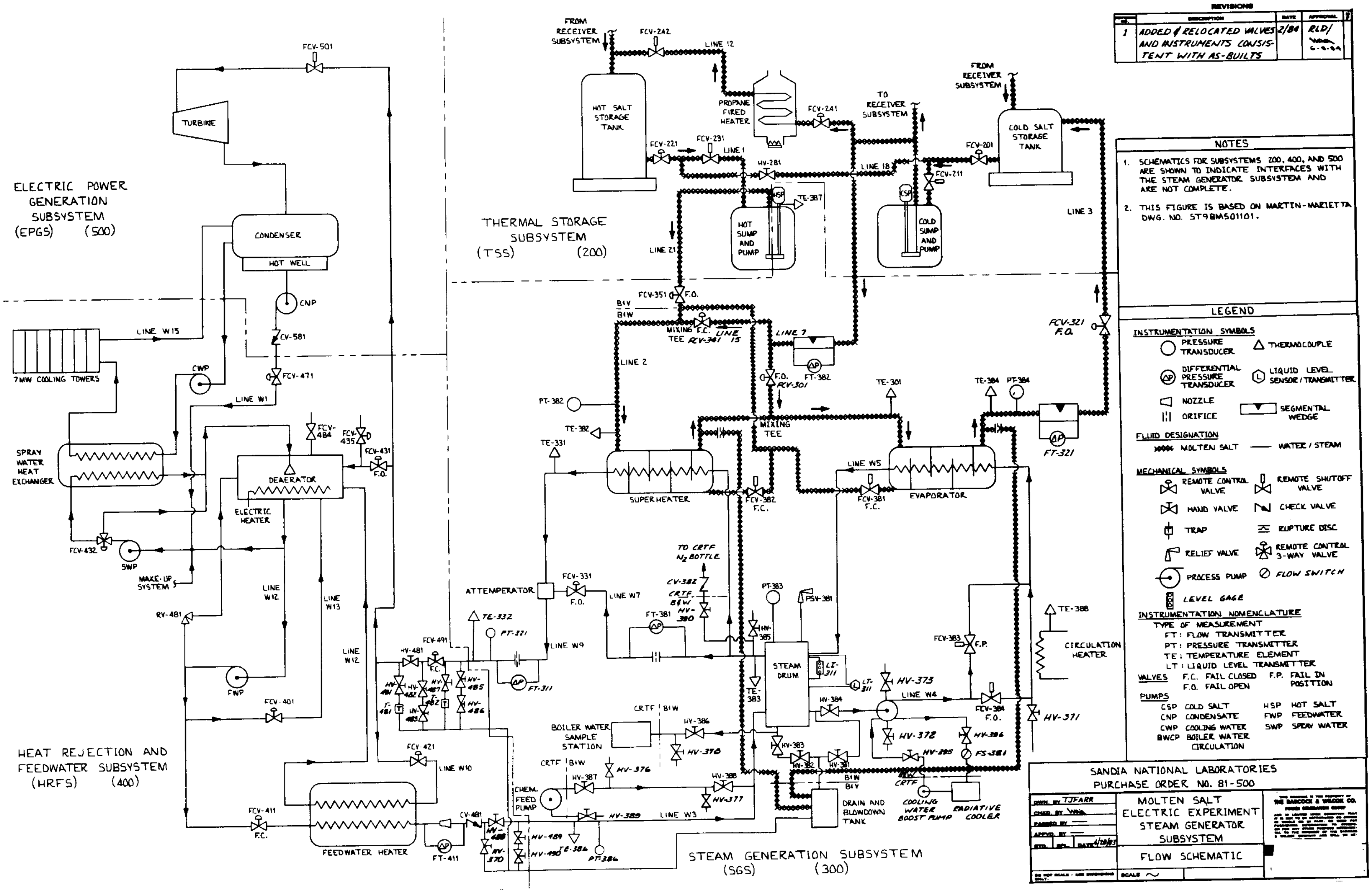
Radiant energy from the MSEE Collector Subsystem is input to the molten salt flowing through the solar receiver, where the salt temperature is increased from 580°F (304°C) to 1050°F (566°C). The receiver outlet flow is delivered to the TSS hot storage tank. The SGS produces superheated steam at 1100 psig (7584 kPa) and 950°F (510°C) for delivery to the HRFS and to the turbine in the EPGS by a transfer of energy from molten salt flowing through the SGS superheater and evaporator. Molten salt at 1050°F (566°C) from the hot salt storage tank is pumped through the superheater, evaporator, and associated salt piping. Molten salt exiting the SGS at 580°F (304°C) is returned to the cold salt storage tank. The flow of molten salt through the SGS is regulated to maintain the steam delivery pressure at 1100 psig (7584 kPa). Salt from the cold salt storage tank is mixed with salt exiting from the superheater to control the evaporator salt inlet temperature to 850°F (454°C). Subcooled water from the steam drum is circulated by the boiler water circulation pump into the evaporator. The steam-water mixture generated in the evaporator flows to the steam drum.

The dry saturated steam removed from the mixture by the steam drum separation equipment flows to the superheater where it is superheated to approximately 1000°F (538°C). Final adjustment of the superheated steam temperature flowing to the turbine at 950°F (510°C) is made by the steam attemperator which mixes saturated steam with the superheated steam exiting the superheater. Feedwater is added to the steam drum at a rate equal to steam flow to maintain a constant steam drum water level.

A flow schematic of the SGS with applicable component nomenclature and interfaces with other MSEE subsystems is shown on Figure 2.1-2. The subsystem nomenclature indicated on this figure will be referred to throughout this report.



General Location Plan
Figure 2.1-1



Molten Salt Electric Experiment Steam Generator Subsystem Flow Schematic
Figure 2.1-2

2.2 Heat Balance

The specification (Reference 1) provides the required thermal performance information for the Steam Generator Subsystem. The SGS provides sufficient energy input to produce 7800 lbm/hr (0.983 kg/sec) superheated steam for delivery to the turbine at 940°F (504°C) and 1050 psig (7240 kPa) based on flow from the condenser at 140°F (60°C) and 250 psig (1724 kPa). The total SGS steam flow is sufficient to meet the turbine requirement and to provide heating of the feedwater flow (equal to steam flow) to SGS feedwater inlet temperature of 550°F (288°C). The required total SGS steam flow is 11530 lbm/hr (1.453 kg/sec). Energy input to the SGS is supplied by molten salt flowing from the hot storage tank at 1050°F (566°C) and returning to the cold storage tank at 580°F (304°C). The required hot salt flow is 62310 lbm/hr (7.851 kg/sec). The rated heat load of the SGS based on the energy input requirements on the water/steam side is 1.061×10^7 Btu/hr (3.109 MW).

2.3 SGS Molten Salt System

The molten salt system of the SGS includes the superheater, the evaporator, and the interconnecting piping between these heat exchangers and the Thermal Storage Subsystem (TSS). The design of the overall SGS salt system discussed in this section is based on the specification requirements summarized below. Additional discussion of the design of various SGS components as related to these and other component-related salt system requirements is included in subsequent sections of this report. The design requirements are:

- Provide hot salt to the superheater inlet
- Provide cold salt for attemperation of the superheater salt outlet temperature
- Provide for filling of the SGS with cold salt; provide venting of air to cold salt storage tank during fill
- Provide for increasing the superheater salt inlet temperature for daily start-up from cold salt temperature to hot salt temperature
- Provide for complete salt system drainage by gravity
- Limit the salt system volume to be drained to the hot pump sump to 30 ft^3 (0.85 m^3)
- Limit the salt side pressure drop of the components at full load flow conditions to 35 psi (241 kPa)
- Provide overpressure protection
- Provide heat tracing to maintain the salt system above 480°F (249°C)

The heat exchangers and the salt piping have been arranged to meet the specification requirements noted above. Hot salt at 1050^{o}F (566^{o}C) flows from the hot salt storage tank to the hot salt pump sump in the TSS. The hot salt pump has been designated as part of the SGS although the pump is existing equipment from previous experimental work. During normal load range operation hot salt flows from this pump through existing hot salt piping and the SGS skid hot salt piping to the superheater salt inlet nozzle. Salt exiting the superheater flows through interconnecting piping to the evaporator salt inlet nozzle. A mixing tee is located in this interconnecting piping to permit mixing of cold salt at 580^{o}F (304^{o}C) with the salt flow from the superheater outlet to control the salt inlet temperature to the evaporator. The cold salt flows from the cold salt storage tank to cold salt pump sump in the TSS. Cold salt flows from this pump through existing cold salt piping and through one of two branches on the SGS skid cold salt control piping to the mixing tee. Control valve FCV-301 in the cold salt control piping is modulated to regulate the evaporator salt inlet temperature (TE-301) to 850F (454C). Salt exiting the evaporator flows through the SGS salt outlet piping and existing TSS piping to the cold salt storage tank. Control valve FCV-321 in the salt outlet piping is modulated during normal load range operation to control steam delivery pressure (PT-321).

A mixing tee is located in the hot salt piping to permit the salt temperature at the superheater inlet (TE-382) to be increased to the normal operating hot salt temperature from the cold salt temperature which exists subsequent to daily filling of the SGS salt system. Salt from the cold salt pump flows to this mixing tee through the other branch of the SGS cold salt control piping. Valve FCV-341 in the cold salt control piping and valve FCV-351 in the hot salt piping control salt flow to provide proper mixing of hot and cold salt to ramp the superheater salt inlet temperature at the desired rate. The cold salt control piping and this mixing tee in the hot salt inlet piping also provide the flow path for the daily fill of the SGS with cold salt.

The general arrangement of the salt piping and the heat exchangers has been established to permit gravity drainage of the SGS salt inventory to the hot salt pump sump with a minimum of additional piping, changes to existing CRTF piping, and/or valves dedicated to the purpose of drainage. The high point in the system is in the existing CRTF cold salt return piping to the cold salt storage tank. The system is arranged such that flow can drain from this location, in the reverse direction from normal, to the hot pump sump. The evaporator is located above the superheater, and all piping is sloped towards the hot salt inlet piping. The SGS piping and heat exchanger elevations have been established to permit the downward sloping drain path to be maintained at the interface point between the SGS skid hot salt piping and the existing CRTF salt piping. Drain piping and isolation valves FCV-381 and FCV-382 have been installed to provide complete drainage of both the superheater and the evaporator. The only salt inventory in the SGS not designed to be drainable to the hot pump sump is that in the cold salt control piping. Because the hot and cold pumps are essentially at the same elevation it is basically not possible to drain this line to the hot sump, at least not without an additional interconnecting piping/valve arrangement. However, such measures are not necessary as the cold pump sump can easily accommodate the drainage of the cold salt control piping.

The salt volume in the SGS and interconnecting piping which drains to the pump sumps is 28.5 ft^3 (0.81 m^3). Of this total, 27.8 ft^3 (0.79 m^3) is drainable to the hot sump compared to the specification allowable of 30 ft^3 (0.85 m^3). It should be noted that the original plan for SGS salt drainage to the hot sump was revised prior to initial operation of the SGS. The original procedure required salt drain to the hot sump at the end of the operating day without regard to the salt temperatures in the subsystem. A potential concern for thermally shocking the hot pump with cold salt during draining was noted. To minimize any possible thermal shock to either the hot pump or cold pump, the shutdown operating procedure was revised to provide for cooldown of the superheater salt inlet temperature by mixing hot and cold salt at the mixing tee upstream of the superheater until the salt flow through the SGS consists only of cold salt. The salt inventory is then drained to the cold pump sump without concern for thermal shock. The residual salt in the hot salt inlet piping is drained to the hot sump.

In developing the design of the salt piping and the salt sides of the superheater and evaporator, the maximum allowable system volume of 30 ft^3 (0.85 m^3) had to be considered in parallel with the maximum allowable pressure drop constraint on the salt system. These two design constraints tended to produce opposing results when considered separately. For example, minimizing salt volume required smaller pipe diameters while minimizing pressure drop required larger pipe diameters. Therefore, it was necessary to iterate the design of the salt system components to achieve an arrangement which met both these requirements.

Certain clarifications were developed in regard to the allowable pressure drop for the SGS salt system. The only stated pressure drop limit for the salt system was 35 psi (241 kPa) at full load (Section 3.4 of Reference 1). That section of the specification listed requirements for the SGS components, which were defined as the superheater, evaporator, and steam drum. On that basis other system losses in the piping and valves would be additive to the components losses. In discussions between B&W and SNL it was agreed that the total allowable salt system unrecoverable pressure loss should be based on the head generated by the hot salt pump at the specified full load hot salt flow of 62310 lbm/hr (7.851 kg/sec) at 1050^{o}F (566^{o}C). SNL provided the hot salt pump characteristic curve (Figure 2.3-1); at the full load conditions, the pump generates 87.5 ft of head (65 psi) at 72.5 GPM. Therefore, the allowable unrecoverable pressure loss between the hot pump and the cold salt storage tank, based on a salt flow of 62310 lbm/hr (7.851 kg/sec) between the pump and the salt attemperation mixing tee and on a salt flow of 75840 lbm/hr (9.566 kg/sec) for the remainder, was 65 psi (448 kPa). Of this total, approximately 20 psi (138 kPa) was reserved for the pressure drop across the main salt flow control valve FCV-321. This control valve was SNL-supplied equipment for which the flow-pressure drop characteristics had already been established. SNL indicated that margin was available in the 20 psi (138 kPa) value as the valve is less than 80% of full open at the full load condition. With the 20 psi (138 kPa) allowance for FCV-321, 45 psi (310 kPa) pressure drop was allowable for the remainder of the salt system. The system as designed has pressure drops of 11 psi (76 kPa) for the superheater, 14 psi (97 kPa) for the evaporator, and 16 psi (110 kPa) for the piping and head losses. The total calculated pressure drop of 41 psi (283 kPa) is approximately 10% below the allowable of 45 psi (310 kPa).

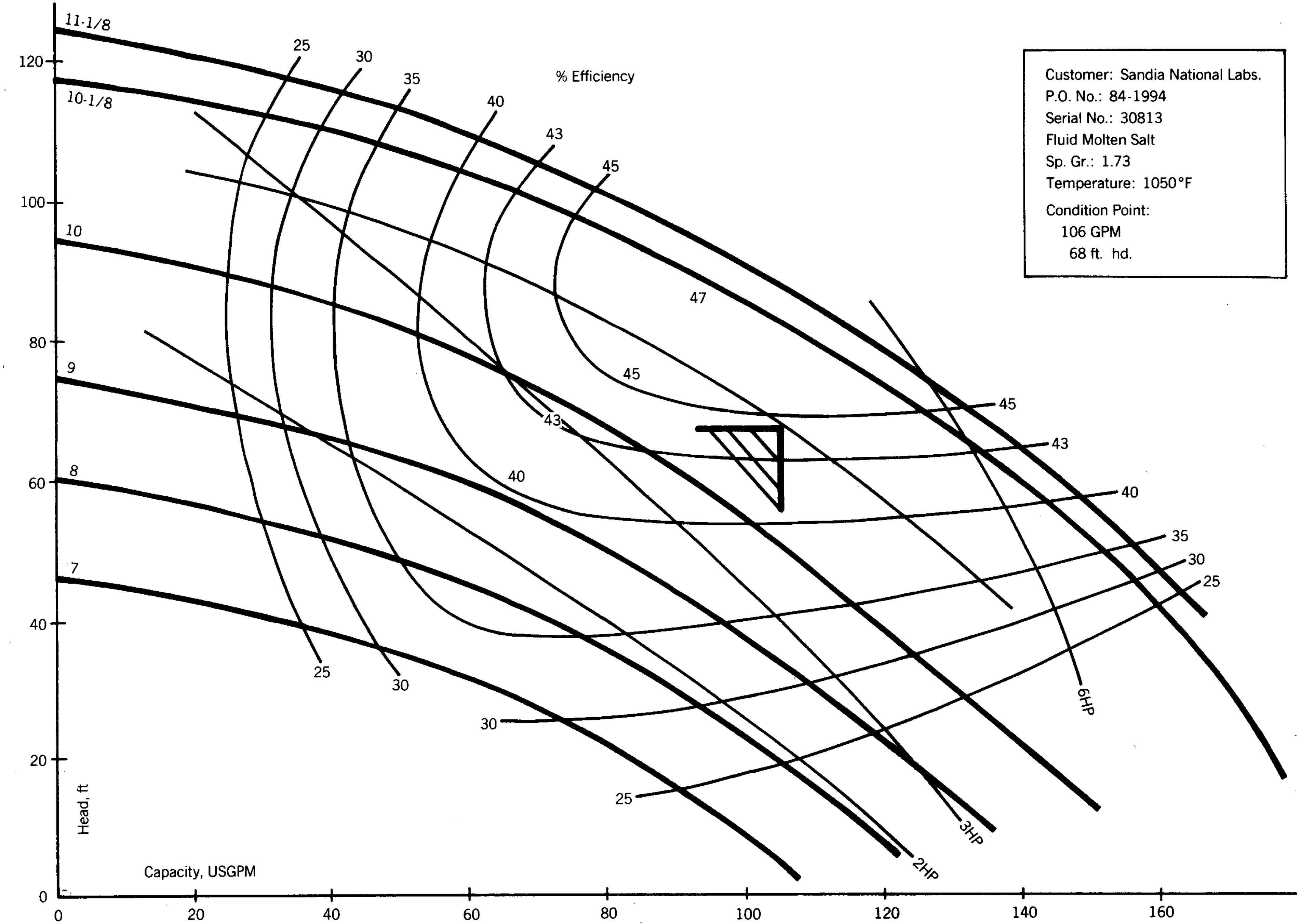
Overpressure protection for the SGS salt system is provided by two overpressure piping/rupture disc assemblies. One assembly is connected to the salt piping between the superheater and the evaporator; the other assembly is connected to the evaporator salt outlet piping. Both overpressure pipes are routed to the east edge of the SGS skid assembly at which point additional piping, supplied and installed by CRTF, routes the overpressure piping to the CRTF drain and blowdown tank located within the berm near the southeast corner of the skid.

Sizing of the overpressure piping was based on an evaluation of a water side to salt side leak in one of the heat exchangers. To provide a conservative estimate of the magnitude of the volumetric leak rate which must be relieved through the overpressure piping, a double-ended tube break was assumed to occur in the evaporator. Leakage was assumed to be essentially unrestricted at the two locations where the water leaks into the salt, and the entire evaporator tube was assumed to be filled with subcooled water at 550^{o}F (288^{o}C) and 1200 psig (8274 kPa).

Based on an analysis of the instantaneous double-ended tube failure, a design maximum leak rate of 0.6 ft^3/sec (.017 m^3/sec) must be relieved through the overpressure protection piping. Two overpressure lines have been provided. These are located as noted above to provide essentially equivalent relief paths for both the evaporator and the superheater. Each of the overpressure lines uses 4" Sch. 10 pipe between the rupture disc and the overflow tank, resulting in a relieving capability on the order of 30% higher than the maximum leak rate of 0.6 ft^3/sec (.017 m^3/sec).

The rupture disc assembly in each of the overpressure lines is located as close as possible to the main salt piping to minimize stagnant salt volume. Each 4" rupture disc assembly consists of a rupture disc flange assembly, an inconel rupture disc, and a vacuum support. The rupture disc is sized to meet the requirements of Reference 2 such that the burst pressure does not exceed 110% of the salt system design pressure of 175 psig (1207 kPa). The vacuum support is provided to prevent any flexing or reverse buckling of the disc should any vacuum occur at the disc location, for example during draining of the salt system.

The entire SGS salt system is provided with a heat tracing system to raise and maintain the system above the freezing point of the salt. Heat tracing on existing CRTF hot salt and cold salt piping is provided by CRTF and is not considered part of the SGS heat tracing. Discussion of the SGS salt system heat tracing design is included in Section 2.11.



Hot Salt Pump
Characteristic Curve
Figure 2.3-1

2.4 SGS Water/Steam System

The water/steam system of the SGS includes the superheater, evaporator, steam drum, boiler water circulation pump, circulation heater, and interconnecting piping between these components and between the SGS and the Heat Rejection and Feedwater System (HRFS). The design of the overall water/steam system is discussed in this section based on the specification requirements summarized below. Additional discussion of the design of various SGS components as related to these requirements is included in subsequent sections of this report. The design requirements are:

- Design a recirculating steam generator which provides 11530 lbm/hr (1.453 kg/sec) superheated steam to the HRFS and EPGS at 1100 psig (7584 kPa) and 950^{o}F (510^{o}C) based on an equal supply of feedwater from the HRFS at 550^{o}F (288^{o}C)
- Design the recirculation loop for a flow which precludes departure from nucleate boiling in the evaporator
- Limit the overall pressure drop at full load in water/steam system to 350 psi (2413 kPa)
- Provide sufficient subcooling in the downcomer of the recirculation loop to prevent flashing during transient operation
- Provide for water/steam system drainage by gravity
- Provide overpressure protection
- Establish the power requirement for an electrical circulation heater to heat the water/steam system from ambient conditions to the normal operating pressure and to maintain water/steam system pressure during diurnal shutdown

The water/steam system components and piping have been designed to meet the requirements noted above. The SGS feedwater line which interfaces with the HRFS feedwater piping at the north edge of the skid supplies feedwater to the steam drum. The SGS circulation loop includes the steam drum, the evaporator, and the boiler water circulation pump (BWCP). The BWCP circulates fluid in this loop from the steam drum through the downcomer line, the evaporator, and the riser line back to the steam drum. Dry saturated steam flows from the drum to the superheater, and superheated steam at the required temperature and pressure flows through the SGS steam outlet piping to the interface point with the HRFS steam line at the north edge of skid. The steam attemperator line provides a controlled flow of saturated steam, using FCV-331, for mixing with the superheater outlet steam flow to achieve the required steam delivery temperature (TE-332). The circulation heater is located in a by-pass loop between the BWCP and the evaporator water inlet nozzle which diverts recirculation loop flow through the heater during initial system heat-up and during diurnal shutdown.

The general arrangement of the water/steam system components and piping has been established to permit gravity drainage of the SGS water inventory for shutdown. Drainage of the recirculation loop components and piping is accomplished through the water drain line routed to the CRTF drain and blowdown tank and through drain valves located at system low points in the BWCP and the circulation heater. The SGS feedwater piping is sloped to permit drainage to the low point in the HRFS feedwater line. Likewise, all SGS steam piping downstream of the drum is sloped to allow drainage to the low point in the HRFS steam piping.

The design of each of the components in the recirculation loop plays a role in developing a design which precludes departure from nucleate boiling in the evaporator. The overall design of the loop has been established to provide sufficient recirculation flow through the evaporator to meet this requirement; design consideration for the various components are discussed in subsequent sections. Likewise, the downcomer subcooling is related to the overall design of the recirculation loop and is also discussed in subsequent sections.

The 350 psi (2413 kPa) limit on pressure drop is of no practical significance in the design of the water/steam system as the nominal full load steam drum pressure is about 1200 psig (8274 kPa) and the stated discharge pressure of the feedwater pump in the HRFS is 1250 psig (8619 kPa). With a steam delivery pressure of 1100 psig (7548 kPa), the total pressure drop is well below 350 psi (2413 kPa).

Overpressure protection for the SGS water/steam system is provided by a safety relief valve located on top of the steam drum. In accordance with Reference 2, the valve set pressure of 1310 psig (9032 kPa) is equal to the lowest design pressure in the system. The valve capacity at this pressure is 15400 lbm/hr (1.940 kg/sec), which represents a margin of 33% over the full load steam generation capacity of the system.

2.5 Superheater

The superheater (B&W Drawing 405325E) is a U-tube, U-shell heat exchanger oriented horizontally with both legs in the same horizontal plane. The vessel is mounted to the skid support steel with two fixed supports and two sliding supports. The material of construction is 304 stainless steel.

Based on the full load heat balance (Section 2.2), the superheater was sized to the following requirements:

Salt side

Salt flow = 62310 lbm/hr (7.851 kg/sec)

Salt inlet temperature = 1050°F (566°C)

Steam side

Steam flow = 10330 lbm/hr (1.302 kg/sec)

Steam outlet pressure = 1100 psig (7584 kPa)

Steam outlet temperature = 1000°F (538°C)

Dry saturated steam at inlet

Together with meeting these heat balance requirements, a number of other requirements had to be considered as the design of the superheater developed. The overall length of the heat exchanger had to be compatible with the available space envelope. The design of the salt side had to consider the contribution of both salt side pressure drop and salt volume to the total allowable for the SGS. The steam side pressure drop had to be such that, when considered together with the steam piping pressure drop, the full load operating pressure in the steam drum is not greater than approximately 1200 psig (8274 kPa). The fouling resistance on both the salt and steam sides of the tubes was considered negligible. The tube bundle arrangement and surface area had to incorporate sufficient margin to account for various uncertainties affecting superheater heat transfer. The arrangement of the superheater had to be such that the salt and steam sides are drainable and ventable.

Based on previous studies, the basic configuration of the superheater was established as a horizontal, U-tube, U-shell, counterflow heat exchanger with shell side salt flow and tube side steam flow. B&W steam generator design and analysis computer program VAGEN (Reference 3) was used to develop the basic sizing of the superheater tube bundle. Initially, tube sizes in the range of 1/2 inch OD (13 mm) to 3/4 inch OD (19 mm) were considered. The 1/2 inch OD x .059 inch minimum wall tubes (13 mm x 1.50 mm) were chosen for the superheater tube bundle because, for a fixed steam side pressure drop, the required bundle length was shorter, the salt side volume tended to be lower, and the salt side pressure drop tended to be lower while still maintaining sufficient salt velocity for turbulent flow. Also, the number of tubes increased as the tube diameter decreased. For this design the number of tubes was in the range of 10 to 30 for the tube diameter range of 3/4 inch (19 mm) to 1/2 inch (13 mm). When considering the effect of tube plugging on available heat transfer surface with this low total number of tubes, it was advantageous to choose a design with a greater number of tubes so that if tube plugging becomes a necessity, either during the fabrication process or at sometime during the operating life, the percentage of the total surface affected by plugging a tube was reduced. With 1/2 inch (13 mm) OD tubes on a 3/4 inch (19 mm) triangular pitch chosen as the basic tube pattern, some further iteration on the number of tubes was done to reach to the final tube bundle configuration of 23-1/2 inch (13 mm) tubes. This configuration, together with the required bundle shroud and tie rod arrangement, was suitable for use with a 6" Sch. 40 pipe as the heat exchanger shell. Based on preliminary estimates of the required tube length the salt volume of the superheater, as part of the total allowable salt volume of 30 ft^3 (0.85 m^3), was acceptable.

In finalizing the design of the salt side of the superheater, the tube bundle shroud in the straight portions of the bundle was designed such that the salt flow through the superheater passes through the tube bundle with a uniform flow per tube. The .143 inch (3.6 mm) clearance between the shroud I.D. and the tubes on the outer periphery of the bundle was established based on uniform flow per tube. The looped end portion of the tube bundle is not enclosed in a shroud. A tight-fitting shroud in the looped end could result in tube to shroud interference due to differential thermal expansion between the tubes and shroud. The tube support plates are located at 35 inch (0.89 m) intervals along the bundle length. With the salt pressure drop across each support plate greater than salt pressure drop in each 35 inch (0.89 m) bundle section, each support acts as a flow distribution plate which helps equalize the flow per tube in the bundle. Equal salt flow per tube results in equal salt temperature drop along the bundle length for all tubes, assuming an equal overall heat transfer coefficient (U_o) for each tube. However, with equal salt flow per tube there is a slight variation of U_o between the tubes on the bundle periphery and the tubes within the bundle, which can result in a minor variation in the salt temperature drop along the bundle on the periphery as compared to within the bundle. However, the distribution effect of the support plates tends to negate these small temperature differences. Because the shroud section between each pair of support plates is welded to the support plates, there is no by-pass around the edge of the support plates; all salt flow is forced to flow through the lobes of the broached holes in the support plate. This flow path tends to create mixing and uniform salt temperature on the downstream side of each support plate. The lack of support plate by-pass and the re-mixing at support plate effectively eliminate concern for significant stratification of salt temperatures within the tube bundle.

The space between the shroud O.D. and the shell I.D. in each of the straight legs of the superheater is part of the salt volume. To minimize any by-pass of superheater salt inlet flow through this annulus, flow restrictors are installed at the two bundle support plates closest to the looped end. Each restrictor (B&W Drawing 405334E) is a ring whose outside diameter is machined to assure diametral clearance between the shell I.D. and the restrictor of no greater than .010 inches (0.25 mm). The vent and drain paths in the restrictors are of a labyrinth design to increase flow resistance at these locations. The maximum by-pass of the salt flow outside the shroud with these restrictors in place is 2-1/2%.

The 12 inch (0.305 m) length of each leg of the tube bundle closest to the tubesheet is provided with two thermal baffles spaced at 6 inches (0.152 m). The baffles are similar to the tube support plates with the exception that the tube holes are straight and close-fitting as opposed to the broached holes in the support plates. These baffle plates form two adjacent regions of essentially stagnant salt on the shell side between the tubesheet and the salt flow path into (or out of) the superheater.

An axial temperature gradient between the flowing salt temperature and the steam temperature is established in the salt in this zone, thus removing a large temperature gradient from the face of the tubesheet. This stagnant region also imposes the axial temperature gradient in the shell over a longer shell length, thereby reducing shell stresses.

The salt-to-steam temperature difference of about 340F (189 C) at the salt outlet-steam inlet end of the superheater is the largest steady-state temperature difference in either the superheater or evaporator. The plot on Figure 2.5-1 shows the predicted effect of the thermal baffle plates on the shell axial temperature gradient and on the salt temperature at the tubesheet face at the steam inlet end of the superheater. For transient salt temperature conditions, the stagnant zone provides a buffer for the tubesheet and moves the location of shell temperature gradients resulting from a transient away from the tubesheet to shell discontinuity.

The installed heat transfer surface (i.e. the tube length) for the 23 tube bundle was finalized based on first establishing a surface requirement for a nominal set of heat transfer, fluid flow, and geometry conditions using B&W computer program VAGEN. A suitable margin was then added to the nominal surface to account for various actual or potential degradations of the nominal heat transfer capability of the surface. The nominal, or baseline, heat transfer surface area requirement was based on the following:

- The full load conditions listed previously in this section
- Equal salt flow per tube
- Equal steam flow per tube
- 23-1/2 inch (13 mm) OD tubes on a 3/4 inch (19 mm) triangular pitch with a wall thickness 10% over minimum

- Salt flow area per tube 3% over the maximum based on shroud tolerances
- No fouling resistance on either the salt side or the steam side (a specification requirement)
- With no shroud in the looped end, consider that surface 50% effective for heat transfer
- Neglect surface in the thermal baffle regions for heat transfer

To establish a suitable margin on the heat transfer surface area, several parameters were examined with regard to the effect of each on the heat transfer. Quantitative evaluation and engineering judgment were applied to the evaluation of each parameter as well as to the combination of the parameters to establish the required margin on the baseline heat transfer surface. The following effects were considered in establishing margin:

- Tube plugging

  An allowance was made for the reduction of heat transfer surface due to plugging two tubes.
- By-pass of salt flow in the shroud-shell annulus

  An allowance was made considering worst case by-pass of salt flow in the shroud-shell annulus.
- Variation of the overall heat transfer coefficient, U_o

  Each component of the overall heat transfer coefficient was evaluated for possible variations which could affect U_o. Variation of the salt flow heat transfer coefficient due to the geometry variations of the tube O.D. and of the shroud I.D. was considered together with possible variation of the coefficient due to correlation accuracy. Variation of the tube wall conductance considered tube wall thickness and tube metal conductivity variations. The steam flow coefficient variation considered tube ID variation and correlation accuracy.

- o Maldistribution of the steam flow

  Consideration was given to the possibility of distribution of the total steam flow such that the flow per tube was not equal.

- o Maldistribution of salt flow

  Consideration was given to the effect of variations of shroud dimensions on salt flow distribution in the bundle and potential stratification of salt temperature in the bundle.

Evaluation of these parameters with regard to the actual or potential effect on heat transfer established a requirement of 25% margin on the baseline heat transfer surface. The installed average tube length in the superheater of 33.0 ft. (10.06 m) has a 30% margin with regard to the baseline surface required for heat transfer. With a 33.0 ft. (10.06 m) tube length, the overall superheater length is 17'-9" (5.41 m) which is well within the available space envelope.

Figures 2.5-2 through 2.5-4 plot the salt and steam parameter predictions based on VAGEN analysis over the range of 30% to 100% load. Plots are included for the nominal case of maximum predicted surface effectiveness and for the case of heat transfer effectiveness reduced by 30%. As indicated on Figure 2.5-2a the required steam outlet temperature of 1000^{o}F (538^{o}C) is met for the reduced heat transfer case. The steam side pressure drop and resulting saturated steam inlet pressure of 1142 psig (7874 kPa) at 100% load are compatible with the requirements for the steam drum pressure.

The salt outlet nozzle is oriented vertically upward and the salt inlet nozzle is oriented vertically downward to provide for venting and draining of the superheater and the salt system downstream of the superheater. The superheater internals, including support plates, baffle plates, and flow restrictors, are designed to permit venting and draining. A 1 inch salt drain nozzle, connected to the salt drain piping (B&W Drawing 179941C), is located in the same leg of the superheater as the salt outlet nozzle to allow complete drainage.

The steam outlet nozzle of the superheater is designed with an eccentric reducer for connection to the steam outlet piping to permit drainage of the steam side of superheater to that piping. A 1 inch drain plug is provided at the bottom of the steam inlet nozzle to permit drainage of the small residual water volume in this head.

The 6" Sch 40 heat exchanger shell is insulated with five inches (127 mm) of calcium-silicate insulation as required by the specification. The insulation is covered with a .016 inch (0.40 mm) aluminum jacket to protect the insulation from weather and mechanical abuse.

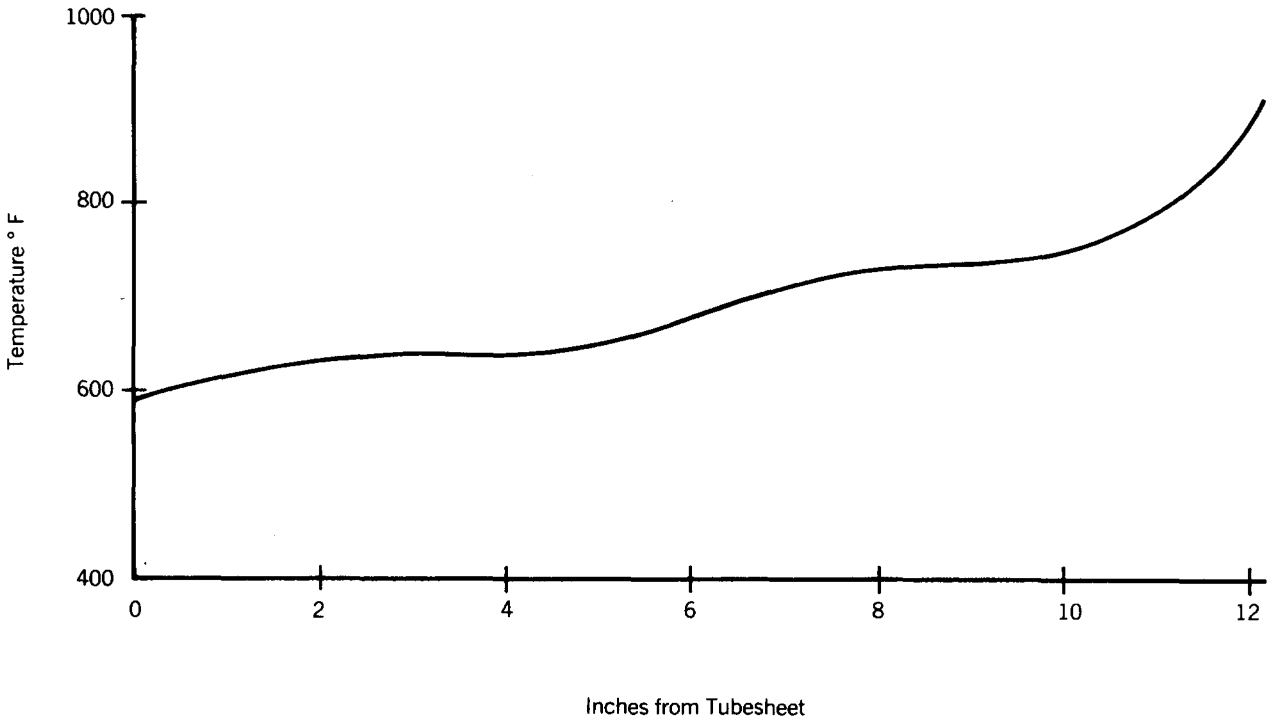
The superheater was designed and fabricated in accordance with the requirements of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, 1980 Edition plus addenda through Winter 1981 and the Class

C Standards of the Tubular Exchanger Manufacturers Association (TEMA), 5th Edition. The following design conditions apply:

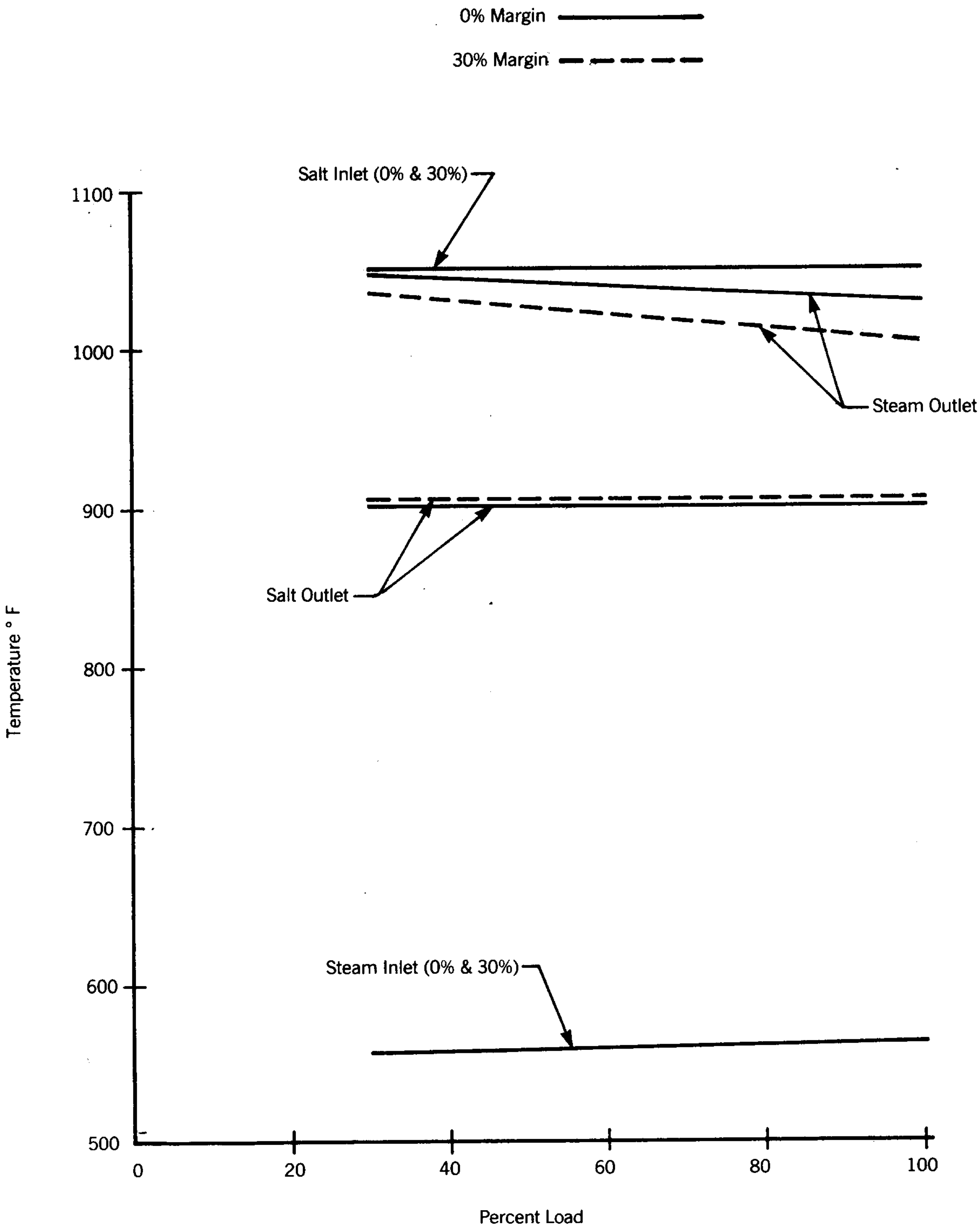
- o Tube side pressure 1310 psig (9032 kPa)
- o Shell side pressure 175 psig (1207 kPa)
- o Temperature $1075^{o}F$ ($579^{o}C$)

There are two fixed supports on the superheater shell located in the vicinity of the salt inlet and outlet nozzles. The support near the salt inlet nozzle is anchored to the external support steel. The other fixed support is allowed to move in a horizontal plane to accommodate motion due to thermal expansion. The fixed supports are fabricated of type 304 stainless steel which is compatible with the superheater shell material and which minimizes the conduction heat loss from the shell to the adjoining structural steel.

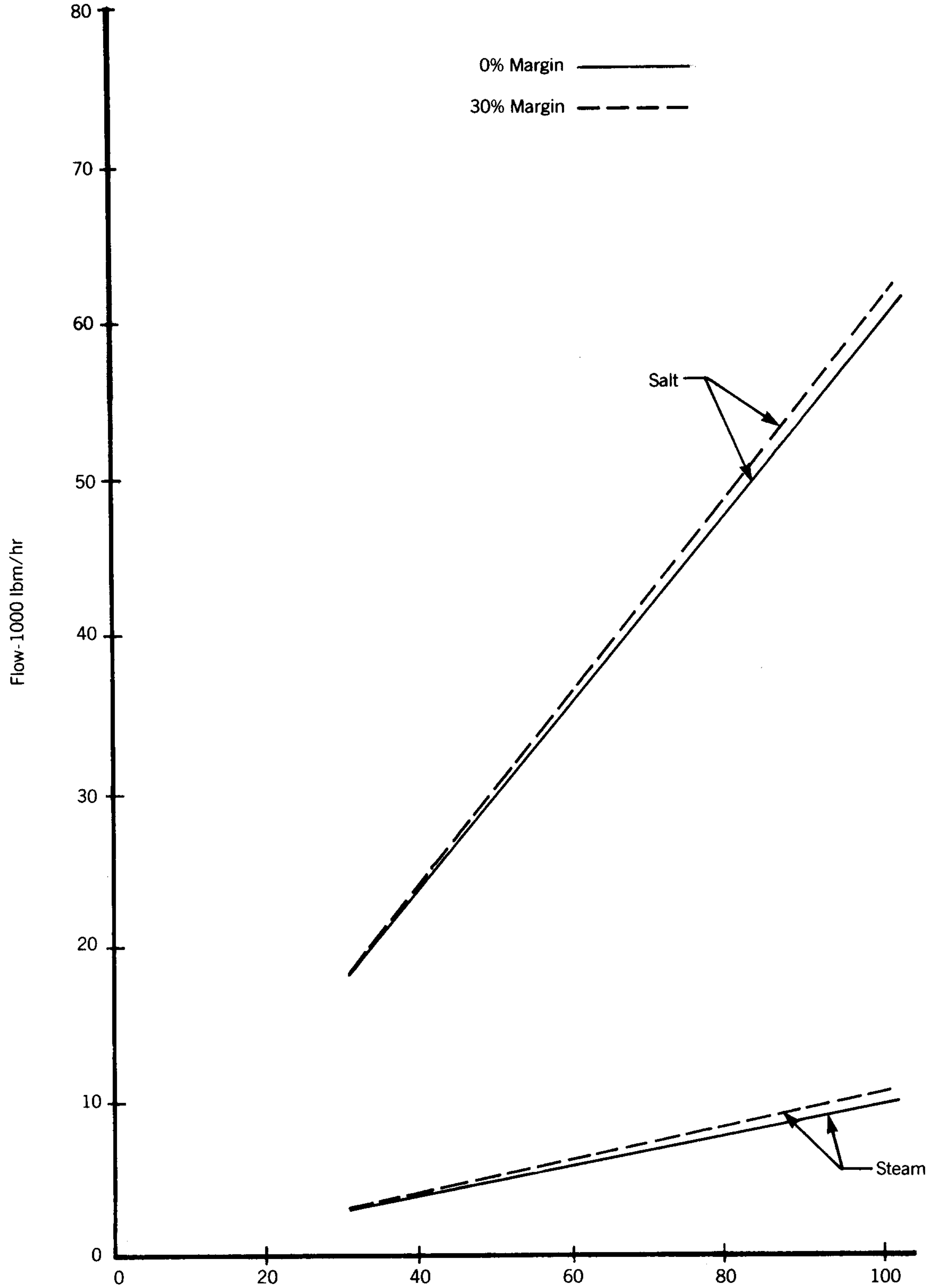
An additional pair of supports for the superheater shell is provided near the return bend. These supports are designed to support the shell from outside the insulation and to permit thermal expansion in the horizontal plane. These supports are fabricated of structural steel. Both pairs of superheater supports are mounted on structural pipe and channel bents which are welded to the skid.



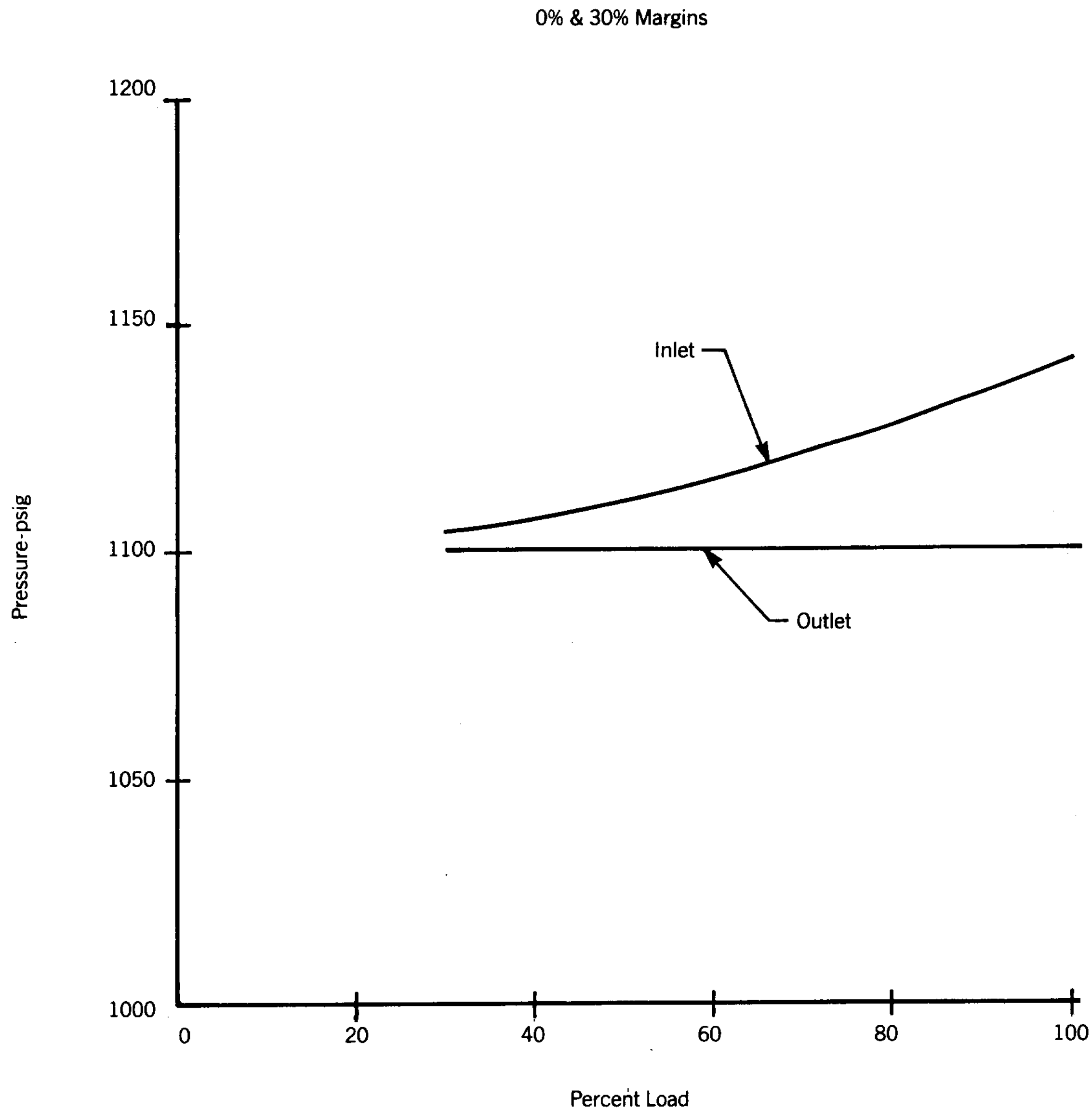
Shell Temperature
Superheater Salt Outlet
Nozzle Region
Figure 2.5-1



Superheater Temperatures Versus Load
Figure 2.5-2



Superheater Flows Versus Load
Figure 2.5-3



Superheater Steam Pressure Versus Load
Figure 2.5-4

2.6 Evaporator

The evaporator (B&W Drawing 405328E) is a U-tube, U-shell heat exchanger oriented horizontally with both legs in the same horizontal plane. The vessel is mounted to the skid support steel with two fixed supports and four sliding supports. The material of construction is 2-1/4 Cr - 1 Mo.

Based on the full load heat balance (Section 2.2) the evaporator was sized to the following requirements:

Salt side

Salt flow = 75840 lbm/hr (9.556 kg/sec)

Salt inlet temperature = 850^{o}F (454^{o}C)

Steam side

Steam flow = 11530 lbm/hr (1.453 kg/sec)

Saturated steam outlet pressure = 1175 psig (8101 kPa)

Feedwater temperature to steam drum = 550^{o}F (288^{o}C)

Together with meeting these heat balance requirements, a number of other requirements had to be considered as the design of the evaporator was developed. The overall length of the heat exchanger had to be compatible with the available space envelope. The design of the salt side had to consider the contribution of both salt side pressure drop and salt volume to the total allowable for the SGS. The design had to preclude departure from nucleate boiling (DNB) from occurring in the evaporator tubes. The fouling resistance on the salt side of the tubes was considered negligible; the fouling resistance for the water side of the tubes was assumed as 0.0001 hr-ft^{2}-F/Btu (1.76 x 10^{-5} m^{2}-C/w). The tube bundle arrangement and surface area had to incorporate sufficient margin to account for various uncertainties affecting evaporator heat transfer. The arrangement of the evaporator had to be such that the salt and steam sides are drainable and ventable.

Based on previous studies, the basic configuration of the evaporator was established as a horizontal, U-tube, U-shell, counterflow heat exchanger with shell side salt flow and tube side steam flow. B&W steam generator design and analysis program VAGEN (Reference 3) was used to develop the basic sizing of the evaporator tube bundle. One of the features of the evaporator design with regard to precluding DNB is the use of multi-lead ribbed (MLR) tubes in the high heat flux, two phase flow region of the bundle. The smallest diameter MLR tube readily available is a 7/8 inch (22 mm) OD tube. As with the superheater design discussed in the previous section, using the smallest tube diameter was advantageous. The basic tube pattern chosen for the evaporator was 7/8 inch (22 mm) OD tubes on a 1.063 inch (27 mm) triangular pitch. The number of tubes was based on consideration of several design requirements for the salt and water sides of the bundle.

Precluding DNB on the water side of the tube bundle was one of the requirements used to determine the number of evaporator tubes. Maintaining nucleate boiling throughout the boiling zone of the evaporator prevents dryout on the tube surfaces which can cause deposition of boiler water chemicals and suspended solids on the tubes surfaces, leading to tube corrosion. The parameters influencing the onset of DNB in boiler tubes are the saturation pressure, the heat flux, the mass velocity, the thermodynamic steam quality, the type of internal tube surface (smooth or ribbed), the tube orientation, and the tube inside diameter. The tube orientation for this design is horizontal. Tubing with a multi-lead ribbed pattern on the tube I.D. was chosen for use in the two phase flow region of the evaporator. For a fixed set of conditions, the onset of DNB occurs at higher steam quality in ribbed tubes as compared to smooth tubes, thus allowing more flexibility in establishing the total water flow through the evaporator. The nominal tube I.D. for the 7/8 inch (22 mm) OD MLR tube is .546 inches (14 mm). The full load outlet saturation pressure of the evaporator is 1175 psig (8101 kPa). With these four parameters fixed, the relationship between heat flux, mass velocity, and steam quality was examined to establish a design to preclude DNB.

The maximum heat flux in the evaporator boiling zone occurs at the salt inlet/water outlet end of the bundle, where the salt to water temperature difference is the largest. The heat flux at the water outlet end, based on the tube inside surface, is 130000 Btu/hr-ft^2 (410 kw/m^2). Considering the information available on DNB in horizontal smooth tubes and allowing for some increase in the heat flux value due to local or upset effects, a maximum steam quality of about 30% at a mass velocity of approximately 1.0 x 10^6 lbm/hr-ft^2 (1356 kg/sec-m^2) was established as a reasonable design point for the evaporator. The ribbed tubes added a significant margin to the design based on smooth tube information, i.e. the quality at which DNB would occur was well in excess of the 30% value noted above.

The 1.0 x 10^6 lbm/hr-ft^2 (1356 kg/sec-m^2) mass velocity and the 30% quality were used to determine the total evaporator water flow and the number of tubes in the bundle. The shroud and tie rod arrangement, the required shell size and resulting salt volume, and the salt side pressure drop were also considered in establishing the number of tubes in the bundle. Based on a 27 tube bundle and a preliminary estimate of the required tube length, an 8" Sch 40 pipe was suitable for the heat exchanger shell. The portion of the total allowable salt volume of 30 ft^3 (0.85 m^3) attributable to the evaporator was acceptable for this arrangement. A total evaporator full load water flow of 43300 lbm/hr (5.418 kg/sec) results in an exit quality, x, of 27% (Circulation Ratio, CR=1/x= 3.76) and a mass velocity of 0.99×10^6 lbm/hr-ft^2 (1342 kg/sec-m^2).

The preliminary tube length and resulting evaporator length for the 27 tube bundle arrangement together with the preliminary SGS skid arrangement resulted in an arrangement which exceeded the 30 foot (9.14 m) space envelope length available for the SGS within the existing Thermal Storage Subsystem berm. While it was possible to shorten the bundle by increasing the number of tubes, such an increase required a larger shell diameter with the net effect of increasing the evaporator salt volume to the extent of violating the 30 ft^3 (0.85 m^3) salt volume limit. SNL indicated that space was available north of the existing berm and that the berm could be moved north in the area of the SGS to accommodate a greater overall length requirement; the 30 ft. (9.14 m) length requirement on space envelope was waived, and the 27 tube bundle arrangement was maintained.

Finalizing the design of the salt side of the evaporator was done using the same considerations as for the superheater as discussed in the previous section. To establish uniform salt flow per tube the tube O.D. to shroud I.D. clearance was set at .076 inches (1.93 mm). The basic spacing of the support plates in the bundle was established at 44 inches (1.12 m). At the salt inlet end of the evaporator, the rate of salt temperature drop along the bundle length is greater than in the superheater bundle because of the large salt to water temperature difference. This increases the potential for differences in salt temperature and for salt stratification in this region of the bundle. To reduce the potential for these concerns, the support plate spacing in the initial 25% of the bundle length was reduced to 22 inches (0.56 m) with four additional support plates. The additional support plates improve bundle flow distribution by increasing the ratio of support plate to bundle pressure drop and provide four additional locations for re-mixing of the bundle flow. Flow restrictors of the same design as on the superheater limit by-pass of salt flow outside the shroud to 1-1/2%. As with the superheater, the 12 inch (0.305 m) length of each leg of the tube bundle closest to the tubesheet is provided with two thermal baffles spaced at 6 inches (0.152 m) to protect the tubesheet and establish acceptable axial thermal gradients in the shell near the tubesheet.

The installed heat transfer surface (i.e. the tube length) for the 27 tube bundle was finalized based on first establishing a surface requirement for a nominal set of heat transfer, fluid flow, and geometry conditions using B&W computer program VAGEN. A suitable margin was then added to the nominal surface to account for various actual or potential degradations of the nominal heat transfer capability of the surface. The nominal, or baseline, heat transfer surface area requirement was based on the following:

- o The full load conditions listed previously in this section and a total water flow of 43300 lbm/hr (5.418 kg/sec)
- o Equal salt flow per tube
- o Equal water flow per tube
- o 27-7/8 inch (22 mm) O.D. tubes on a 1.063 inch (27 mm) triangular pitch with a wall thickness 11% over minimum
- o A ribbed tube length of 32 ft. (9.75 m) at the water outlet end of the bundle; smooth tubes for the remainder of the length
- o Salt flow area per tube 2% under the nominal

- No fouling resistance on the salt side; .0001 hr-ft^2-F/Btu (1.76×10^{-5} m^2 - C/w) fouling resistance on the water side
- With no shroud in the looped end, consider that surface 40% effective for heat transfer
- Neglect surface in the thermal baffle regions for heat transfer

A suitable margin on the evaporator heat transfer surface area was established by evaluating parameters affecting heat transfer in the same manner as discussed for the superheater. Evaluation of tube plugging, by-pass of salt flow in the shroud-shell annulus, variation of U_o, and maldistribution of water and salt flows established a requirement of 29% margin on the baseline heat transfer surface. The installed average tube length in the evaporator of 68.2 ft. (20.79 m) has a 30% margin on heat transfer surface. The overall evaporator length is 35'-6-3/4" (10.84 m).

Figures 2.6-1 through 2.6-3 plot the salt and steam parameter predictions based on VAGEN analysis over the range of 30% to 100% load. Plots are included for the nominal case of maximum predicted surface effectiveness and for the case of heat transfer effectiveness reduced by 30%. As indicated by the plots the total evaporator flow, based on recirculation loop flow losses, exceeds the design value of 43300 lbm/hr (5.418 kg/sec), thus the steam exit quality predicted for full load steam generation of 11530 lbm/hr (1.453 kg/sec) is lower than the design value of 27%.

The salt outlet nozzle is oriented vertically upward and the salt inlet nozzle is oriented vertically downward to provide for venting and draining of the evaporator and the salt system downstream of the evaporator. The evaporator internals, including support plates, baffle plates, and flow restrictors, are designed to permit venting and draining. A 1 inch salt drain nozzle, connected to the salt drain piping (B&W Drawing 179941C), is located in the same leg of the evaporator as the salt outlet nozzle to assure complete drainage.

The water inlet nozzle of the evaporator is designed with an eccentric reducer for connection to the water inlet piping to permit drainage of the water side of evaporator to that piping. A 1 inch drain plug is provided at the bottom of the water side outlet nozzle to permit drainage of the small residual water volume in this head.

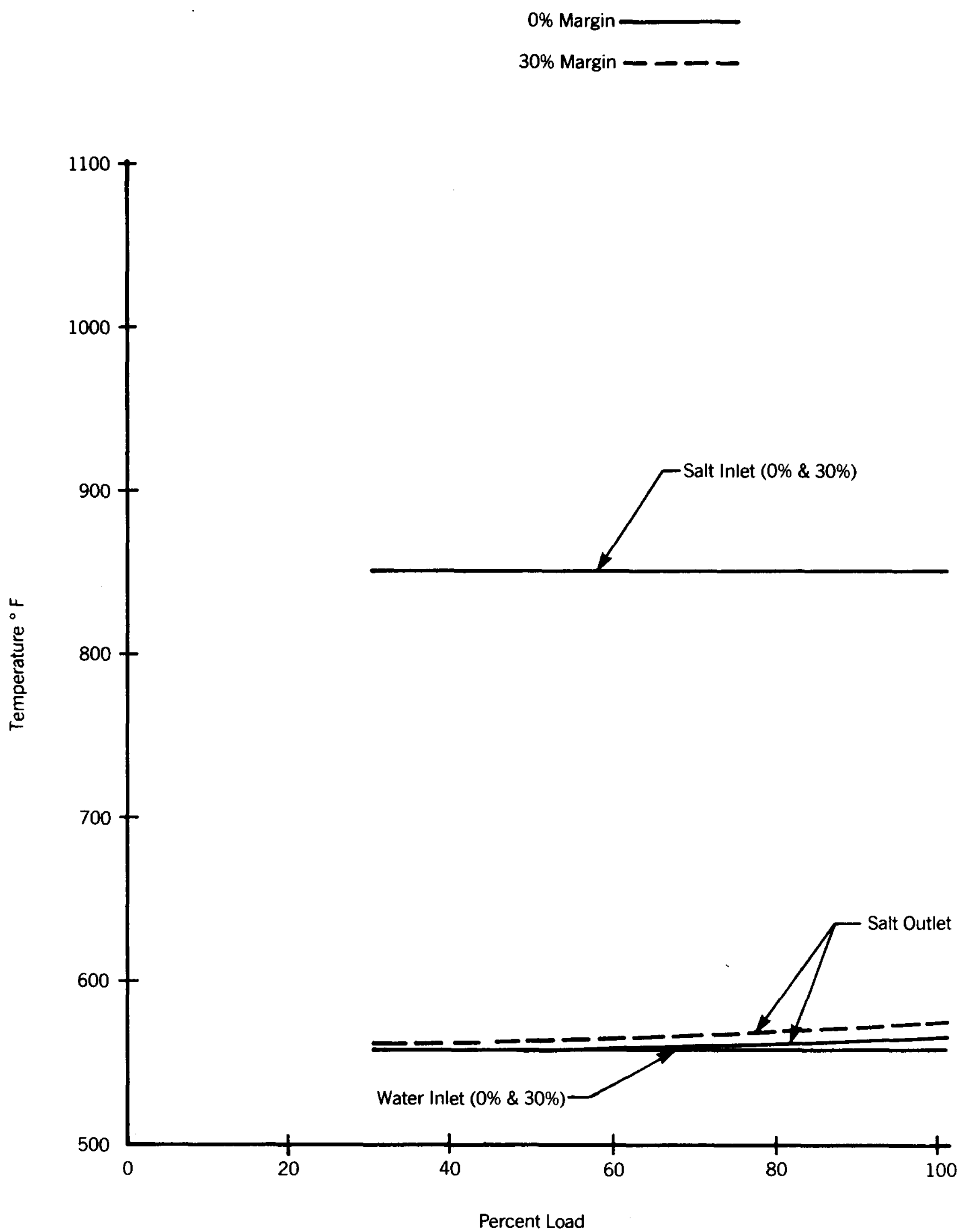
The 8" Sch. 40 heat exchanger shell is insulated with five inches (127 mm) of calcium-silicate insulation as required by the specification. The insulation is covered with a .016 inch (0.40 mm) aluminum jacket to protect the insulation from weather and mechanical abuse.

The evaporator was designed and fabricated in accordance with the requirements of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, 1980 Edition plus addenda through Winter 1981 and the Class C Standards of the Tubular Exchanger Manufacturers Association (TEMA), 5th Edition. The following design conditions apply:

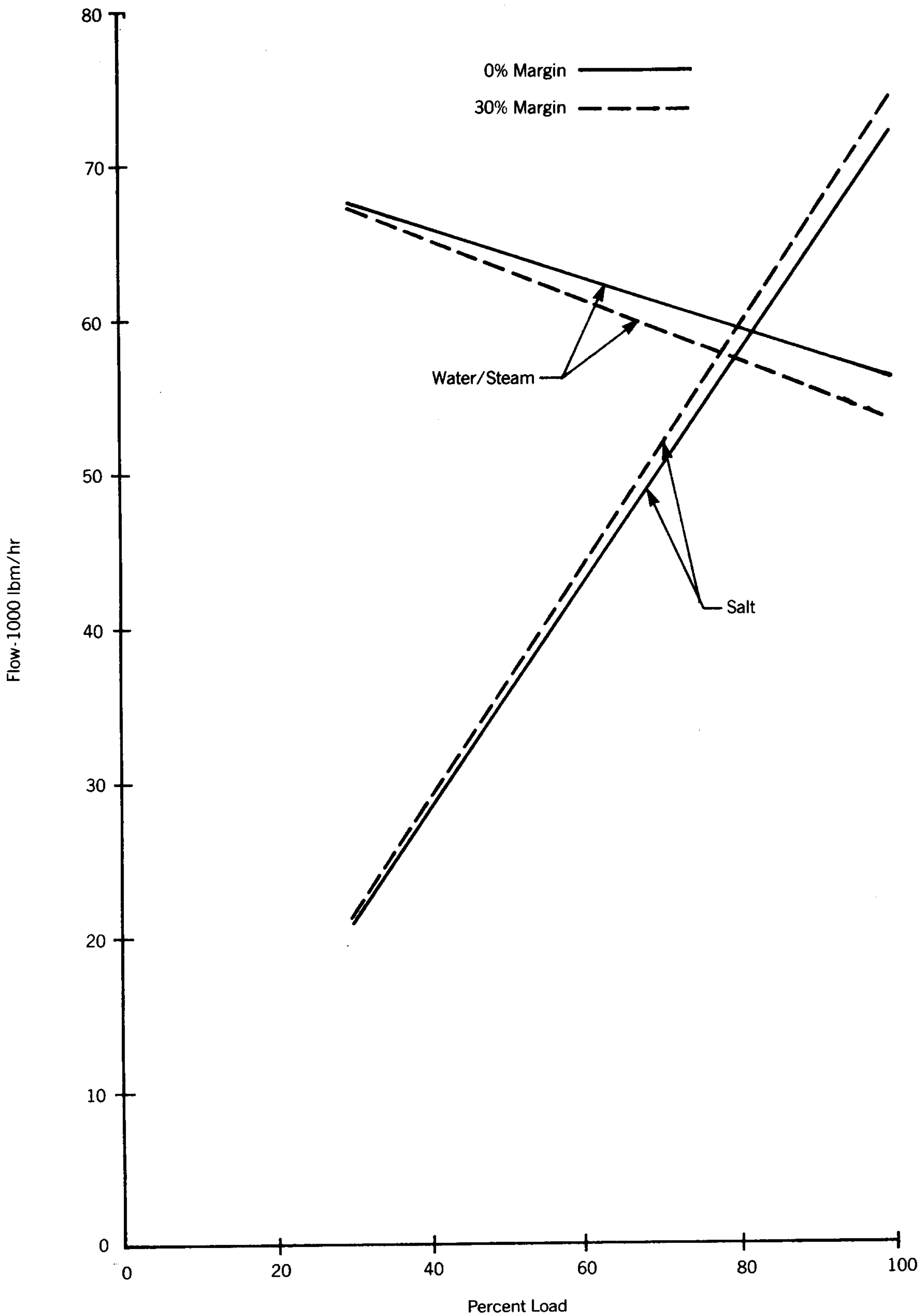
- o Tube side pressure 1385 psig (9549 kPa)
- o Shell side pressure 175 psig (1207 kPa)
- o Temperature $900^{\circ}F$ ($482^{\circ}C$)

Two fixed supports on the evaporator shell are located in the vicinity of the salt inlet and outlet nozzles. The support near the salt outlet nozzle is anchored to the external support steel. The other fixed support is allowed to move in a horizontal plane in order to accommodate motion due to thermal expansion. A change in material from Croloy 2-1/4 to Type 304 stainless steel is made in the fixed supports midway through the insulation to minimize the conduction heat loss from the evaporator shell to the adjoining structural steel.

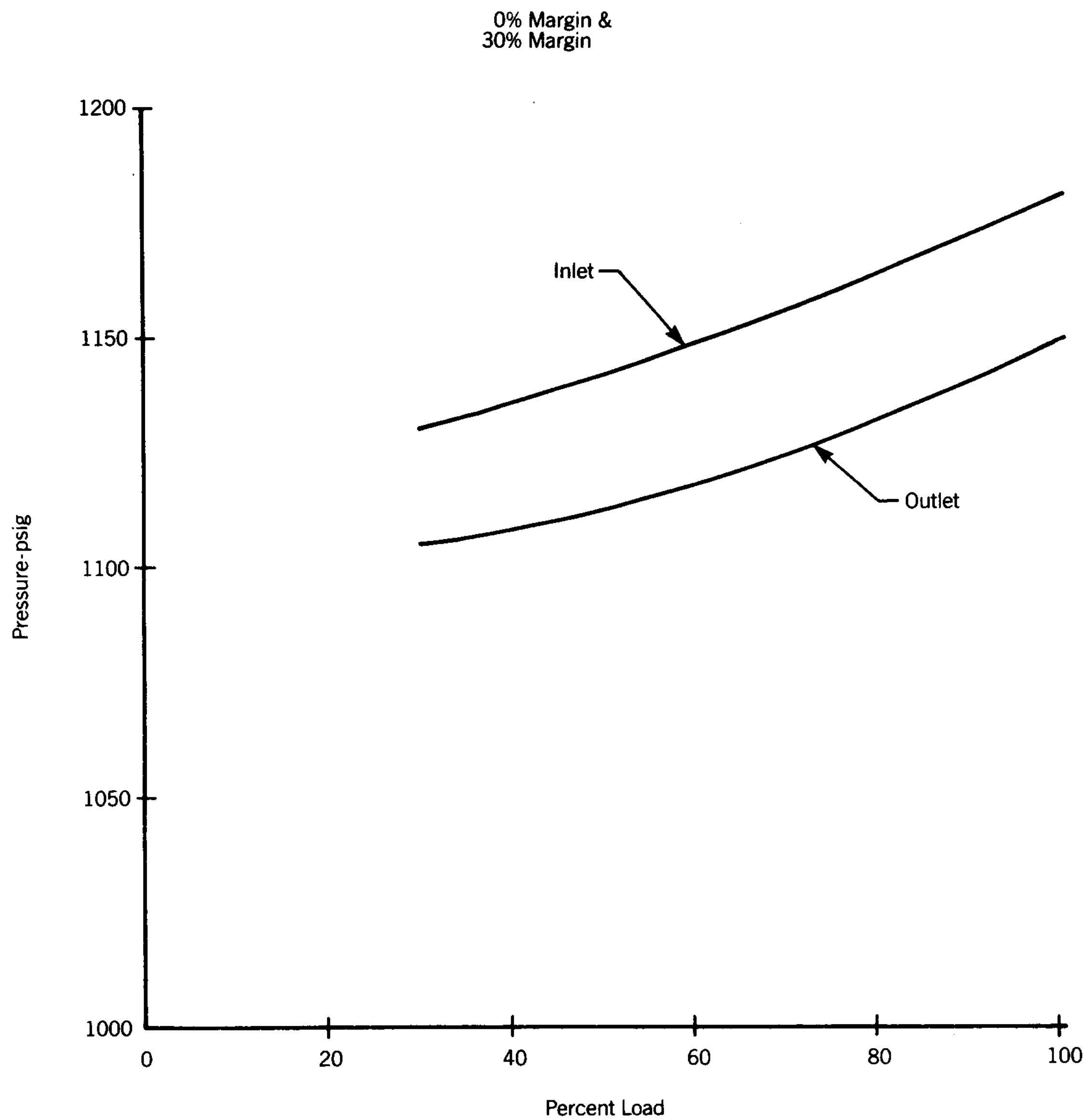
Two additional pairs of supports are provided for the evaporator shell spaced at 161 inch (4.09 m) increments from the fixed supports. These supports are designed to support the shell from outside the insulation and to permit thermal expansion in the horizontal plane. The supports are fabricated from structural steel. All three pairs of supports are mounted on structural pipe and channel bents which are welded to the skid.



Evaporator Temperatures Versus Load
Figure 2.6-1



Evaporator Flows Versus Load
Figure 2.6-2



Evaporator Steam Pressure Versus Load
Figure 2.6-3

2.7 Steam Drum

The steam drum (B&W Drawings 405326E and 405327E) is a 24 inch (0.610 m) I.D. cylindrical vessel with 2:1 elliptical heads. The vessel is mounted vertically on the skid assembly steam drum tower by means of four bolted supports. The material of construction is carbon steel.

Within the steam drum is standard B&W equipment for steam-water separation including a primary cyclone separator and primary and secondary steam scrubbers. At the full load drum operating pressure of 1175 psig (8101 kPa), the steam flow of 11530 lbm/hr (1.453 kg/sec) is well below the capacity limit of the separation equipment. The steam-water mixture from the evaporator enters the steam drum through the riser nozzle. The primary cyclone and the scrubbers remove the water from the mixture, allowing dry saturated steam to exit the steam drum through the steam outlet nozzle on the upper head. Feedwater enters the drum through the feedwater nozzle and distribution pipe and mixes with the saturated water from the separation equipment. The resulting subcooled mixture exits the steam drum through the downcomer nozzle and is recirculated to the evaporator by the boiler water circulation pump. The drum is fitted with a vortex inhibitor at the exit to the downcomer to prevent drawdown of steam into the downcomer piping. The steam drum is equipped with taps for remote water level sensing equipment as well as a gage glass for local observation of water level. The blowdown pipe permits periodic adjustment of boiler water chemistry as well as adjustment of water level during start-up from the empty condition.

The elevation of the steam drum was established to maintain sufficient net positive suction head (NPSH) on the suction side of the boiler water circulation pump. For the pumps considered for SGS head and flow requirements, locating the steam drum normal water level approximately 15 ft. (4.57 m) above the pump inlet provided sufficient margin to assure pump NPSH requirements would be met.

The diameter and the overall height of the steam drum were established based on two factors. One was to provide sufficient space to install the required separation equipment and internal piping. The second was to provide sufficient water inventory in the drum such that, for an instantaneous load reduction from 100% to 0%, water level was maintained within the cylindrical portion of the drum.

The steam drum was insulated with 6 inches (152 mm) of calcium-silicate insulation. The insulation is covered with a .016 inch (0.40 mm) aluminum jacket to protect the insulation from weather and mechanical abuse.

The steam drum was designed and fabricated in accordance with the requirements of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, 1980 Edition plus addenda through Winter 1981. The following design conditions apply:

- o Pressure 1310 psig (9032 kPa)
- o Temperature 600 ^{o}F (316 ^{o}C)

The steam drum-to-tower interface was designed to accomodate the radial thermal growth of the drum.

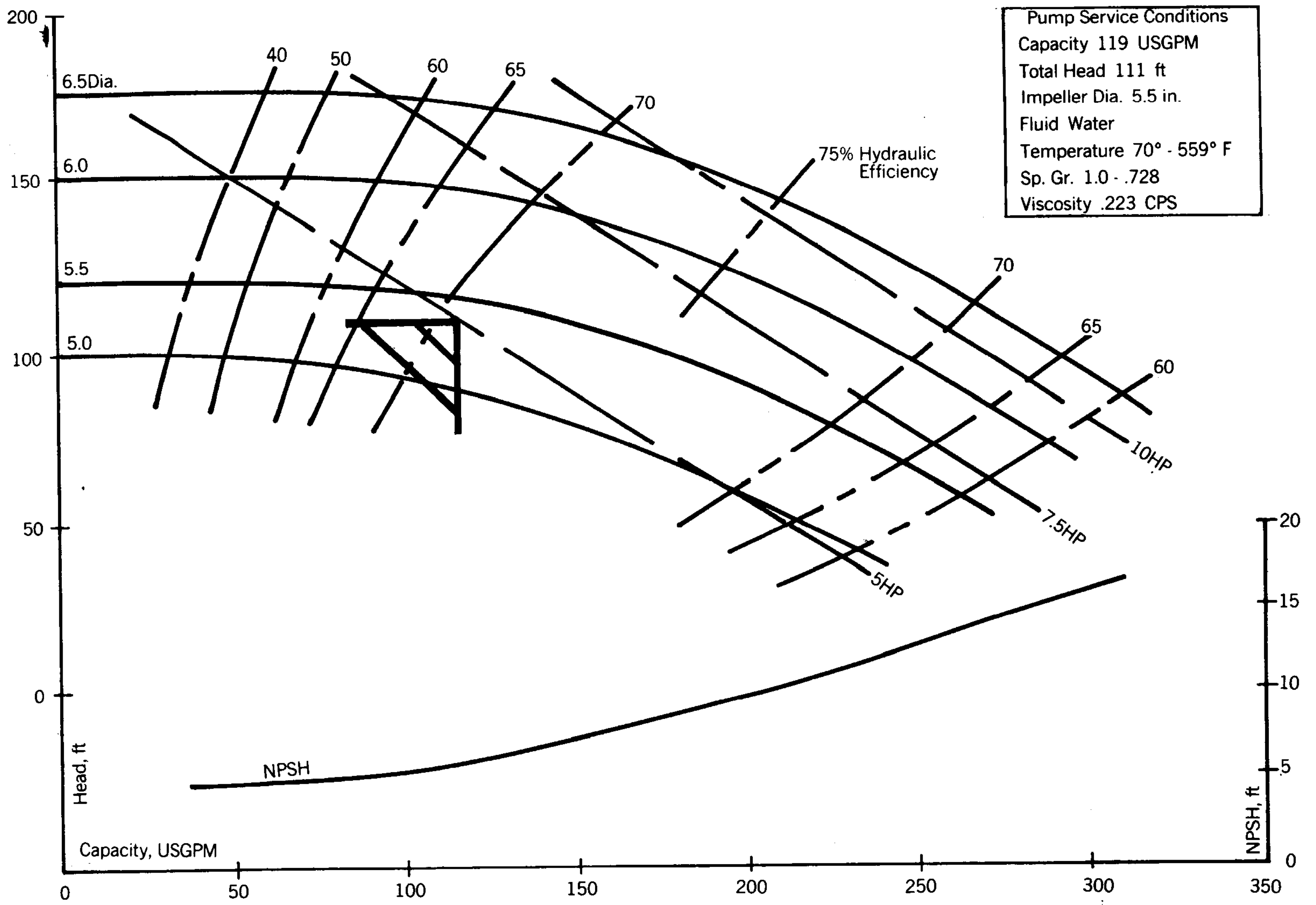
2.8 Boiler Water Circulation Pump

The boiler water circulation pump (BWCP) is located in the SGS water recirculation loop. The required hydraulic performance design point of the pump was established based on the required recirculated water flow at full load and on the net pressure drop in the recirculation loop based on that flow. The full load flow is 43300 lbm/hr (5.418 kg/sec) which was established in the evaporator design based on DNB considerations (see Section 2.6). The net pressure drop in the loop was based on pressure losses in the evaporator, steam drum, and interconnecting piping and on the static heads in the downcomer and riser legs of the loop. The net loop pressure drop was conservatively calculated at 35 psi (241 kPa). The downcomer flow temperature of 559^{o}F (293^{o}C) was based on the full load feedwater temperature of 550^{o}F (288^{o}C), the 1175 psig (8101 kPa) saturation pressure, and a CR of 3.76. The design point of the pump is 119 GPM and 111 ft. head at 559^{o}F.

Both horizontal centrifugal pumps and canned pumps were considered for BWCP service. Both types of pumps were available for the required design point conditions at comparable cost and delivery schedules. A canned pump designed and manufactured by Lawrence Pump and Engine Co. (LP&E) was chosen for service in the SGS. This pump occupies considerably less floor space than a horizontal centrifugal pump with external motor. The LP&E pump requires a space of approximately 2 ft. x 3 ft. (0.610 m x 0.915 m) compared to an approximate 4 ft.x 8 ft. (1.22 m x 2.44 m) space required by the centrifugal pump. This was a significant factor in arranging the equipment on the skid assembly as the overall tight envelope put floor space at a premium. The LP&E pump coolant requirement for the bearings and motor is one GPM compared to approximately 12 to 15 GPM for a centrifugal pump. An ethylene glycol-water mixture is used for pump coolant to prevent freezing at low ambient temperatures. CRTF supplies the coolant to the BWCP from a closed loop coolant system. The canned pump coolant requirements are more compatible with existing CRTF coolant system capabilities.

The LP&E canned pump Model A2XD-X is designed to deliver 119 GPM at 111 feet of head with a required NPSH of 6 ft. The 5 horsepower pump motor operates on 480 vac, 3 phase. The pump performance curve is shown on Figure 2.8-1. At the normal operating temperature the pump can operate over the entire range of the 5.5 inch diameter impeller operating curve on Figure 2.8-1 as required by the recirculation loop losses.

The coolant source and connections to the pump are provided by CRTF. An electrical interlock from a flow switch in the coolant outlet line prevents pump operation with less than the minimum one GPM coolant flow to the pump. The pump inlet and outlet flanges and the volute are insulated. The pump and adjacent portions of the suction and discharge piping are drained through the drain valve on the lower portion of the pump volute.



BWCP Performance Curve
Figure 2.8-1

2.9 Circulation Heater

The circulation heater in the water/steam system was not part of the original design concept of the SGS. The SGS specification indicated that steam pressure during diurnal shutdown would be maintained by circulation of cold salt through the SGS. During the SGS design phase, SNL indicated that neither circulating salt by an automatic, unmanned system nor maintaining personnel on site around the clock to control salt circulation was an acceptable operating alternative. Also, during the design phase, the addition of a circulation heater to the SGS was being considered for heat-up of the water/steam system from ambient conditions, rather than using the HRFS to provide heat input for this cold start-up operation. The circulation heater could therefore serve the dual purpose of cold system start-up and overnight pressure maintenance without the need for salt recirculation or manned operation at all times.

The power requirement for the circulation heater was determined for the cold start-up operation based on a 500^{o}F (278^{o}C) increase of the SGS water/steam system temperature from ambient conditions in 12 hours. The power required is 70 KW. Steam pressure can be maintained by the heater during the diurnal shutdown condition using a fraction of the full heater power.

The circulation heater was supplied by SNL. Other than the power input requirement established by B&W, SNL established the design conditions required for the heater. The heater was manufactured by Pacific Chromalox Division of Emerson Electric Co. The heater is a special 6" chamber type, Model NWH1-970E4XX, which is mounted vertically on the skid assembly base plate. The heater is located downstream from the boiler water circulation pump in a 2" Sch 80 pipe line parallel to the main 4" Sch 80 water inlet line to the evaporator as shown on

B&W Drawing 405332E. The heater has nine heating elements with a total power of 70 KW at 480 vac. The heaters are wired in five separate circuits to permit partial power operation for maintenance of steam pressure during diurnal shutdown conditions. The control of the heater during diurnal shutdown is discussed in Section 2.12.8.2.1. (The original heater design had 12 heaters in five circuits with a total power of 70 KW. Subsequent to the circulation heater pressure boundary failure, as discussed in Section 5.3, the heater was redesigned with the nine heater elements noted above.)

2.10 Piping and Valves

2.10.1 Salt System Piping and Valves

This section provides additional description and drawing references for the salt system piping and valves. The salt system is described in Section 2.3. Pipe sizing in the various pipe runs was based on meeting the SGS maximum salt volume requirement of 30 ft^3 (0.85 m^3) and the SGS salt pressure drop requirement of 45 psi (310 kPa), as well as considering the size of various other components. All piping was designed in accordance with the Power Piping code, ANSI B31.1 (Reference 5), for the design temperature and pressure indicated on the B&W piping drawings referenced in the following subsections.

2.10.1.1 Hot Salt Inlet Line

The hot salt inlet piping (B&W Drawing 179936C) provides molten salt from the CRTF hot salt pump to the superheater salt inlet nozzle. The SGS piping interfaces with existing CRTF pipe 3"-SMH-3-FSX at the south end of the skid assembly at CRTF work point elevation (W.P. EL.) 5589'-5-7/16". The hot salt inlet line includes the salt start-up mixing tee (see Section 2.10.1.7), details of which are shown on B&W Drawing 405329E. This tee provides for mixing of salt from the cold salt control piping (see Section 2.10.1.4) with hot salt to provide controlled temperature increase or decrease of salt entering the superheater during start-up or shutdown from warm standby conditions. The start-up hot salt flow control valve FCV-351 is located in the existing CRTF piping. Most of the hot salt line is 3" Sch 40 pipe; 4" Sch 40 pipe is used to connect the 4" mixing tee and 4" superheater inlet nozzle. The piping is sloped downward from the superheater inlet nozzle to the sump of the hot salt pump to allow drainage. Piping material is 304 stainless steel.

2.10.1.2 Evaporator Salt Inlet Line

Molten salt from the superheater salt outlet nozzle flows to the evaporator salt inlet nozzle through the evaporator salt inlet piping as shown on B&W Drawing 179937C. The entire pipe run is 4" Sch 40 pipe, which is compatible with the superheater outlet nozzle, evaporator inlet nozzle, mixing tee, and overpressure pipe. This salt piping includes a mixing tee (see Section 2.10.1.7), details of which are shown on B&W Drawing 405329E. This tee provides for mixing of salt from the cold salt control piping (See Section 2.10.1.4) with salt exiting from the superheater to control the salt temperature entering the evaporator to 850^{o}F (454^{o}C). The piping is sloped downward from the evaporator inlet nozzle to the superheater outlet nozzle to allow drainage. Piping material is 304 stainless steel.

2.10.1.3 Evaporator Salt Outlet Line

Molten salt from the evaporator salt outlet nozzle flows to the CRTF cold salt storage tank through the evaporator salt outlet piping as shown on B&W Drawing 179940C. The SGS piping interfaces with CRTF pipe 3"-SMC-2-FBA at the south end of the skid assembly at CRTF W.P. EL. 5598'-0". The piping is sloped downward from this work point to the evaporator salt outlet nozzle to allow drainage through the evaporator and superheater. CRTF piping from the above work point is sloped downward toward the cold storage tank to allow drainage. SGS piping material is carbon steel.

The total salt flow control valve FCV-321 is located in the evaporator salt outlet line. The valve is a 2" Valtek Mark 11 air operated, cylinder actuated valve. The valve body is 316 stainless steel with butt weld ends. This valve was sized and supplied by SNL.

2.10.1.4 Cold Salt Control Lines

The cold salt control piping (B&W Drawing 179938C) is 1-1/2" Sch 40 pipe which provides molten salt from the CRTF cold salt pump to the SGS. The SGS piping interfaces with CRTF pipe 2"-SMC-1-FBA south of the SGS skid at CRTF W.P. EL. 5587'-6-7/8". The main cold salt control piping branches to the salt start-up mixing tee and to the salt attemperator mixing tee as described in Sections 2.10.1.1 and 2.10.1.2, respectively. The piping is sloped downward from the two mixing tees to provide drainage to the cold salt pump sump. Piping material is carbon steel with the exception of (1) the 304 stainless steel elbows at the end of each branch line which provide transition to the ends of the stainless steel mixing tees, and (2) the 304 stainless steel nipples on either side of both control valves.

The start-up cold salt flow control valve FCV-341 is located in the start-up branch of the cold salt control piping. The valve is a 1" Valtek Mark 11 air operated, cylinder actuated valve. The valve body is 316 stainless steel with socket weld ends. This valve was sized and supplied by SNL.

The evaporator salt inlet temperature control valve FCV-301 is located in the attemperator branch of the cold salt control piping. The valve is a 1" Valtek Mark 11 air operated, cylinder actuated valve. The valve body is 316 stainless steel with socket weld ends. This valve was been sized and supplied by SNL.

2.10.1.5 Salt Drain Lines

The salt drain piping (B&W Drawing 179941C) permits complete drainage of the salt side of the superheater and the evaporator as described in Sections 2.5 and 2.6. The 1" Sch 40 drain pipes from the superheater and the evaporator combine into a common 1-1/2" Sch 40 line which is routed to the hot salt inlet piping upstream of the start-up mixing tee (B&W Drawing 179936C). All drain piping is sloped downward from the superheater and the evaporator to the hot salt piping to allow drainage. Piping material is 304 stainless steel.

Each branch line has a remote-operated isolation valve. The superheater valve is FCV-382; the evaporator valve is FCV-381. Each valve is a 1" Kieley and Mueller air operated, diaphragm actuated valve. Each valve body is stainless steel with socket weld ends.

2.10.1.6 Salt Overpressure Lines

Overpressure protection of the molten salt side of the SGS is provided by two 4" rupture discs as discussed in Section 2.3. One rupture disc is located in the 4" salt overpressure piping which branches from the evaporator salt inlet piping as shown on B&W Drawing 179937C; this piping is 304 stainless steel. One rupture disc is located in the 4" salt overpressure piping which branches from the evaporator salt outlet piping as shown on B&W Drawing 179940C; this piping is carbon steel. From the SGS overpressure piping terminal points on the above drawings, pipe is routed to the CRTF blowdown/drain tank located to the east of the SGS skid. In the event of overpressure on the salt side and attendant rupture disc failure, fluid from the salt side flows through the overpressure piping to the blowdown/drain tank.

2.10.1.7 Salt Mixing Tees

Two mixing tees are required for the SGS salt system. A start-up mixing tee is required upstream of the superheater. The function of this tee is to provide a mixing point for cold salt flow at 580°F (304°C) and hot salt flow at 1050°F (566°C) so that the superheater salt inlet temperature can be ramped up during start-up from warm standby and ramped down during shutdown to warm standby. A mixing tee is required in the salt piping between the superheater and the evaporator. The purpose of this tee is to mix cold salt flow at 580^{o}F (304^{o}C) with salt flow exiting the superheater (nominal 908^{o}F (487^{o}C) at full load) so that the evaporator salt inlet temperature can be controlled to 850^{o}F (454^{o}C). Maintaining the evaporator temperatures below 850^{o}F (454^{o}C) is important in minimizing corrosion of the 2-1/4 Cr - 1 Mo evaporator material over the life of the unit.

Several criteria were established for the design of the mixing tees. The tee was to have good mixing efficiency over a wide range of hot-to-cold salt flow ratios to minimize any downstream fluctuations of the pressure boundary pipe wall temperature. The tee was to be capable of sustaining a step change in fluid temperature between the cold and hot salt temperatures, nominally 500^{o}F (278^{o}C). The full load pressure drop was to be compatible with the total salt system pressure drop requirement; the nominal allowable tee pressure drop was established at one psi (6.9 kPa) for full load flow. The configuration was to be such that the tee and adjacent salt piping are drainable.

A survey of mixing tee designs was made to establish some potential candidate designs. Tees designed for water service and for sodium service were reviewed, including standard tees, standard tees with thermal sleeves, injector-type tees, perforated plate tees, and coaxial perforated pipe tees. Based on the survey the coaxial, perforated pipe concept was selected. Based on test data (Reference 4), this type of mixing tee has good mixing efficiency over widely varying hot-to-cold flow ratios and can be designed to meet the nominal one psi (6.9 kPa) pressure drop requirement.

The design of the SGS coaxial, perforated pipe mixing tee is shown on B&W drawing 405329E. The hotter salt flow enters the tee through the smaller 2" diameter inner pipe. The colder salt flow enters through the larger 4" diameter outer pipe, passes through the perforations in the inner pipe, and combines with the hotter flow in the mixing section of the inner pipe downstream from the perforations. Concern for any thermal striping or temperature fluctuation effects in the mixing zone is greatly reduced because the mixing occurs in this non-pressure boundary pipe section. After passing through the mixing section, the flow expands to a 4" diameter pipe to eliminate any unnecessary pressure drop and to mate with salt system piping. The mixing tee has a calculated pressure drop at full load flow of 1.0 psi (6.9 kPa). The configuration permits drainage of salt when installed at an angle from the horizontal of 10^{o}.

The salt mixing tees were designed so that flexibility was built into the interior 2" schedule 10 pipe to accommodate differential thermal expansion between the inner and outer pipes.

2.10.2 Water/Steam System Piping and Valves

This section provides additional description and drawing references for the water/steam system piping and valves. The water/steam system is described in Section 2.4. Pipe sizing criteria in the various piping sections are also discussed. All piping was designed in accordance with the Power Piping code, ANSI B31.1 (Reference 5), for the design temperature and pressure indicated on the B&W piping drawings referenced in the following subsections.

2.10.2.1 Evaporator Water Inlet Line

The evaporator water inlet line (B&W Drawing 179933C) provides subcooled water to the evaporator water inlet nozzle from the discharge of the boiler water circulation pump. The water inlet line is 4" Sch 80 carbon steel pipe. The pipe size was established based on considering the net pressure loss in the recirculation loop for full load conditions and the physical arrangement requirements of the system. It was advantageous to minimize the net pressure loss in the recirculation loop to reduce pumping requirements for the boiler water circulation pump. The evaporator, steam drum, evaporator water inlet piping, riser piping, and downcomer piping contribute to the net pressure loss in the recirculation loop. The evaporator configuration established the full load design flow, temperature, and steam quality conditions in the recirculation loop: 43300 lbm/hr (5.418 kg/sec) flow with a downcomer temperature of 559^{o}F (293^{o}C) and an evaporator exit quality of 27% at a saturation pressure of 1175 psig (8101 kPa). Based on these conditions and the physical arrangement of the piping, the velocity and pressure drop in the evaporator inlet pipe, as well as the downcomer pipe and riser pipe, were calculated. Considering the velocities and net pressure losses in the total recirculation loop, 4" Sch 80 pipe was selected for the three piping runs in the loop. The net pressure loss in the recirculation loop with the 4" Sch 80 pipe was conservatively calculated at 35 psi (241 kPa). The evaporator water inlet line is sloped downward from the evaporator inlet nozzle to allow drainage through the water drain line (See Section 2.10.2.8), the circulation heater drain valve, and the pump drain valve.

A 4" gate valve, FCV-383, is located in the evaporator water inlet line. This valve is a motor operated isolation valve. During normal SGS operation this valve is open. During periods when the circulation heater is in operation the valve is closed to route flow from the boiler water circulation pump through the heater to the evaporator inlet nozzle. This valve, together with HV-384 and FCV-384, can be used to isolate the boiler water circulation pump for maintenance while permitting the balance of the water/steam system to be maintained in a dry or wet layup condition.

2.10.2.2 Riser Line

The riser line (B&W Drawing 179934C) connects the evaporator water/steam outlet nozzle with the steam drum steam inlet nozzle. During normal operation, the water/steam mixture produced in the evaporator flows through the riser line to the steam separation equipment in the steam drum. The riser line is 4" Sch 80 carbon steel pipe. The pipe size was established based on the full load design conditions for the recirculation loop as discussed in Section 2.10.2.1. The piping is sloped downward from the steam drum to the evaporator outlet nozzle for drainage.

2.10.2.3 Downcomer Line

The downcomer line (B&W Drawing 179932C) connects the steam drum downcomer nozzle with the suction side of the boiler water circulation pump. Subcooled water from the steam drum inventory flows through the downcomer line to the pump. The downcomer line is 4" Sch 80 carbon steel pipe. The pipe size was established based on the full load design conditions for the recirculation loop as discussed in Section 2.10.2.1. An additional consideration for sizing the downcomer line was to minimize unrecoverable pressure losses, consistent with the net positive suction head required by the boiler water circulation pump. The downcomer piping is sloped downward from the steam drum to the pump to allow drainage through the water drain line and the pump volute drain valve.

A 4" gate valve, HV-384, is located in the downcomer line. This is a manually operated isolation valve. During all SGS operating conditions this valve is locked open. This valve, together with FCV-383 and FCV-384, can be used to isolate the boiler water circulation pump for maintenance while permitting the balance of the water/steam system to be maintained in a dry or wet layup condition.

2.10.2.4 Feedwater Line; Chemical Feed Line

The feedwater line (B&W Drawing 179944C) supplies feedwater to the steam drum from the Heat Rejection and Feedwater Subsystem (HRFS). Feedwater combines with the saturated water from the steam drum separation equipment to form a subcooled mixture for the recirculation loop. Feedwater flow matches steam flow to maintain a constant drum water level. The feedwater line is 1-1/4" Sch 80 carbon steel pipe. The pipe size was based on the standard B&W design practice of limiting full load feedwater velocity to less than 10 ft/sec (3.0 m/sec) and on minimizing the pressure drop in the SGS portion of the feedwater piping. The 1-1/4" Sch 80 pipe results in a full load feedwater velocity of less than 8 ft/sec (2.4 m/sec) with an unrecoverable pressure drop of less than 2 psi (14 kPa). The SGS feedwater pipe interfaces with the HRFS feedwater pipe at the north end of the SGS skid assembly. The feedwater pipe is sloped from the steam drum to the interface point to permit drainage at the low point in the HRFS feedwater piping. The feedwater flow control valve FCV-411 is located in the HRFS feedwater piping.

A 3/4" Sockolet is provided on the feedwater line near the steam drum feedwater nozzle for connection of the chemical feed line. The chemical feed line is connected to the chemical feed pump supplied by CRTF. The pump is located adjacent to the west side of the SGS skid and the piping is run between the pump and the feedwater line connection to suit field connections. Boiler water chemicals are added based on the requirements and procedures of the SGS Operating and Maintenance Manual (Reference 6).

2.10.2.5 Superheater Inlet Line; Water/Steam Side Vent Line

The superheater inlet line (B&W Drawing 179935C) delivers dry saturated steam from the steam drum outlet nozzle to the superheater steam inlet nozzle. This pipe run includes the high point in the SGS steam/water system. The superheater inlet line is 2-1/2" Sch 80 carbon steel pipe. This pipe was sized consistent with the requirements of the physical arrangement and with maintaining acceptable pressure drop between the superheater steam inlet and the steam drum such that the full load steam drum pressure was not greater than about 1200 psig (8274 kPa).

The piping is sloped downward from the high point to the superheater to allow drainage through the superheater and steam delivery piping.

The vent piping for the water/steam side of the SGS is a vertical line off the high point horizontal run in the superheater inlet line. The piping material is carbon steel. The vent line isolation valve HV-385 is a 1" manually operated, Y-pattern globe valve.

2.10.2.6 Superheater Steam Outlet Line

The superheater steam outlet flow is delivered to the Heat Rejection and Feedwater Subsystem (HRFS) through the piping shown on B&W Drawing 179939C. This steam delivery line is 2-1/2" Sch 160 pipe made of 2-1/4 Cr - 1 Mo material. This pipe was sized consistent with the requirements of the physical arrangement and with maintaining an acceptable pressure drop between the superheater outlet and the interface point with the HRFS steam piping. With the 2-1/2" Sch 160 pipe, the full load unrecoverable piping pressure drop is less than 8 psi (55 kPa). The SGS steam delivery pipe interfaces with the HRFS steam pipe at the north edge of the skid assembly. The steam pipe is sloped from the eccentric reducer on the superheater steam outlet nozzle to the interface point to permit drainage at the low point in the HRFS steam piping.

2.10.2.7 Steam Attemperator Line

The steam attemperator line (B&W Drawing 179939C) provides dry saturated steam from the superheater inlet line (B&W Drawing 179935C) to the superheater steam outlet line (B&W Drawing 179939C) to control the steam delivery temperature to the turbine to 950^{o}F (510^{o}C). The superheater was designed for an outlet steam temperature of 1000^{o}F (538^{o}C) at full load. The flow of saturated steam required to produce a steam delivery temperature of 950^{o}F (510^{o}C) is controlled by a

1" Fisher Controls Type 657-EHS globe valve (FCV-331) located in the steam attemperator line. The valve is air operated, diaphragm actuated. Valve sizing was based on considering flow requirements between 30% and 110% of full load. A range of saturated steam flow was established based on possible variation of the superheater steam outlet temperature due to both superheater performance margin and load. A pressure drop of 30 psi (207 kPa) across the valve was used for full load conditions. To provide some additional margin in valve sizing, the valve was sized based on 90% of full stroke at the maximum specified flow.

The attemperator line piping is 1" Sch 80. Piping material is carbon steel upstream of valve FCV-331 and 2-1/4 Cr - 1 Mo downstream of the valve. The piping is sloped downward from the superheater inlet line connection to the superheater steam outlet line connection to allow drainage.

2.10.2.8 Water Drain Line

The water drain line (B&W Drawing 179943C) provides for drainage of certain portions of the water side of the SGS. The drain line is 1" Sch 80 carbon steel pipe. The water drain piping tees from the downcomer line (B&W Drawing 179932C) and is sloped downward from that point to the pipe termination location on the east side of the skid assembly. From this termination point, the piping is routed by SNL to the blowdown/drain tank located east of the SGS skid assembly. The steam drum blowdown line (See Section 2.10.2.9) tees into the water drain line upstream of the skid termination point. Fluid from both the water drain line and the blowdown line flows to the blowdown/drain tank through the common pipe. The drain line isolation valve HV-381 is a 1" manually operated, Y-pattern globe valve.

2.10.2.9 Blowdown Line; Boiler Water Sample Line

The steam drum blowdown line (B&W Drawing 179942C) provides for intermittent blowdown of boiler water to maintain correct boiler water chemistry. The blowdown line also allows adjustment of steam drum water level during start-up. The blowdown line is 1" Sch 80 carbon steel pipe. The piping is sloped downward from the steam drum to the point where it is tied into the water drain line (See Section 2.10.2.8). Blowdown fluid is routed to the blowdown/drain tank located to the east of the SGS skid. The B&W/CRTF piping interface is described in Section 2.10.2.8. The blowdown line isolation valve HV-383 is a 1" manually operated, Y-pattern globe valve. A manually operated 1" Yarway Hy-Drop throttling valve (HV-382) is located in the blowdown line to adjust blowdown flow rate.

A 3/4" Thredolet is provided on the blowdown line upstream of isolation valve HV-383 for connection of the boiler water sample line. The sample line terminates at a SNL supplied sampling station located in the thermal storage subsystem control room. Boiler water is sampled based on the requirements and procedures of the SGS Operating and Maintenance Manual (Reference 6). A 3/4" general purpose gate valve for sample line isolation is located in the sample line near the connection to the blowdown line.

2.10.2.10 Circulation Heater Piping

Inlet and outlet piping to the circulation heater is shown on B&W Drawings 179945C and 179946C. The circulation heater lines are 2" Sch 80 carbon steel pipe. This piping is compatible with the 2", 900 lb. raised face inlet and outlet flanges on the circulation heater. The heater inlet piping branches from the evaporator inlet piping upstream of 4" isolation valve FCV-383 (B&W Drawing 179933C) and is routed to the lower heater flange. The heater outlet piping connects the upper heater flange to the evaporator inlet piping downstream of the 4" isolation valve. Both the inlet and outlet piping are sloped to permit drainage to the heater drain valve. Piping material is carbon steel.

A 2" Valtek Mark Two air operated, cylinder actuated valve (FCV-384) is located in the heater inlet line. This valve is furnished by SNL. The valve has 2500 lb. raised face flanges for mounting the valve in the piping. During periods of circulation heater operation, the valve is open; otherwise the valve is closed.

2.11 Heat Tracing

The SGS superheater shell, evaporator shell, and salt system piping are provided with a trace heating system. This system allows the heat exchangers and salt piping to be heated from ambient conditions to a temperature above the freezing point of the salt, prior to loading molten salt into the SGS. The heat tracing system also maintains the temperature of the system above the salt freezing point during periods of diurnal shutdown.

Based on discussions with SNL, the SGS specification requirements for salt system heat tracing were clarified and amplified. Heat tracing was sized to meet the following requirements:

- Power input based on a $500^{\circ}F$ ($278^{\circ}C$) temperature difference between salt system component temperature and ambient temperature
- 4" (102 mm) insulation thickness on piping; 5" (127 mm) insulation thickness on heat exchangers
- Calcium-silicate insulation; assume conductivity is 0.055 Btu/hr-ft-F (0.095 w/m-C)
- Heat trace cable to be Nelson Electric Co. Inconel sheath, mineral insulated cable with nichrome wire; 3/16" (4.8 mm) diameter, single conductor cable to be used wherever possible; 3/16" (4.8 mm) diameter, two conductor cable wired in parallel as an alternate; based on system operating temperatures, choice of cables limited to those indicated on Figure 2.11-1.
- Maximum cable power 45-50 w/ft (148 - 164 w/m)
- Operating voltage 277 vac

- Additional heat trace cable length at locations of local additional heat loss such as fixed supports and valves

The heat tracing power for the salt system piping and the heat exchangers was based on the above requirements with the exception that a conservatively higher insulation conductivity of 0.06 Btu/hr-ft-F (0.104 w/m-C) was used. The outside surface temperature of the insulation was assumed equal to ambient temperature. Following are the calculated salt system heat trace power requirements:

4" Pipe	54 w/ft (177 w/m)
3" Pipe	46 w/ft (151 w/m)
2" Pipe	37 w/ft (121 w/m)
1-1/2" Pipe	33 w/ft (108 w/m)
1" Pipe	28 w/ft (92 w/m)
Superheater	66 w/ft (217 w/m)
Superheater fixed support	51 w
Evaporator	79 w/ft (259 w/m)
Evaporator fixed support	74 w
1" Valve Bonnet (FCV-301, FCV-341, FCV-381, FCV-382)	170 w
2" Valve Bonnet (FCV-321)	185 w

The choice of heat trace cables and the design of heat trace circuitry were based on these power requirements and the previously listed heat trace requirements.

There are ten heat tracing zones in the SGS salt system. Heat tracing information is summarized on Table 2.11-1. All the heat tracing, with the exception of circuit O-Q in zone HT-4, is Nelson Electric Company 3/16 inch (4.8 mm) diameter, inconel sheath, mineral insulated cable with single conductors of nichrome wire. The heating cable in circuit O-Q is the same as described above except that the cable is two conductor, with the conductors wired in parallel. For each primary heat trace cable installed, a redundant (or back-up) cable is also installed. Both the primary and the back-up cables are terminated in the same field junction box; in the event of a failure of the primary cable the back-up cable can be placed in service by transferring the electrical power source from the primary to the back-up cable in the field junction box. In general, heat tracing cable is installed along the axis of the piping and the heat exchangers. The bonnet extensions on salt side valves FCV-301, FCV-321, FCV-341, FCV-381, and FCV-382 are heat traced to assure that salt in the bonnet extensions does not freeze. "Loops" are included in the heat exchanger cables at the fixed support locations to provide the required local heat input.

In general, the salt system heat tracing has performed satisfactorily. Some re-work on the bonnet insulation of the valves was done to increase the temperature on the bonnets above the salt freezing temperature. The added insulation achieved the desired results except on valve FCV-341. On this particular valve local conditions at bonnet-yoke region of the valve prevented installing sufficient additional insulation. On certain days, the combined ambient temperature and wind conditions caused enough heat loss from the valve that the temperature of the bonnet extension was 40^{o}-50^{o}F (22^{o}-28^{o}C) below the minimum required 480^{o}F (249^{o}C). With the concurrence of SNL, the back-up heat trace cable on valve FCV-341 was wired to a 110 vac. circuit which included a Variac (B&W Drawing 405343E) to control cable power (heat trace zone HT-3B on Table 2.11-1). The Variac was adjusted to increase power input to the valve extension such that the extension temperature exceeded $480^{o}F$ ($249^{o}C$). This proved to be a satisfactory fix.

The SGS feedwater piping is heat traced to provide freeze protection during extended periods when the feedwater flow is zero, such as diurnal shutdown. Heat tracing is sized to meet the following requirements:

- o Power input based on a temperature difference of approximately $100^{o}F$ ($56^{o}C$) between the feedwater pipe temperature and ambient temperature
- o 3" Insulation thickness on piping
- o Calcium-silicate insulation; assume conductivity is 0.06 Btu/hr-ft-F (0.104 w/m-C)
- o Heat trace cable to be Nelson Electric Co. Inconel sheath, mineral insulated cable with nichrome wire; 3/16" (4.8 mm) diameter, single conductor cable to be used if possible; 3/16" (4.8 mm) diameter, two conductor cable wired in parallel as an alternate
- o Maximum cable power 45 - 50 w/ft (148 - 164 w/m)
- o Operating voltage 110 vac
- o Outside surface temperature of insulation assumed equal to ambient temperature

The heat tracing power for the feedwater piping based on these requirements is 7.2 w/ft. The heat trace cable selected (Zone HT-9 on Table 2.11-1) has a power input of 6.8 w/ft, which maintains a temperature difference of $94^{o}F$ ($52^{o}C$) between the feedwater pipe and ambient.

The instrument piping for the pressure, flow, and level transmitters in the water/steam system is provided with heat tracing for freeze protection (Zone HT-10 on Table 2.11-1) during periods when the ambient temperature could result in freezing of the stagnant water in these instrument lines. Freeze protection is installed for the following:

Steam Drum Water Level	LT-311
Steam Drum Pressure	PT-383
Main Steam Flow	FT-311
Steam Delivery Pressure	FT-321
Feedwater Pressure	PT-386
Attemperation Steam Flow	FT-381
Gage glass	LI-311

The seven heat trace cables were initially sized to provide 2-3 w/ft. with the cables wired in series on a 110 vac. circuit. This power input proved inadequate for certain ambient temperature/wind conditions, and freezing occurred in some transmitter piping runs. A revised series-parallel circuit for the heat tracing cables was implemented to increase power input approximately 4 w/ft. This power increase was insufficient to prevent freezing in the transmitter lines. Additional evaluation of the freeze protection for the instrument piping was done, including a review of the as-installed heat trace cable lengths and locations and piping insulation locations and thicknesses. Based on this review, changes to insulation arrangements and heat tracing were made, and wind shields were added to the instrument piping isolation valves. Additional heat trace was placed on the steam drum pressure instrument line and on the chemical feed line (Zone HT-10A on Table 2.11-1). A complete discussion of these changes is included in B&W Letter Report 700-0027-45-LR-1 in Appendix B.

The insulation at the main salt flow transmitter (FT-321) and the attemperation salt flow transmitter (FT-382) was to have been arranged as shown on Figures 2.11-2 through 2.11-5 to maintain the temperature of the salt in the standpipes above the salt freezing point. Periodic freezing occurred in these standpipes as evidenced by faulty flow indications. A 110 vac. heat trace circuit was added to heat the standpipes. A heat trace cable was added to each pair of standpipes; these cables were wired in series with a Variac (Zone HT-3A, Table 2.11-1), and power was adjusted to maintain standpipe temperature above 480F (249C) as indicated by thermocouples installed on the standpipes. When the insulation was disassembled to install the heat trace cables, it was discovered that the region around the standpipes was packed with blanket insulation rather than being empty as indicated on Figures 2.11-2 through 2.11-5; this undoubtedly caused the freezing problem in the standpipes. It was decided to proceed with installation of the heat trace as a more positive approach to maintaining standpipe temperature as opposed simply removing the insulation and establishing the configuration as shown on Figures 2.11-2 through 2.11-5. This proved to be an effective fix and was subsequently used on other MSEE salt side transmitters, outside the SGS, to alleviate similar freezing problems.

Table 1

Two Conductor Inconel 600
600 Volt Maximum

Cable Number	Forms Available	Ohms Per Cable Ft. @25°C	Resistance-Temperature Curve Number	@25° Process Temp. Maximum Watts/Ft. QHT-3
627B	A,E	.027	1	N.A.
640B	A,E	.043	1	N.A.
670B	A,E	.070	1	N.A.
710B	A,E	.104	N.A.	70
715B	A,E	.162	N.A.	70
720B	A,E	.205	N.A.	70
732B	A,E	.325	N.A.	70
750B	A,E	.500	N.A.	70
774B	A,E	.735	N.A.	70
810B	A,E	1.162	N.A.	70
819B	A,E	1.870	N.A.	70
830B	A,E	2.970	N.A.	70
840B	A,E	4.300	N.A.	70
859B	A,E	5.980	N.A.	70

.3125 In. O.D., Hot Section Wt. .22 Lbs/Ft., Cold Section Wt. .22 Lbs/Ft., Maximum 45 Watts/Ft. w/o QHT-3 at 25°C Process Temperature.

Table 2

Two Conductor Inconel 600
300 Volt Maximum

Cable Number	Forms Available	Ohms Per Cable Ft. @25°C	Resistance-Temperatura-ture Curve Number	@25° Process Temp. Maximum Watts/Ft. QHT-3
721K	A,E	.213	3	N.A.
722K	A,E	.213	1	50
732K	A,E	.319	N.A.	50
742K	A,E	.416	N.A.	50
752K	A,E	.520	N.A.	50
774K	A,E	.740	N.A.	50
810K	A,E	1.000	N.A.	50
813K	A,E	1.300	N.A.	50
818K	A,E	1.800	N.A.	50
824K	A,E	2.340	N.A.	50
830K	A,E	2.960	N.A.	50
838K	A,E	3.700	N.A.	50
846K	A,E	4.720	N.A.	50
866K	A,E	6.600	N.A.	50
894K	A,E	9.000	N.A.	50

.1875 In O.D. Hot Section Wt. .07 Lbs/Ft., Cold Section Wt. .22 Lbs/Ft. Maximum 30 Watts/Ft. w/o QHT-3 at 25°C Process Temperature.

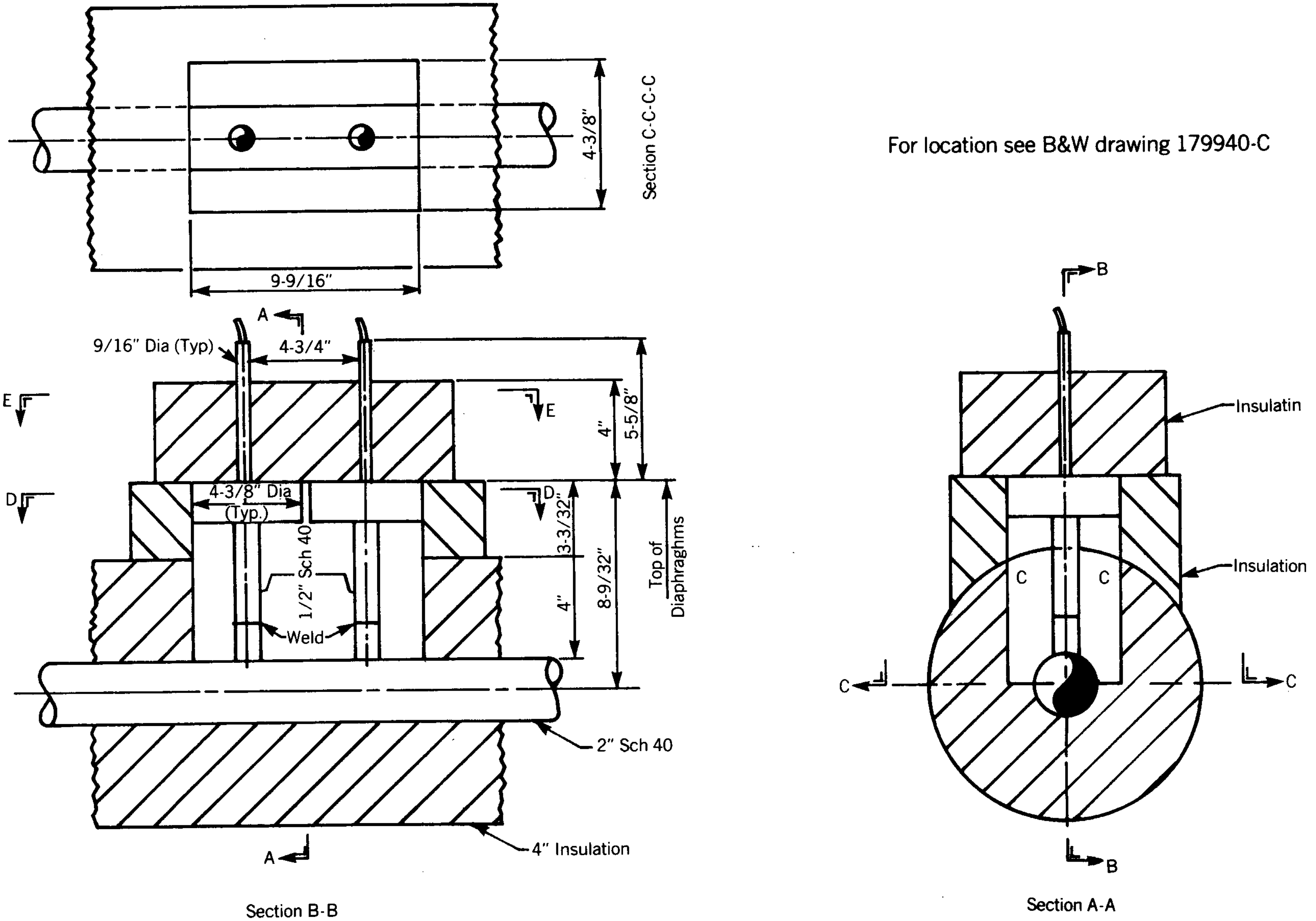
Table 4

One Conductor Inconel 600 and Copper

Cable Number	Forms Available	Sheath Material	Ohms Per Cable Ft. @25°C	Resistance-Temperature Curve Number	Maximum Volts	O.D. Inches
239K	E	Inconel	.039	N.A.	600	.1875
250K	E	Inconel	.050	N.A.	600	.1875
279K	E	Inconel	.079	N.A.	600	.1875
310K	E	Inconel	.095	N.A.	600	.1875
316K	E	Inconel	.157	N.A.	600	.1875
326K	E	Inconel	.260	N.A.	600	.1875
333K	E	Inconel	.330	N.A.	600	.1875
346K	E	Inconel	.457	N.A.	600	.1875
372K	E	Inconel	.730	N.A.	600	.1875
412K	E	Inconel	1.170	N.A.	600	.1875
415K	E	Inconel	1.480	N.A.	600	.1875
423K	E	Inconel	2.360	N.A.	600	.1875
430K	E	Inconel	2.800	N.A.	600	.1875
447K	E	Inconel	4.500	N.A.	600	.1875

Nelson Electric Company
Heat Trace Cable
Figure 2.11-1

For location see B&W drawing 179940-C



Cold Salt Flow Transmitter (FT-382)
Diaphragm Insulation
Figure 2.11-2

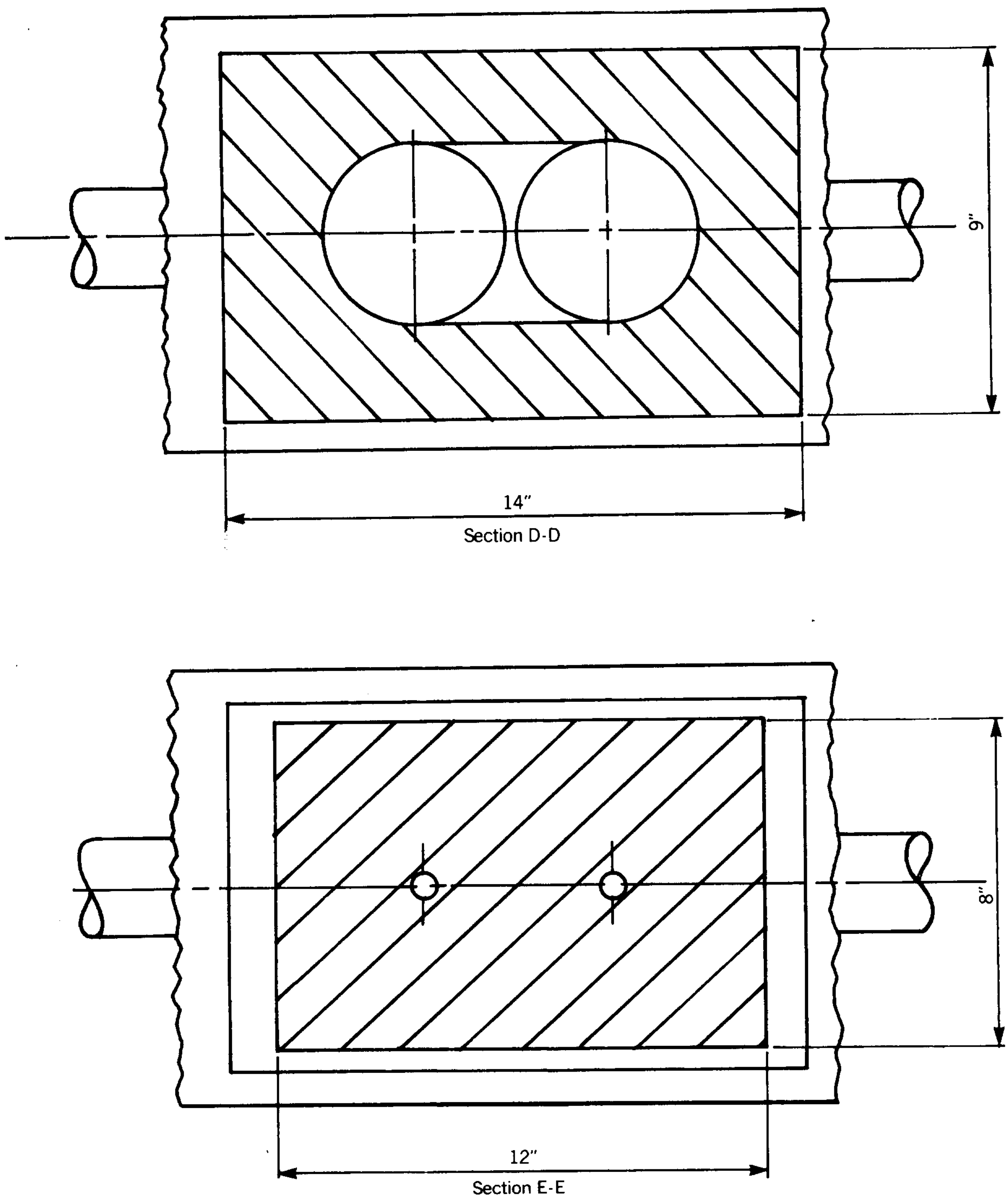
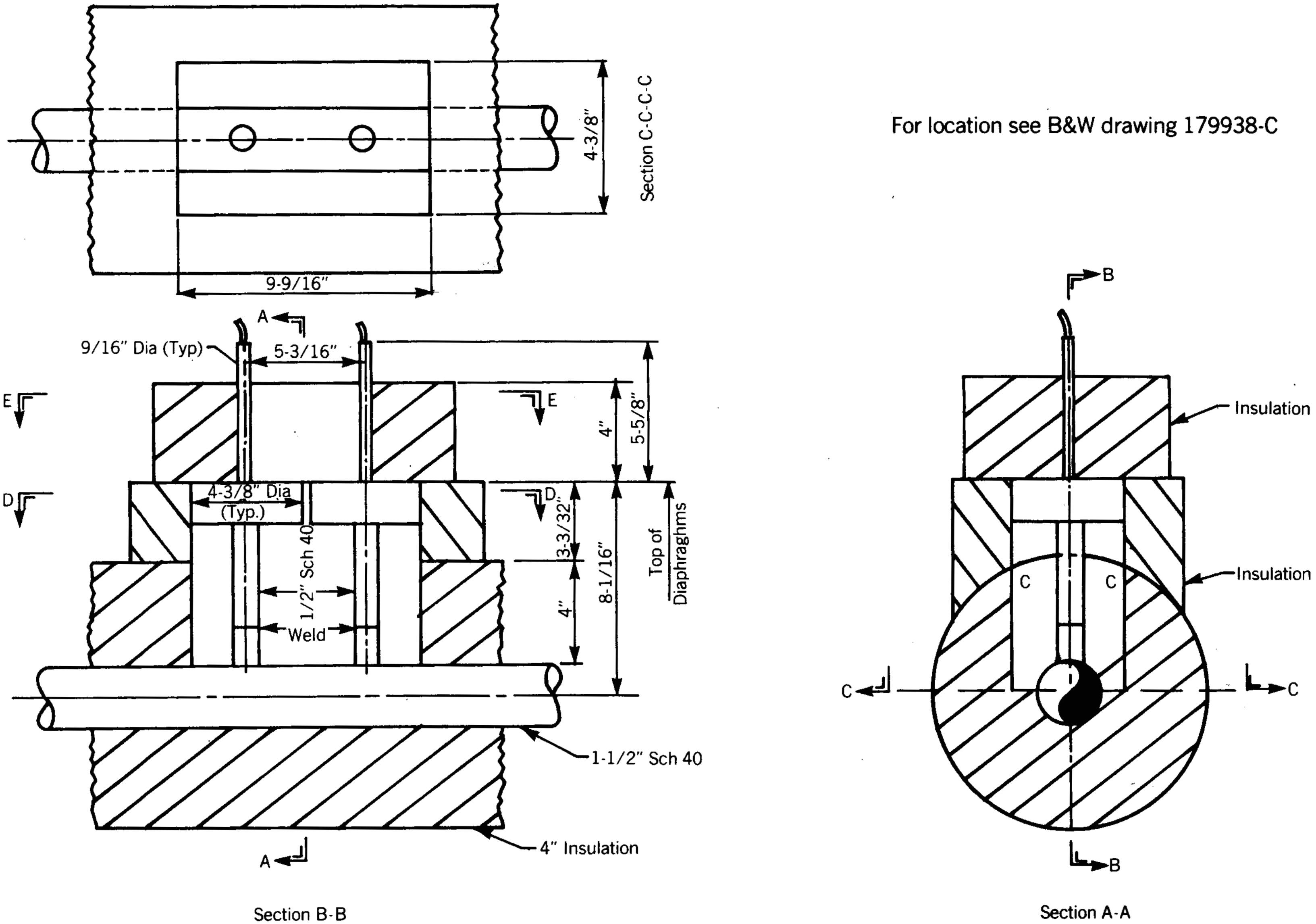
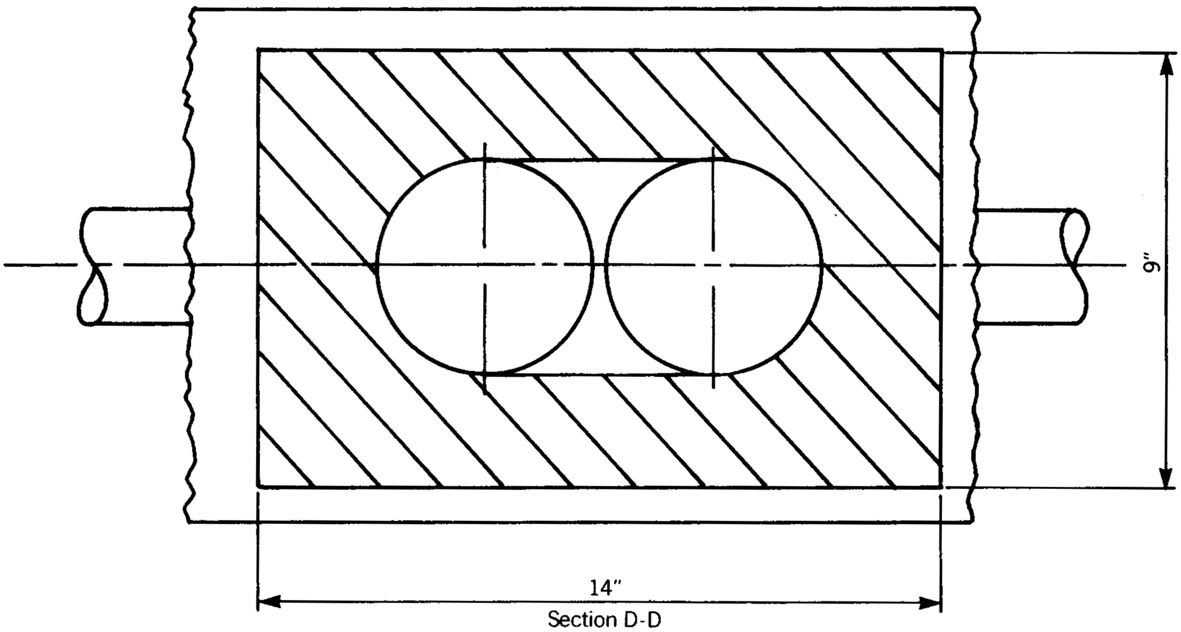


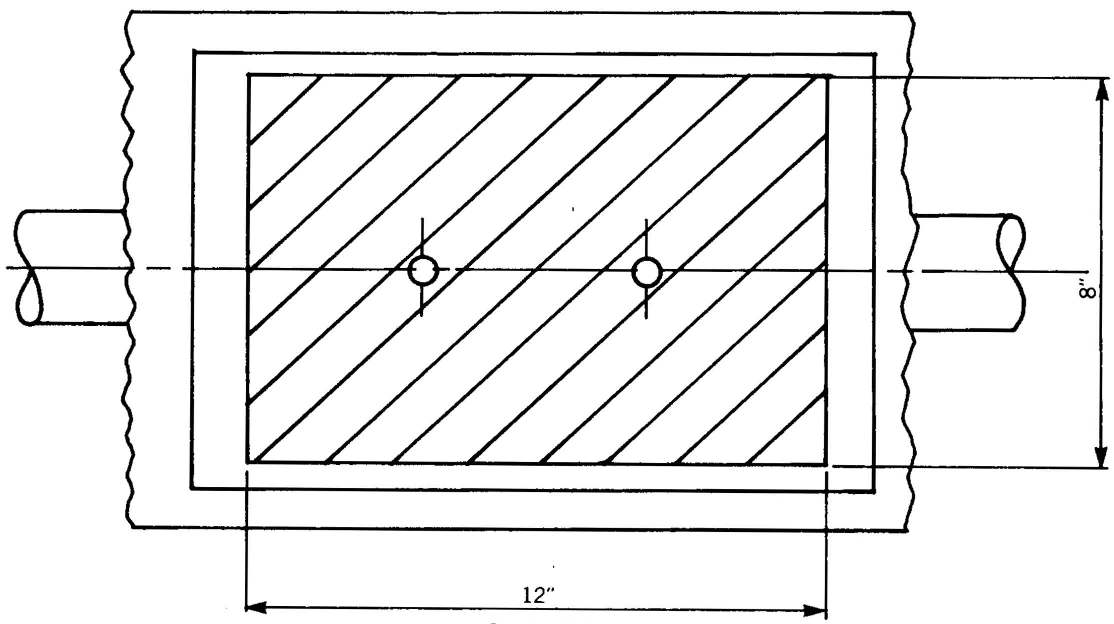
Figure 2.11-3



Cold Salt Flow Transmitter (FT-382)
Diaphragm Insulation
Figure 2.11-4



Section D-D



Section E-E

Figure 2.11-5

TABLE 2.11-1

SGS Heat Trace Zones

Location	Heat Tracing Zone No.	B&W Circuit	Drawing
Hot Salt Inlet Piping	HT-1	A-B	179936C
Hot Salt Inlet Piping		B-C-G	179936C
Salt Piping Between SH and EV	HT-2	J-E-J	179937C
Salt Piping Between SH and EV		K-D-K	179937C
Salt Flow Transmitters FT-321, FT-382	HT-3A	N/A	N/A
Valve FCV-341 Bonnet	HT-3B	N/A	179938C
EV Salt Outlet Piping	HT-4	M-N	179940C
EV Salt Outlet Piping		N-O	179940C
EV Salt Outlet Piping		O-Q	179940C
Salt Drain Piping	HT-5	R-S	179941C
Salt Drain Piping		U-T	179941C
Salt Drain Piping		S-V	179941C
SH Outlet Overpress. Piping	HT-6	Y-Z	179937C
EV Outlet Overpress. Piping		W-X	179940C
Superheater	HT-7	AA-BB	405325E
Superheater		AA-BB	405325E
Evaporator	HT-8	CC-DD	405328E
Evaporator		CC-DD	405328E
Feedwater Piping	HT-9	EE-GG	179944C
Instrumentation Piping FW Pressure Drum Pressure By-Pass Steam Flow Steam Delivery Pressure Drum Level Gage Glass Main Steam Flow	HT-10	N/A	N/A
Instrumentation Piping Drum Pressure Chemical Feed Line	HT-10A	N/A	N/A

2.12 CONTROLS/INSTRUMENTATION/ELECTRICAL

2.12.1 Overview

The control and monitoring of the SGS as part of the overall MSEE system is accomplished through a Bailey Controls Company Network 90 system. The Network 90 sends and receives signals from various components in the SGS as well as several components in other MSEE subsystems which are required for control of the SGS. The Network 90 system also interfaces with the CRTF EMCON control system such that the SGS may be operated directly from the EMCON control system in CRTF main control room. This section describes the transmitters, thermocouples, and other equipment which provide signals necessary for the control and monitoring of the SGS. The junction boxes mounted on the skid assembly to accommodate power/control components, signal wiring, and thermocouple wiring are discussed. The logic of the various SGS control loops and monitoring functions are described and related to both the Network 90 control system and the Network 90/EMCON interface.

2.12.2 Transmitters

The transmitters discussed below are located on the SGS skid assembly. These transmitters measure flows, pressures, and steam drum level and transmit signals through the SGS signal wiring junction box to the Network 90 control system. Unless otherwise noted, the signals transmitted to the signal wiring junction box are 4-20 ma. The designations for each of the transmitters discussed below are taken from the SGS flow schematic (see Figure 2.1-2).

In addition to the transmitter signals from the SGS, the feedwater flow signal (FT-411) from the Heat Rejection and Feedwater System is required as part of the steam drum level control loop. The feedwater flow transmitter is part of the CRTF equipment; the 4-20 ma. signal from this transmitter is supplied directly to the Network 90 control system.

Main Salt Flow Transmitter FT-321

Manufacturer: Taylor Instrument Company

Model: X3423TD10264-02-00-10(146)

The transmitter senses pressure drop across the Taylor segmental wedge flow element located in the evaporator salt outlet piping as shown on B&W Drawing 179940C. Salt flow rate is a function of this pressure drop. The main salt flow rate is part of the SGS load control loop as discussed in Section 2.12.8.2.1. The transmitter is mounted on the skid adjacent to the flow element. The transmitter assembly includes two diaphragm seal elements and capillary tubes which are filled with silicon DC702. The fill fluid in each capillary tube transmits the salt pressure to the transmitter while providing a barrier between the molten salt and the transmitter.

By-Pass Salt Flow Transmitter FT-382

Manufacturer: Taylor Instrument Company

Model: X3423TD10264-02-00-10 (146)

The transmitter senses the pressure drop across the Taylor segmental wedge flow element located in the cold salt control piping as shown on B&W Drawing 179938C. Salt flow rate is a function of this pressure drop. The by-pass salt flow is measured for indicating and recording purposes. The transmitter is mounted on the skid adjacent to the flow element. The transmitter assembly is the same as described for the main salt flow transmitter above.

Main Steam Flow Transmitter

Manufacturer: Bailey Controls Company

Model: BQ75221

The transmitter senses the pressure drop across the orifice plate located in the main steam outlet piping as shown on B&W Drawing 179939C. The transmitter is mounted adjacent to the orifice plate and is connected to the pressure taps on either side of the orifice plate. Main steam flow rate is a function of the pressure drop across the orifice plate. The main steam flow is part of both the SGS load control loop and the SGS drum water level control loop as discussed in Section 2.12.8.2.1.

By-Pass Steam Flow Transmitter FT-381

Manufacturer: Bailey Controls Company

Model: BQ75221

The transmitter senses the pressure drop across the orifice plate located in the attemperator steam piping as shown on B&W Drawing 179939C. The transmitter is mounted adjacent to the orifice plate and is connected to the pressure taps on either side of the orifice plate. By-pass steam flow is a function of the pressure drop across the orifice plate. The by-pass steam flow is measured for indicating and recording purposes.

Superheater Salt Inlet Pressure Transmitter PT-382

Manufacturer: Kaman Instrumentation Company

Model: KP-1911-A200P-FW-C05

The transmitter senses the absolute pressure of the molten salt in the hot salt inlet piping near the superheater salt inlet nozzle as shown on B&W Drawing 179936C. The transmitter sensor mounted on the salt piping converts the pressure to an electronic signal which is transmitted to the signal conditioning electronics package mounted adjacent to the sensor location. A 15 vdc input signal to the signal conditioning electronics package is provided by the power supply located in the NEMA 4 enclosure with the electronics package. The 0-1 vdc output signal of the electronics package indicates the pressure. The 0-1 vdc signal is converted to a 4-20 ma signal by the Acromag E/I Converter located in the Signal Wiring junction box mounted on the skid (see Section 2.12.6). The superheater salt inlet pressure is measured for indicating and recording purposes.

Evaporator Salt Outlet Pressure Transmitter PT-384

Manufacturer: Taylor Instrument Company

Model: X3443TF10222-02-10 (146)

The transmitter senses the gage pressure of the molten salt in the salt outlet piping near the evaporator salt outlet nozzle as shown on B&W Drawing 179940C. The transmitter assembly includes a diaphragm seal element, which is mounted on the salt piping, and a capillary tube filled with silicon DC702. This fill fluid transmits the salt pressure to the transmitter while providing a barrier between the molten salt and the transmitter. The evaporator salt outlet pressure is measured for indicating and recording purposes.

Superheated Steam Delivery Pressure Transmitter PT-321

Manufacturer: Bailey Controls Company

Model: KA15111

The transmitter senses the gage pressure of the superheated steam downstream of the steam attemperator location as shown on B&W Drawing 179939C. The transmitter is mounted adjacent to the pressure tap location and is connected to that tap. The steam pressure is part of the SGS load control loop as discussed in Section 2.12.8.2.1.

Steam Drum Pressure Transmitter PT-383

Manufacturer: Bailey Controls Company

Model: KA14121

The transmitter senses the saturated steam gage pressure in the steam drum through the pressure tap location shown on B&W Drawing 405326E. The transmitter is mounted adjacent to the steam drum and is connected to the pressure tap. The saturation pressure is measured for indicating and recording purposes.

Feedwater Pressure Transmitter PT-386

Manufacturer: Bailey Controls Company

Model: KA14121

The transmitter senses the gage pressure of the feedwater upstream of the steam drum feedwater nozzle as shown on B&W Drawing 179944C. The transmitter is mounted adjacent to the pressure tap location and is connected to that tap. The feedwater pressure is measured for indicating and recording purposes.

Steam Drum Water Level Transmitter LT-311

Manufacturer: Bailey Controls Company

Model: BQ74221

The transmitter senses the pressure difference between the steam drum water level indication taps shown on B&W Drawing 405326E. The transmitter is mounted adjacent to the steam drum and is connected to the pressure taps. The low pressure side of the transmitter is connected to the upper of the two pressure taps on the steam drum. This tap is located in the steam space above the drum water level. A reservoir, or condensate pot, is located at the elevation of the upper pressure tap.

This reservoir maintains the low pressure side instrument piping full of water and provides a constant, or reference, pressure head on the low pressure side of the transmitter.

The high pressure side of the transmitter is connected to the lower of the two pressure taps on the steam drum. As the drum water level changes, the pressure head on the high side of the transmitter changes as does the pressure difference measured by the transmitter, which is indicative of drum water level. The drum level is part of the SGS drum level control loop as discussed in Section 2.12.8.2.1.

2.12.3 Valve Positioners, Position Indicators, Limit Switches

Pneumatically operated valves in the SGS are positioned by the control system by a 4-20 ma signal to the valve positioner. The positioner converts this signal to an air pressure applied to the valve diaphram or piston to move the valve between 0% and 100% of full open. Valves used for control purposes have position indicators which transmit a 4-20 ma feedback signal to the control system to indicate 0% to 100% of full open valve position. Valves used for isolation purposes (open/closed only) have limit switches which provide a positive indication to the control system that the valves are fully open or fully closed. Table 2.12-1 lists the valves for which the SGS control system has signals to valve positioners and position indicators or limit switches. All signals between the valves and the control system for the valve positioners, position indicators, and limit switches for the SGS are routed through the signal wiring junction box, unless otherwise noted below.

The feedwater flow control valve FCV-411 is part of the Heat Rejection and Feedwater System; however, control of the feedwater flow is part of the SGS control system as discussed in Section 2.12.8.2.1. The 4-20 ma signals to the FCV-411 positioner are routed directly to the Network 90 control system from the valve. The hot salt isolation/control valve FCV-351 is nominally part of the Steam Generation Subsystem, and control of the valve position is part of the SGS control system. However, the valve was supplied and installed by SNL and is not part of the SGS skid assembly. Therefore, the positioner signals are routed directly to the Network 90 control system.

The 4" isolation valve FCV-383 is a motor operated isolation valve. The motor operator allows the valve to be placed only in the open or closed position. Limit switches provide indication to the control system that the valve is opened or closed.

The location of the various SGS valves is included in Section 2.10, Piping and Valves.

2.12.4 Thermocouples

The thermocouples installed as part of the SGS are grouped into three categories: Control/indicating thermocouples, heat tracing control thermocouples, and informational thermocouples.

2.12.4.1 Control/Indicating Thermocouples

The thermocouples required for control of the SGS and for indicating and recording of various temperatures in the SGS are noted on the SGS flow schematic (see Figure 2.1-2) and are listed in Table 2.12-2. With the exception of the feedwater temperature and circulation heater element temperature thermocouples, the thermocouples are immersion-thermocouples which are installed in the fluid stream to approximately the centerline of the pipe. The installation locations are indicated on the B&W drawings listed in Table 2.12-2. The thermocouples are ungrounded, type K, dual element (one functioning thermocouple, one back-up thermocouple) with a waterproof head located outside the pipe insulation. Thermocouple lead wire is routed from each head to the SGS signal wiring junction box. The thermocouples have been calibrated by the manufacturer.

The feedwater temperature thermocouple is a pad-type thermocouple installed on the feedwater pipe. The thermocouple is ungrounded, type K, dual element (one functioning thermocouple, one back-up thermocouple) with a waterproof head located outside the pipe insulation. Thermocouple lead wire is routed from the head to the SGS signal wiring junction box.

The circulation heater element temperature thermocouple is a sheath-type thermocouple installed on heater element HR-5 near the top of the heated portion of the element. The thermocouple is ungrounded, Type K. The thermocouple lead wire is routed to the SGS signal wiring junction box.

In the event of a thermocouple failure, the back-up thermocouple can be placed in service by connecting its leads to the thermocouple lead wire in the waterproof head.

2.12.4.2 Heat Tracing Thermocouples

The operation of heat trace zones HT-1 through HT-9 is controlled by thermocouple signals transmitted to the CRTF Acurex Data Logger. The thermocouples are pad-type thermocouples. The pads are mounted on the pipe outside surfaces at the locations indicated on the drawings listed in Table 2.12-3. Each pad is contoured to conform to the particular pipe to which it is attached. The thermocouples are ungrounded, type K, dual element (one functioning thermocouple, one back-up thermocouple) with a waterproof head located outside the pipe insulation. Thermocouple lead wire is routed from each head to the SGS signal wiring junction box. In the event of a thermocouple failure, the back-up thermocouple can be placed in service by connecting its leads to the thermocouple lead wire in the waterproof head.

2.12.4.3 Informational Thermocouples

Forty-six thermocouples are installed at various locations in the SGS to provide additional information on the operating characteristics of the system. The thermocouples are sheathed thermocouples located as indicated on the drawings listed in Table 2.12-4. The thermocouples are ungrounded, type K with a plug type connector located outside the insulation. Thermocouple lead wire with a mating plug type connector is routed to the SGS informational thermocouple junction box. Since the informational thermocouples are considered a temporary connection, the thermocouple lead wires are not run in conduit. From the junction box, the thermocouple signals are routed to the CRTF Acurex Data Logger located in the Salt Storage Control Room adjacent to the SGS. The Acurex Data Logger allows temperature data to be monitored and recorded.

2.12.5 Control/Power Junction Box

A control/power junction box is provided on the SGS skid for monitoring and control signals of various equipment on the SGS. The junction box is a NEMA 4 enclosure which is approximately 84 inches high by 72 inches wide by 12 inches deep (2.13m x 1.83m x 0.30m), located as shown on B&W Drawing 405332E. It is a double door enclosure with a manual disconnect switch provided in the upper right hand corner. All AC power to the SGS is provided through this junction box. The power source is 480 vac, 4 wire, 3 phase, 60 hz. The total estimated power consumption of the equipment on the SGS which is operated through this junction box is 105 kw. The schematic for the power/control equipment is on B&W Drawing 405343E.

The internal arrangement of the control/power junction box includes the following components:

- A fusible main disconnect switch with three 150 amp fuses for 480 vac service.
- A motor starter for operation of the 480 vac, boiler water circulation pump motor.
- A reversing motor starter for the operation of the 480 vac motor on the 4" isolation valve FCV-383.
- Five contactors for control of the 480 vac circulation heater circuits HR-1 through HR-5. The contactors are operated by the control system via the 110 vac power source available in the junction box.
- Eight contactors for control of eight zones (HT-1 through HT-8) of the salt side heat tracing. The contactors control a 277 vac single phase power source for each zone. Heat trace monitoring thermocouples in each of the eight zones send signals to the CRTF Acurex Data Logger, which controls the contactors via 24 vdc relays located in the junction box.
- One relay for control of heat tracing zone HT-9 on the feedwater line for freeze protection. This 24 vdc relay controls a 110 vac power source for the heat tracing and is located in the junction box. The relay is energized from the CRTF Acurex Data Logger in the same manner as described above.

- One thermoswitch and one relay for control of freeze protection zone HT-10 on various water/steam side transmitter piping runs. The thermoswitch sensing bulb for ambient temperature is mounted on the bottom surface of the junction box. Zone HT-10 is energized when the ambient temperature falls below the thermoswitch set point of 40^{o}F (4^{o}C).
- A 5 kva, 480 vac to 110 vac transformer is provided in the junction box for operation of the following components mounted on the SGS:

  Boiler Water Circulation Pump motor start and stop

  Boiler Water Circulation Pump motor thermal overload

  Boiler Water Circulation Pump coolant flow switch

  Boiler Water Circulation Pump current sensing relay

  Power for contactors HR-1 through HR-5 and contactors HT-1 through HT-8

  Heat trace zones HT-3A, HT-3B, HT-9, HT-10, HT-10A

  Kaman remote power supply

  Thermoswitch and relay for HT-10

  Duplex receptacle

  Current sensing relay for circulation heater circuit HR-5

  Valve FCV-383 Motor stop and start

The current sensing relay for the boiler water circulation pump motor (BWCP) provides a feedback signal to the Network 90 system as to whether or not the BWCP is running. This signal provides indication of the pump status to the operator and is used for interlocks related to the BWCP. The current sensing relay for circulation heater circuit HR-5 provides a feedback signal to the Network 90 system as to whether or not the single heater element in circuit HR-5 is energized. This signal provides indication of HR-5 status to the operator and is used for interlocks related to heater operation.

2.12.6 Signal Wiring Junction Box

A signal wiring junction box is provided on the SGS skid for wire terminations used for monitoring and control of thermocouples, valves, transmitters, and switches. The junction box is a NEMA 4 enclosure which is 36 inches high by 30 inches wide by 8 inches deep (0.91m x 0.76m x 0.20m), located as shown on B&W Drawing 405332E. All signals in this junction box are dc.

The internal arrangement of this junction box includes the following components:

- Seventy terminal blocks with alternate chromel and alumel terminal lugs. These terminals are used for connection of the control, monitoring, and heat trace control thermocouples located on the SGS (see B&W Drawing 405344E). Fourteen spare terminals have been provided. The following control and monitoring thermocouple signals are sent to the Network 90 from the signal wiring junction box:

TE-331	TE-382
TE-332	TE-301
TE-383	TE-384
TE-386	TE-388

The following heat trace control thermocouple signals are sent to the CRTF Acurex Data Logger from the Signal Wiring Junction Box:

HTTC-AB-45-3117	HTTC-RS-45-3509
HTTC-BCG-45-3118	HTTC-UT-45-3510
HTTC-JEJ-45-3213	HTTC-SV-45-3511

HTTC-KDK-45-3214	HTTC-WX-45-3424
HTTC-FG-45-3320	HTTC-YZ-45-3215
HTTC-IJ-45-3321	HTTC-AABB-45-2219
HTTC-FL-45-3322	HTTC-AABB-45-2220
HTTC-MN-45-3421	HTTC-CCDD-45-2120
HTTC-NO-45-3422	HTTC-CCDD-45-2121
HTTC-QQ-45-3423	HTTC-EEGG-45-4117

- One hundred and twelve terminals for connection of valve positioners, position indicators, limit switches, remote contacts, and pressure, flow, and level transmitters. All terminals in this group are connected to the Network 90. Eleven spare terminals have been provided.
- An Acromag converter, Series 530, is provided for transmitting the PT-382 pressure signal to the Network 90. The input and output signal and 24 vdc power source connect directly to the converter.
- Three Actionpak converters for position indication of valves FCV-301, FCV-321, and FCV-341.

2.12.7 Informational Thermocouple Junction Box

An informational thermocouple junction box is provided on the SGS skid for wire terminations used for monitoring of thermocouples (see Section 2.12.4.3) mounted at various locations on piping, valves, valve extensions, the superheater, and the evaporator. The junction box is a NEMA 4 enclosure which is 30 inches high by 24 inches wide by 6 inches deep (0.76m x 0.61m x 0.15m). It is located as shown on B&W drawing 405332E.

The internal arrangement of the junction box includes four rows of terminal blocks with alternating chromel and alumel terminal lugs. These terminals are used for connection of forty-six informational thermocouples mounted on the SGS. The thermocouple signals are sent to the CRTF Accurex Data Logger from the informational thermocouple junction box.

2.12.8 Network 90 Control System; Network 90/EMCON Control System Interface

The control and monitoring of the SGS as a part of the overall MSEE system is accomplished through a Bailey Controls Company Network 90 controls system. The components discussed in the foregoing subsections provide the input and output signals for the Network 90. The Network 90 system also interfaces with the CRTF EMCON control system such that the SGS may be operated directly from the EMCON control system in the CRTF main control room.

2.12.8.1 Network 90 System Equipment

All the Network 90 control system equipment was originally installed in the thermal storage system control room adjacent to the SGS. The equipment includes an operator interface unit (OIU), a driver cabinet for the OIU, two process control unit (PCU) cabinets, and a printer. About eight months after installation of the Network 90 SNL moved the OIU, the driver cabinet, and the printer to the main control room. SNL provided the necessary cabling to connect this equipment with the PCU cabinets, which remained in the salt storage control room.

The OIU consists of a CRT console and keyboard for SGS operation overview, control, alarm indicating, trending of parameters, and tuning and configuration of the control system. The OIU driver cabinet contains the necessary electronics for OIU operation. The printer can produce a hard copy of any information displayed on the OIU CRT at any time by depressing the "print" button. The PCU cabinets contain the required power supply equipment, controller modules, logic master modules, configuration and tuning module, and termination units. Wiring cables from the SGS skid control/power and signal wiring junction boxes terminate in the PCU. Wiring terminations for the Network 90/EMCON interface are located in the PCU. Interface with the EMCON control system is accomplished through wiring connections between the Network 90 PCU and the EMCON process control module (PCM) located in the salt storage control room. Two modes of SGS operation are available. The SGS can be operated directly from the Network 90 OIU console, or the Network 90 can be placed in the cascade mode to transfer all control of the SGS to the EMCON control system.

2.12.8.2 Control System Logic and EMCON Interface

This section discusses the principles of the various SGS control loops, indicating signals, equipment operation signals, interlock signals, and the interface of this control system logic with the EMCON control system. The control system logic, including EMCON interfaces, is shown on Bailey Controls Company drawings D566770, D566771, and D566772. The configuration of control system components in the Network 90 process control unit cabinets and the wiring connections from these cabinets to the SGS skid junction boxes and to the EMCON process control module, are detailed on Bailey Controls Company drawings D8083958 through D8083969 and D8084086. All Bailey Controls drawings are in the O&M Manual (Reference 6).

2.12.8.2.1 SGS Control Loops

- Steam Delivery Pressure (Load) Control

As the MSEE system turbine load demand changes, the heat load on the SGS is changed by control of the molten salt flow through the

SGS using the main salt flow control valve FCV-321. The logic diagram for load control is shown on Bailey Controls drawing D566771. The SGS load is controlled using the steam delivery pressure (PT-321), the main steam flow (FT-311), and the main salt flow (FT-321) signals. The set point for load control is steam delivery pressure (1100 psig/7584 kPa). A change in the steam flow is used as an anticipatory signal of a change in steam pressure. As the steam flow changes and steam pressure deviates from the set point, the main salt flow control valve changes position to return pressure to the set point. As the valve position begins to affect the salt flow, the salt flow signal is used as a trim signal together with the steam pressure and steam flow to set the valve position required to match steam pressure to the set point.

The steam pressure, steam flow, and salt flow signals are sent to both the Network 90 OIU and the EMCON control system for control and indicating. The steam pressure set point may be set from the OIU or from the EMCON system.

- Steam Drum Water Level Control

Maintenance of the steam drum water level is accomplished by adjusting the feedwater flow to the steam drum using the feedwater flow control valve FCV-411 in the Heat Rejection and Feedwater Subsystem. The logic diagram for steam drum water level control is shown on Bailey Controls drawing D566770. The level is controlled using the drum level (LT-311), feedwater flow (FT-411), and steam flow (FT-311) signals. The control set point is the drum water level (0 inches, normal water level).

A change in the steam flow is used as an anticipatory signal of a change in water level. As the steam flow changes and drum level deviates from the set point, the feedwater flow control valve changes position to bring the level back to the set point. As the valve position begins to affect feedwater flow, the feedwater flow signal is used as a trim signal together with the drum level and steam flow signals to set the valve position required to match the steam drum level set point.

The drum level, steam flow, and feedwater flow signals are sent to both the Network 90 OIU and the EMCON control system for control and indicating. The drum level set point may be set from the OIU or from the EMCON system.

- <u>Evaporator Salt Inlet Temperature Control</u>

Control of the evaporator salt inlet temperature is accomplished by adjusting the flow rate of cold salt which mixes with the superheater salt outlet flow. Cold salt flow is adjusted by control valve FCV-301. The logic diagram for evaporator salt inlet temperature control is shown on Bailey Controls drawing D566770. The control set point is the evaporator salt inlet temperature, TE-301 (850°F/454°C). A deviation of the evaporator salt inlet temperature changes the position of FCV-301 to return the temperature to the set point.

The evaporator salt inlet temperature signal is sent to both the Network 90 OIU and the EMCON control system for control and indicating. The temperature set point may be set from the OIU or from the EMCON system.

- <u>Steam Delivery Temperature Control</u>

Control of the steam delivery (or turbine throttle) temperature is accomplished by adjusting the flow of saturated steam to the steam attemperator using steam attemperator control valve FCV-331. The logic diagram for steam delivery temperature control is shown on Bailey Controls drawing D566771. The control set point is the steam delivery temperature, TE-332 (950°F/510°C). A change in the superheater steam outlet temperature, TE-331, is used as an anticipatory signal of a change in steam delivery temperature. As this temperature changes and the steam delivery temperature deviates from the set point, the position of FCV-331 is adjusted to change flow rate of saturated steam mixing with the steam from the superheater until the steam delivery temperature set point is matched.

The steam delivery temperature and superheater steam outlet temperature signals are sent to both the Network 90 OIU and the EMCON system for control and indicating. The temperature set point may be set from the OIU or from the EMCON system.

- <u>Superheater Salt Inlet Temperature Control</u>

During start-up from standby conditions or during cooldown in anticipation of draining salt, the SGS salt flow and the salt inlet temperature to the superheater are controlled in a manual mode from either the Network 90 OIU or from the EMCON control system. The flows of hot and cold salt to the mixing tee upstream of the superheater are controlled by independently adjusting the positions of valves FCV-351 and FCV-341 to obtain a ramp rate on superheater inlet temperature of not greater than 100°F (55°C) per six minutes. The specific valve positions for FCV-341 and FCV-351 are detailed in the Operating and Maintenance Manual (Reference 6). As shown on Bailey Controls drawing D566771, manual control of these valves is available from either the Network 90 OIU or the EMCON control system.

- <u>Steam Pressure Control During Diurnal Shutdown</u>

  As discussed in Section 2.9 the circulation heater is used to maintain SGS steam pressure during diurnal shutdown. The original concept of steam pressure maintenance during diurnal shutdown was to activate one or more of the five heater circuits at the end of the operating day to maintain approximately 1100 psig (7584 kPa) steam pressure overnight. The number of heater elements required to be activated was to be based on operating experience. There was no active control on heater element operation during diurnal shutdown.

  Operating experience indicated that the heat input required to have steam pressure reasonably close to 1100 psig (7584 kPa) at the end of the diurnal shutdown period tended to vary somewhat with such things as ambient conditions and length of the diurnal shutdown period. An automatic pressure controller for diurnal shutdown (EHAC) was incorporated into the control system to maintain a nominal steam pressure of 1100 psig (7584 kPa). Using the steam drum pressure signal (PT-383) as the controller set point signal, each of five circulation heater circuits was energized and de-energized at specified steam pressures as indicated on Figure 2.12-1.

  Subsequent to the failure of the circulation heater pressure boundary (See Appendix B) the controller set point signal for the automatic pressure controller was changed from the saturation pressure signal PT-383 to the saturation temperature signal TE-383. This eliminates the concern of an erroneous PT-383 signal affecting the heater operation. Circulation heater element circuit HR-1 was deleted from the automatic pressure control; based on operating experience, having HR-2 through HR-5 in EHAC is sufficient to maintain steam pressure during diurnal shutdown. The heater circuits are energized and de-energized at the TE-383 temperatures indicated on Figure 2.12-2.

2.12.8.2.2 SGS Indicating Signals

In addition to the temperature, flow, pressure, and level indicating signals associated with the control loops discussed in Section 2.12.8.2.1, various other signals from the SGS are provided for indicating purposes. These signals are sent to the Network 90 from the SGS and are available for display on both the Network 90 OIU and the EMCON control system. These indicating signals are shown on Bailey Controls drawings D566770 and D566772.

- Temperature

Feedwater Temperature	TE-386
Steam Drum Saturation Temperature	TE-383
Superheater Salt Inlet Temperature	TE-382
Evaporator Salt Outlet Temperature	TE-384
Circulation Heater Element Temperature	TE-388

- Flow

Cold (or bypass) Salt Inlet Flow	FT-382
Attemperation (or bypass) Steam Flow	FT-381

- Pressure

Feedwater Pressure	PT-386
Steam Drum Pressure	PT-383
Superheater Salt Inlet Pressure	PT-382
Evaporator Salt Outlet Pressure	PT-384

- o Valve Position 0 - 100%

Main Salt Flow Control Valve	FCV-321
Evaporator Salt Inlet Temperature Control Valve	FCV-301
Cold Salt Startup Control Valve	FCV-341
Hot Salt Isolation/Startup Control Valve	FCV-351
Steam Attemperation Flow Control Valve	FCV-331
Feedwater Flow Control Valve	FCV-411

- o Valve Open or Closed

Evaporator Salt Drain Valve	FCV-381
Superheater Salt Drain Valve	FCV-382
Evaporator Inlet Isolation Valve	FCV-383
Circulation Heater Inlet Isolation Valve	FCV-384

- o Boiler Water Circulation Pump

  Pump Started
  Pump Stopped
  Pump Running
  Pump Not Running

- o Circulation Heater Circuits On or Off

  Separate indication for each of the five circuits, HR-1 through HR-5

2.12.8.3 SGS Equipment Operation

Various SGS equipment can be operated from either the Network 90 OIU or the EMCON control system.

- o Control Valves

  The following valves are part of the control loops discussed in Section 2.12.8.2.1. Manual positioning capability for these valves is available from both the Network 90 OIU and the EMCON control system.

Main Salt Flow Control Valve	FCV-321
Feedwater Flow Control Valve	FCV-411

Evaporator Salt Inlet Temperature

Control Valve	FCV-301
Steam Attemperator Control Valve	FCV-331

Valves FCV-341 and FCV-351 are positioned manually from either the Network 90 OIU or the EMCON control system as discussed in Section 2.12.8.2.1.

- Isolation Valves Open or Closed

Evaporator Salt Drain Valve	FCV-381
Superheater Salt Drain Valve	FCV-382
Evaporator BWCP Isolation Valve	FCV-383
Circulation Heater Inlet Isolation Valve	FCV-384

- Boiler Water Circulation Pump Start/Stop
- Circulation Heater On/Off

  Separate on/off for each of the five circuits, HR-1 through HR-5.

2.12.8.4 SGS Interlock and Permissive Signals

Certain interlock and permissive signals are part of the SGS control system. These signals cause certain control system actions to occur in a given sequence.

- Cold Salt Pump Running

  Before salt side valves FCV-301 and FCV-341 can be moved from the fully closed position, a signal must be received by the SGS control system indicating that the cold salt pump is running.

- Hot Salt Pump Running

  Before salt side valve FCV-351 can be moved from the fully closed position, a signal must be received by the SGS control system indicating that the hot salt pump is running.

- Salt Drain Permit

  The Hot Salt Pump Running and Cold Salt Pump Running interlocks described above prevent opening valves FCV-301, FCV-341, and FCV-351 unless the appropriate pump is running. To drain salt from the SGS to the pump sumps, those valves must be opened with the pumps off. To allow these valves to be opened for SGS salt draining, the Salt Drain Permit signal must be energized. This will permit FCV-301, FCV-341, and FCV-351 to be opened as required to drain salt with the pumps not running.

- Circulation Heater Operation

  1. Heater circuit HR-5 must be energized to permit any of the remaining circuits HR-1 through HR-4 to be energized. This interlock is included because temperature signal TE-388 (see below) is located on the heating element in HR-5.
  2. Should heater element temperature TE-388 on circuit HR-5 exceed 565°F (296°C), all heater circuits are de-energized.
  3. Heater inlet valve FCV-384 must be open and valve FCV-383 must be closed to energize the circulation heater.
  4. The boiler water circulation pump must be running to energize the circulation heater.

5. The quality of temperature signal TE-388 is monitored. Should the temperature signal indicate bad quality (e.g. thermocouple failure, loose wire), all power to the circulation heater goes off.

6. Automatic heater operation during diurnal shutdown (EHAC) is controlled by saturation temperature TE-383. The quality of temperature signal TE-383 is monitored. Should the temperature signal indicate bad quality, all power to the circulation heater goes off.

7. The low-low (L-L) steam drum water level (LT-311) alarm de-energizes all heater circuits through the BWCP trip due to L-L water level alarm (see below). If EHAC is on at the time of a L-L water level trip, EHAC is turned off.

8. The quality of water level signal LT-311 is monitored. Should the level signal exceed the range on either the high or low end (e.g. frozen line, loose wire), all power to the circulation heater goes off.

9. Re-start of all heater circuits must be by manual, operator action; no automatic re-start of heaters is permitted.

o Boiler Water Circulation Pump Operation

1. Sufficient pump coolant flow is required to close flow switch FS-381 in the coolant outlet line. The pump will operate only with FS-381 closed.

2. The low-low steam drum water (LT-311) level alarm causes the pump to stop.

3. Either valve FCV-383 or valve FCV-384 must be open for the BWCP to operate.

4. The quality of level signal LT-311 is monitored. Should the level signal exceed the range on either the high or low end (e.g. freezing in transmitter lines, loose wire) the BWCP will not run.

5. Temperature TE-383 must be less than 350F to manually stop the BWCP. This interlock keeps the pump running in the higher operating temperature range, providing better cooling to the pump bearings(see Section 5.2). The interlocks in No. 1-4 above override this temperature interlock and stop the pump.

o Steam Drum Water Level

The high/high and low/low steam drum water level alarms initiate a trip by closing salt side valves FCV-301, FCV-341, and FCV-351. In addition, the low/low alarm stops the BWCP.

2.12.8.5 Trips

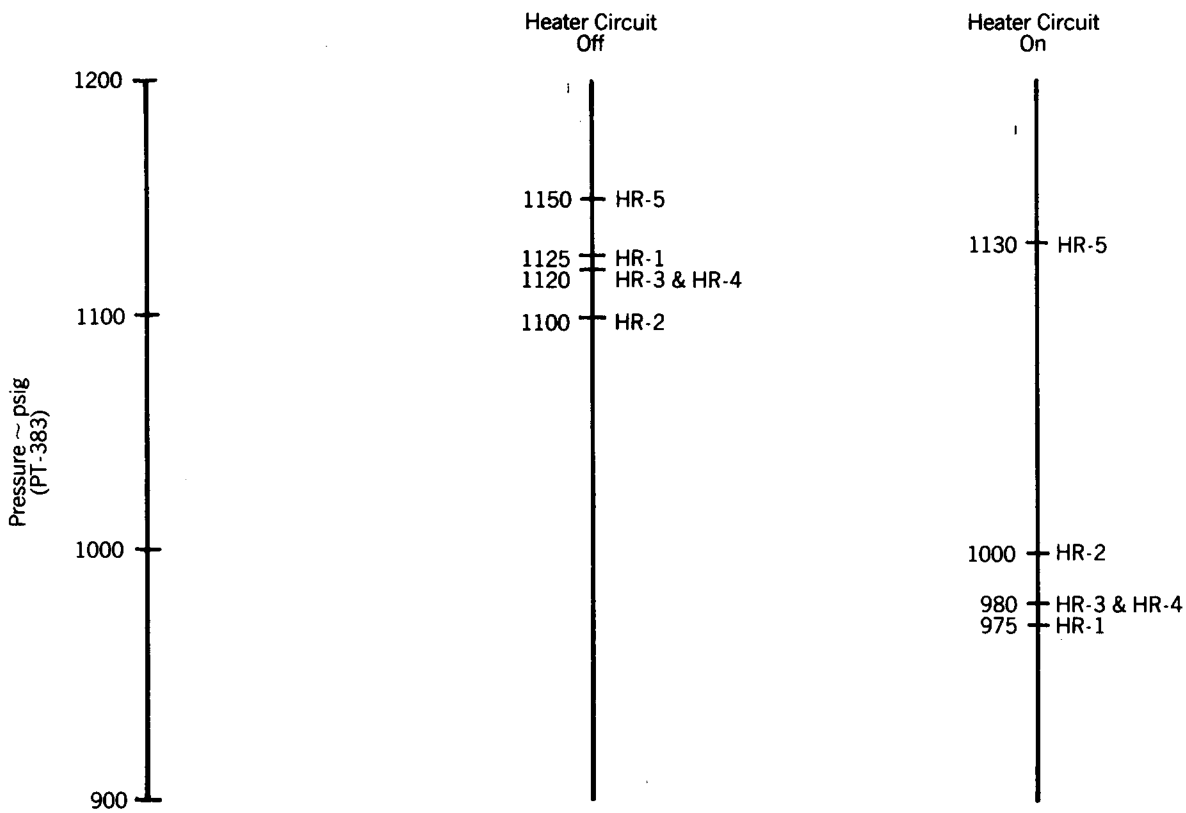
Two trips are initiated within the SGS control system. One trip occurs if the steam drum water level reaches either the high/high or the low/low alarm point. The other trip is initiated if the BWCP stops running. When either of these trips is initiated, salt system valves FCV-351, FCV-341, and FCV-301 close. In addition, the BWCP is stopped on the low/low water level alarm trip. When the turbine is on-line, this trip will eventually result in a turbine trip initiated outside the SGS control system. When the turbine trips, steam flow from the SGS is diverted to the HRFS desuperheater/deaerator, and steam pressure is controlled by HRFS valve FCV-431. The SGS is brought to a Hot Standby/Warm Standby condition by the operator in an orderly manner per the procedures in the Operating and Maintenance Manual (Reference 6).

Turbine trips, or other events in the system (e.g. loss of salt flow, loss of feedwater) which may lead to a turbine trip, are initiated outside the SGS control system. When the turbine trips, steam flow from the SGS is diverted to the HRFS desuperheater/deaerator, and steam pressure is controlled by HRFS valve FCV-431. The SGS is brought to a Hot Standby/Warm Standby condition by the operator in an orderly manner per the procedures in the Operating and Maintenance Manual (Reference 6).

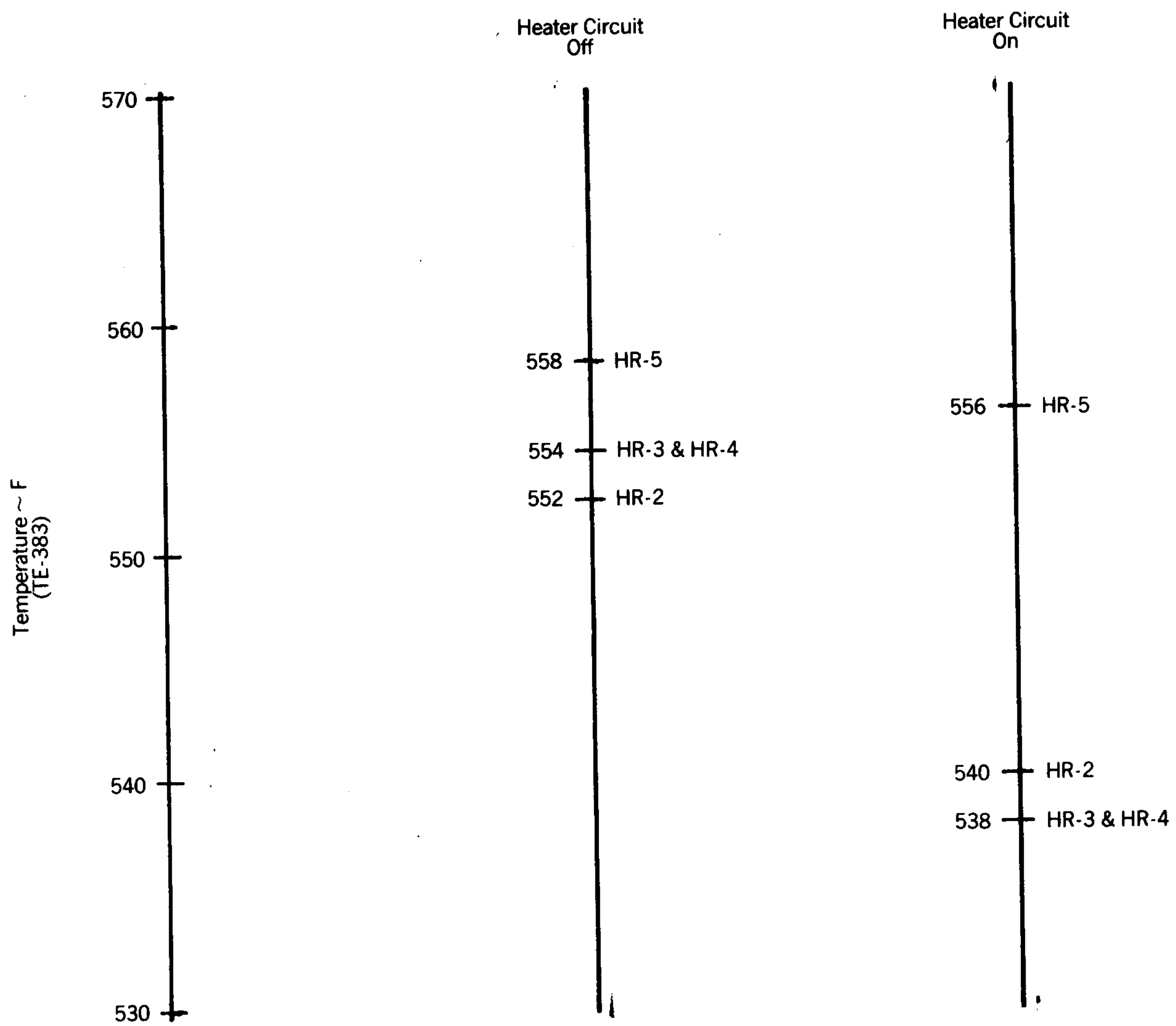
2.12.8.6 Alarms

Certain SGS flow, temperature, pressure, and level signals monitored by the Network 90 control system are provided with alarm indications. An alarm condition is indicated at the Network 90 OIU and at the EMCON control system operator's station. An alarm serves to alert the operator to a deviation of a parameter so that corrective action can be taken if required. In certain instances an alarm will be accompanied by an automatic action in the control system.

The SGS alarm points, together with guidelines on corrective action which can be taken to clear an alarm in various operating modes, are discussed in the Operating and Maintenance Manual (Reference 6).



Original Diurnal Shutdown Pressure Controller Set Points For Circulation Heater
Figure 2.12-1



Revised Diurnal Shutdown Pressure Controller Set Points For Circulation Heater
Figure 2.12-2

TABLE 2.12-1
SGS Remote Operated Valves

Valve	Designation	Mode	
Evaporator Salt Inlet Temp. Control	FCV-301	Control	Position Indicator
Main Salt Flow Control	FCV-321	Control	Position Indicator
Cold Salt Start-up Control	FCV-341	Control/ Isolation	Position Indicator
Hot Salt Isolation/ Control	FCV-351	Control/ Isolation	Position Indicator
Evaporator Salt Drain	FCV-381	Isolation	Limit Switches
Superheater Salt Drain	FCV-382	Isolation	Limit Switches
Steam Attemperation Flow Control	FCV-331	Control	Position Indicator
Evaporator Inlet Line Isolation	FCV-383	Isolation	Limit Switches
Circulation Heater Isolation	FCV-384	Isolation	Limit Switches
Feedwater Flow Control	FCV-411	Control	Position Indicator

TABLE 2.12-2

SGS Control/Monitoring Thermocouples

Temperature	Designation	B&W Drawing
Superheater Salt Inlet	TE-382	179936C
Evaporator Salt Inlet	TE-301	179936C
Evaporator Salt Outlet	TE-384	179940C
Saturated Steam	TE-383	179935C
Superheater Steam Outlet	TE-331	179939C
Steam Delivery	TE-332	179939C
Feedwater	TE-386	179944C
Circulation Heater Element HR-5	TE-388	N/A

TABLE 2.12-3

SGS Heat Tracing Control Thermocouples

Location	Heat Tracing Zone No.	Circuit	B&W Drawing
Hot Salt Inlet Piping	HT-1	A-B	179936C
Hot Salt Inlet Piping		B-C-G	179936C
Salt Piping Between SH and EV	HT-2	J-E-J	179937C
Salt Piping Between SH and EV		K-D-K	179937C
Cold Salt Control Piping	HT-3	F-G	179938C
Cold Salt Control Piping		I-J	179938C
Cold Salt Control Piping		F-L	179938C
EV Salt Outlet Piping	HT-4	M-N	179940C
EV Salt Outlet Piping		N-O	179940C
EV Salt Outlet Piping		O-Q	179940C
Salt Drain Piping	HT-5	R-S	179941C
Salt Drain Piping		U-T	179941C
Salt Drain Piping		S-V	179941C
SH Outlet Overpress. Piping	HT-6	Y-Z	179937C
EV Outlet Overpress. Piping		W-X	179940C
Superheater	HT-7	AA-BB	405325E
Superheater		AA-BB	405325E
Evaporator	HT-8	CC-DD	405328E
Evaporator		CC-DD	405328E
Feedwater Piping	HT-9	EE-GG	179944C

TABLE 2.12-4

SGS Informational Thermocouples

B&W Mark No.	Location	B&W Drawing No.
6005	DC Pipe Upstream of 4" Valve	179932C
6006	EV Water Inlet Pipe	179933C
6007	SH Salt Outlet Pipe	179937C
6008	SH Shell @ approx.	405325E
6009	25%, 50%, and 75% of length	405325E
6010	between salt inlet/outlet	405325E
6011	SH Shell in the area of	405325E
6012	the baffle plates on	405325E
6013	the salt outlet end	405325E
6014		405325E
6015		405325E
6016		405325E
6017	Spare	
6018	Spare	
6019	Spare	
6020	EV Shell @ approx.	405328E
6021	20%, 40%, 50%, 70%,	405328E
6022	80%, and 90% of length	405328E
6023	between salt inlet/outlet	405328E
6024		405328E
6025		405328E
6026	Start-up (No. 2) Mixing Tee	179936C
6027		179936C
6028		179936C
6029		179936C
6030	Valve FCV-341 Body	179938C
6031	Valve FCV-341 Bonnet	179938C
6032	Valve FCV-301 Body	179938C
6033	Valve FCV-301 Bonnet	179938C
6034	Valve FCV-321 Body	179940C
6035	Valve FCV-321 Bonnet	179940C
6036	Valve FCV-381 Body	179941C
6037	Valve FCV-381 Bonnet	179941C
6038	Valve FCV-382 Body	179941C
6039	Valve FCV-382 Bonnet	179941C
6040	Salt Drain Pipe	179941C
6041	SH Salt Drain Pipe	179941C
6042	EV Salt Drain Pipe	179941C
6043	SH Outlet Salt Overpress Pipe	179937C
6044	Cold Salt Attemperation Piping	179938C
6045	Cold Salt Start-up Piping	179938C

TABLE 2.12-4 (Cont'd)

B&W Mark No.	Location	B&W Drawing No.
6046	Salt Attemperation (No. 1)	179937C
6047	Mixing Tee	179937C
6048	SH Salt Inlet Pipe	179937C
6049	EV Salt Inlet Pipe	179937C
6050	EV Salt Outlet Pipe	179940C
6051	Steam Drum Steam Outlet Pipe	179935C
6052	SH Steam Outlet Pipe	179939C
6053	Main Steam Pipe, downstream of att.	179939C
6054	Spare	

NOTE: 1. Thermocouples are installed on outside surface of piping, heat exchangers, valves, etc.

2. Spare thermocouples are purchased as hazard material and are not installed.

2.13 Structural Steel

The components of the Steam Generator Subsystem (SGS) are mounted on the structural steel skid assembly which is shown on B&W Drawing 405332E. The skid assembly is essentially a horizontal frame 8'-10" wide by 37'-0" long (2.69m x 11.28m) fabricated from 12-inch structural channels and covered by an open grating deck. The skid assembly rests upon four structural steel pedestals which in turn are fastened to individual concrete footers in accordance with B&W Drawing 405330E.

Bents fabricated from structural pipe and channels are welded to the skid to provide supports for the evaporator and superheater. The details of these supports are shown on B&W Drawing 405331E. The steam drum is supported by a 17'-10" (5.44m) high open steel tower which has 6-inch wide flange legs with 4'-1" (1.24m) square spacing. The tower has a horizontal bolted joint located 5'-6" (1.68m) above the skid. The joint was added because the lower portion of the tower could not be field installed due to a lack of clearance once the evaporator and superheater were mounted on the skid and the insulation was applied. The tower has a top platform to provide access around three sides of the steam drum. Details of the tower design are shown on B&W Drawings 405335E, 405336E, and 405337E.

Supports are provided for the piping which was mounted on the skid in the shop. These supports are fabricated of structural pipe, angles and channels which are welded to the skid as shown on B&W Drawings 405333E and 405338E. Additional supports are provided for the piping which was installed on the skid in the field and for the field piping adjacent to the south end of the skid. These supports are shown on B&W Drawing 405345E.

3.0 SGS FABRICATION

The major components of the Steam Generating Subsystem were fabricated and partially assembled prior to shipment to the test site. This work was performed by Basic Systems, Inc. (BSI) located in Derwent, Ohio. BSI is a fabricator experienced in small pressure vessels, piping systems and associated electrical equipment. BSI is qualified to ASME Section VIII, Section IV, and Piping Code B31.1; qualified materials include carbon steel, low alloy steels, Incoloy, and stainless steel. All BSI fabrication processing outlines were submitted to SNL for review and information.

The three main pressure vessels of the system are the evaporator, superheater, and steam drum. The evaporator, superheater, and interconnecting piping were attached to the skid by BSI while the steam drum was shipped separately to the site for subsequent erection. All vessels were completely fabricated by BSI.

The evaporator (B&W Dwg. 405328E) and superheater (B&W Dwg. 405325E) were assembled from piping segments (straights, tees, reducers, U-bends, and caps), tubing, and plate. Evaporator ribbed tubing was supplied by B&W. B&W also fashioned the broached hole configuration in the tube support plates for both units. The heat transfer tubing was expanded into the tubesheets and seal welded. All welds performed on the vessels received proper NDE according to ASME Section VIII. Stress relief was performed on the evaporator after completion of fabrication; the stainless steel superheater required no stress relief. Both heat exchangers were subjected to pressure testing in accordance with Section VIII requirements.

The steam drum (B&W Dwg. 405326E) was assembled from piping segments (straights, caps, elbows, and reducers), structural steel, and steam separation equipment. The separation components (cyclone separator, scrubbers, etc.) were fabricated and supplied by B&W. Welding, NDE, stress relief, and hydrostatic testing were performed by BSI.

The skid assembly proceeded through the following major steps:

- Fabrication of the skid and piping supports.
- Installation of the evaporator, superheater, boiler water circulation pump, and lower half of steam drum tower.
- Installation of piping, valves and instrumentation
- Pressure testing of shop-installed piping
- Installation of electrical equipment (cabinets, heat tracing, thermocouples, transmitters, etc).
- Installation of insulation and jacketing.

The remaining SGS components fabricated by BSI were shipped separately for erection at CRTF.

All fabrication, assembly, erection, and quality assurance was under the management of B&W personnel. BSI manufactured to their own fabrication sketches based on the requirements and the limits of the B&W drawings.

The fabrication and assembly of the subsystem at BSI went smoothly for the most part. No major problems were encountered; minor problems were resolved on an on-going basis with consulation between B&W and BSI personnel. The SGS was shipped to CRTF early in May, 1983.

4.0 SGS INSTALLATION AND PRE-OPERATIONAL CHECKOUT

The shop-fabricated SGS skid assembly and the remainder of the SGS equipment to be field installed were shipped by truck to the CRTF facility. All equipment arrived on the site by May 16, 1983. Prior to erection, the CRTF site was prepared for installation of the SGS. Piping connections to the existing air cooler were severed, and the air cooler was removed. The northern boundary of the earthen berm around the perimeter of Thermal Storage Subsystem was reconstructed to provide the additional space required for the SGS (see Section 2.6). An additional concrete footer, identical to the three footers which supported the air cooler, was installed at the north end of the expanded berm area to provide the required support for the skid assembly.

The detailed requirements for the installation of the SGS are described in the B&W SGS Erection Specification No. DAE-700-0027-45-3 (included in Reference 6). The following is an overview of SGS installation. A skid support was bolted to each of the concrete footers, and the shop fabricated skid assembly was bolted to the top of these supports. The upper portion of the steam drum tower was bolted to the lower tower section which was part of the as-shipped skid assembly. The steam drum was lowered into the tower structure, secured to the tower with bolted connections at the four steam drum legs, and insulated. The circulation heater, supplied by SNL, was installed on the skid. Several sections of water/steam system piping were welded into place; these piping runs required field installation either because they were connected to the steam drum or because they were required to be mounted in the field to CRTF piping interface locations. SGS water/steam system piping connections to the CRTF piping were made by others. Essentially all the SGS salt system piping was shop-installed on the skid assembly. Final connection welds were made to the CRTF salt piping by B&W. After piping installation, any remaining heat trace cables were installed, and the piping was insulated and covered with aluminum jacketing. Several pipe hangers and associated support steel were installed as part of the piping installation task.

The steam drum water level and steam drum pressure transmitters and associated instrument piping were installed. Signal wiring between these transmitters and the signal wiring junction box was completed. Wiring from the plug-in connectors on each of the informational thermocouples was routed to the main informational thermocouple junction box located on the skid; CRTF was responsible for installation of the wiring from this junction box to the Acurex Data Logger located in the Thermal Storage Subsystem Control Room. Final AC electrical wiring was completed for the circulation heater and the boiler water circulation pump. A visual check for correct pump impeller rotation was made before completing the final pump to piping connection to assure correct pump wiring. Any remaining heat trace power wiring was completed. The final connections of the 480 vac power source for the SGS main power/control junction box were completed. Compressed air connections were made to the various air operated valves from the CRTF compressed air supply line. Coolant lines for the boiler water circulation pump were routed to the CRTF coolant source.

The SGS Network 90 control system was installed in the Thermal Storage Subsystem control room adjacent to the SGS skid. The Network 90 equipment includes two process control units (PCU), an operator interface unit (OIU), a driver cabinet, and a printer. Thermocouple wiring, 24 vdc signal wiring, and 110 vac wiring between the PCU and the power/control and signal junction boxes were installed, as well as 110 vac power input for the PCU, OIU, and driver cabinet. Signal wiring connections between the Network 90 PCU and the EMCON control system process control module (PCM No. 3), located adjacent to the Network 90 PCU, were completed. Signal wiring for operation of the SGS heat trace circuits from the Accurex Data Logger was installed.

Those portions of the pre-operational checkout not completed during shop fabrication were completed during the erection phase. The checkout requirements are outlined in the B&W Checkout Plan (Reference 7). Subsequent to completing all water/steam system piping welds, and before installing insulation, the SGS water/steam system was successfully hydrotested at 2100 psig (14480 kPa). After the hydrotest, the pressure relief valve was installed on the steam drum. Although the SGS specification calls for a pneumatic test of the SGS salt system, the Sandia Safety Department would not permit such a test at the facility. In lieu of the pneumatic test, all salt system welds made during the erection phase were radiographically inspected and cleared.

Checkout items completed at the site are listed in Appendix C with pertinent information on these checks. Calibration of all remotely operated control and isolation valves was completed. All thermocouple indications and channels were verified, and EMCON and Network 90 readings were compared. Resistances, megger checks, and current readings for each heat trace zone were taken, and the heating capability of each zone was checked by allowing each zone to operate for half an hour. The current flow in each circuit of the circulation heater was checked. The boiler water circulation pump current draw was checked as was the operation of the BWCP coolant flow switch and current sensing relay. Transmitters were calibrated, and signals to the control system checked. All electrical signals between the skid, Network 90, and EMCON were checked.

In general, the erection and pre-operational check phase of the project proceeded well. The SGS erection and checkout was sufficiently complete to permit the start of operational testing approximately two to three weeks later than originally projected, due to an initially optimistic estimate of the required erection span. Some minor erection tasks, such as completion of insulation jacketing, remained to be completed after the subsystem was ready for operation. During erection several minor problems arose, which were corrected without undue delay. These included minor interferences between pipe supports and pipe insulation, and the need to repeat radiographic examination of several welds in the salt piping to obtain an acceptable film for interpretation.

5.0 SGS OPERATIONAL CHECKOUT AND ACCEPTANCE TESTING

5.1 Overview

Following the installation and pre-operational check-out of the Steam Generator Subsystem, performance of the subsystem was demonstrated through completion of the Acceptance Test Plan (Reference 8). The requirements of this test plan are outlined in the SGS specification (Reference 1); the plan is structured into three major phases:

- Demonstration of full load operation
- Demonstration of load following capability
- Demonstration of safe shutdown during normal transients

Prior to initiation of the acceptance testing, subsystem operational checkout was performed to verify that all equipment was operating satisfactorily. Performance of SGS operational checkout and acceptance testing required that the Thermal Storage Subsystem be in an operational mode, capable of supplying hot and cold salt to the SGS. Also, the Heat Rejection and Feedwater Subsystem had to be in operation to provide feedwater to the SGS at the required temperature, pressure, and flowrate and to provide heat rejection equipment into which steam generated by the SGS could flow.

The operational checkout requirements for the SGS are outlined in the B&W Checkout Plan (Reference 7). Operational checks of heat tracing, valve operation, pump operation, circulation heater operation and instrumentation were performed. In addition, the feedback control loops in the SGS control system were tuned. The acceptance test requirements are outlined in the B&W Acceptance Test Plan (Reference 8). A description of each of the individual test sequences in each of the three test phases is included in that document.

All operational checkout and acceptance testing was conducted under the supervision of the MSEE system integrator, Martin-Marietta (MMC). Integrated Test Procedures (Reference 9) for all steam generator subsystem operational checkout and acceptance testing were prepared by MMC. These procedures were necessary to integrate the detailed SGS operating procedures developed by B&W in the SGS Operating and Maintenance Manual with operating procedures required in other subsystems in the MSEE system. The integrated procedures provided the step-by-step requirements which system operators followed to conduct a specific test procedure. The Integrated Test Procedures document encompassed two broad categories of test procedures: General Steam Generator Procedures (GSGP) and Steam Generator Integrated Test Procedures (SGITP). The GSGP detailed the various procedures required to bring the SGS from ambient conditions to normal load range operation and to return the SGS to ambient conditions, as well as pretest and posttest checklists. Also included were procedures for demonstrating the fossil-fired (propane) heater and for various shutdown conditions. A list of the GSGP is shown on Table 5.1-1. The SGITP detailed the steps required to perform the specific checkout and acceptance testing defined in the Acceptance Test Plan. A list of the SGITP is shown on Table 5.1-2. The GSGP provided the foundation for developing the specific testing sequences for the SGITP. As testing proceeded and operating experience with the SGS and other subsystems was gained, changes to the original procedures were made. Such changes were incorporated either by formal revision to the procedure or by redlining the official test copy of the procedures.

As each step of each SGITP was completed, the official test copy was initialed by the test conductor. A copy of each of the signed off SGITP is included in Appendix D.

The following paragraphs provide a summary of the purpose, description, and objectives of each SGITP. Also included is discussion on the results of the SGITP. Specific evaluation of subsystem performance based on the Acceptance Testing is discussed in Section 6.0.

TABLE 5.1-1

General Steam Generation Procedures (GSGP)

GSGP #1 SGS Pretest Checklist

GSGP #2 SGS Startup (Manual)

GSGP #3 SGS Shutdown (Manual)

GSGP #4 Fossil Fired Heater Demonstration

GSGP #5 Emergency Shutdown

GSGP #6 Post Test Checklist

GSGP #7 MCS/Network 90 Integration of Control Checklist

TABLE 5.1-2

Steam Generator Integrated Test Procedures (SGITP)

SGITP #1 Initial Control Loop Checkout
(using Hot Salt less than 1050F)

SGITP #2 Hot Salt Flows with Transients
(includes Final Control Loop Tuning)

SGITP #3 Diurnal Shutdown (No Salt Flow) - Hold
Overnight

SGITP #4 Load Following - 10%/Minute

SGITP #5 Alternate Diurnal Standby (with Salt Cycling) -
Hold Overnight

SGITP #6 Feedwater Loss Safe Shutdown

SGITP #7 Salt Flow Loss Safe Shutdown

SGITP #8 Manual Sequence Demonstration

SGITP #9 Retest Under MCS Control
(SGITP #2 thru #8)

SGITP #10 Automatic Sequence Demonstration

5.2 SGITP #1 - Initial Control Loop Checkout

SGITP #2 - Hot Salt Flows with Transients

Taken together, these two integrated test procedures encompassed all the elements of the SGS operational checkout as well as providing checkout of operation in the TSS and HRFS. These procedures provided for heat-up of the SGS from ambient conditions to the diurnal shutdown, for initial flow of cold salt into the SGS, and for initial flow of hot salt into the SGS. During these procedures, operational checkout of the SGS equipment was performed, and all the SGS automatic control loops were tuned. To provide a complete picture of the activities related to operational checkout of the SGS, the steam blow operation performed prior to beginning the integrated test procedures is also discussed.

The steam blow operation was the initial procedure for which the SGS was heated up from ambient conditions. The purpose of this operation was to remove any scale from the steam piping between the SGS and the turbine. The operation was not part of SGS operational checkout per se; the SGS was simply used as the source of steam for this operation. The requirements for the steam blow were developed by Black and Veatch. Basically, the SGS water/steam system was isolated and heated to a saturation pressure/temperature of about 300 psig/417^{o}F (2068 kPa/214^{o}C) using the circulation heater. The steam line isolation valve FCV-491 was then opened, and steam was permitted to flow through the HRFS and EPGS steam piping until the saturation pressure/temperature reduced to about 175 psig/370^{o}F (1207 kPa/188^{o}C) at which point the SGS was isolated and repressurized to 300 psig (2068 kPa) for another cycle. Throughout the steam blow operation the salt side of the SGS was maintained at about 400^{o}F (204^{o}C) with the heat tracing.

The initial steam blow operation on July 30, 1983 resulted in burning out all the circulation heater elements due to steam formation in the heater and resulting excessive element temperature. Several factors contributed to the elements' failure. There was no water flow through the heater because the heater inlet valve FCV-384 was inadvertently not opened. Due to an incorrectly set trip point, the control system failed to cut off power on the high heater element temperature (TE-388) signal. It was subsequently discovered that the element temperature thermocouple was incorrectly located near the bottom, rather than the top, of the element, allowing the upper portion of the element to overheat while the lower portion was still covered with water. No formal test procedure had been established for the steam blow operation, and no individual had been assigned overall responsibility for conducting the test.

Replacement elements were installed in the circulation heater on August 31, 1983, and the steam blow operation was successfully completed on September 2, 1983. Several corrective actions were taken as a result of the heater failure. A control system interlock was added to prevent energizing the heaters unless the heater inlet valve FCV-384 was open. SNL instructed the heater vendor to locate the element temperature thermocouple near the top of the heated section of the element, and the power-off trip point for the thermocouple was reduced. A formal test procedure for the steam blow operation was prepared by SNL (Reference 10), and a CRTF test engineer was assigned test conductor responsibility for the steam blow operation.

Subsequent to the steam blow operation, the initial heat-up from ambient conditions to the diurnal shutdown condition commenced. During this initial heat-up temperature readings at several locations on the SGS salt system indicated cold spots where the heat tracing was not raising the salt system temperature to the required minimum of 480°F (249°C). For the most part these cold spots were at valve locations in the salt system, together with a couple of locations on the piping. The piping cold spots were corrected with repairs to the pipe insulation such as filling local gaps in the insulation with insulating blanket. Cold spots on the valves were corrected by adding insulation at the bonnet extension-yoke area of the valves. It should be noted that additional adjustments to salt valves' insulation were made later during the acceptance testing when colder ambient temperatures during the winter months again caused local cold spots on the salt system valves. As noted in Section 2.11 additional heat trace input to salt valve FCV-341 was provided to assure sufficient heating of that valve.

The diurnal shutdown condition for the SGS was achieved on September 15, 1983, permitting the start of the checkout procedures for the SGS and other subsystems as outlined in SGITP #1. Shortly after this time, difficulty was encountered in re-starting the boiler water circulation pump (BWCP) after overnight shutdown. High current draw was popping the pump motor starter fuses. Subsequent inspection indicated a failure of the BWCP bearings. The most probable cause for the failure was determined to be higher than normal temperatures at the front bearing, resulting in bearing/shaft binding. Contributing to this higher bearing temperature was the fact that the pump was not running during diurnal shutdown conditions, which stopped the flow of cooling water in the bearing cavity to the bearings and raised bearing temperatures. There was insufficient shaft/bearing clearance for these higher than normal temperatures resulting in binding and ultimate failure of the bearings. A new rotor-shaft and new bearings were installed in the BWCP on September 27, 1983. Corrective action included increasing the bearing/shaft clearance and changing the bearing material to reduce the difference in thermal expansion coefficients between bearings and shaft. The external pump coolant piping was also revised to better assure adequate coolant supply to the pump.

After completion of the BWCP repair the SGS was back on-line for additional checkout sequences in the diurnal shutdown mode until a CRTF electrical outage required suspension of testing from October 1 through October 10, 1983. Shortly after coming back on-line for additional checkout testing under SGITP #1, the BWCP failed to operate on October 13, 1983. The failure was traced to a short in the motor stator windings. While the cause of the failure was not pinpointed, the most likely cause appeared to be a defective as-built stator which deteriorated over time, possibly aggravated by local overheating which might have occurred as a result of the previous problem with shaft/bearing binding. The BWCP was shipped back to the vendor for installation of a new stator; the pump was re-installed in the SGS on the November 1, 1983. To better assure adequate cooling of the pump, operating procedures were modified to provide for pump operation during diurnal shutdown conditions.

Subsequent to re-installation of the BWCP, checkout testing resumed with SGITP #1 and #2. Initial salt flow through the SGS occurred on November 5, 1983. During this flow test molten salt leaked at the flanged bonnet-to-body connections on valves FCV-301 and FCV-351. Investigation indicated improper assembly of the valves by the valve supplier. The SGS was off-line while the assemblies were corrected, and the valves were re-insulated.

The tuning of the SGS automatic control loops was completed on November 18, 1983 as part of SGITP #1 and SGITP #2. The control loops included the steam drum water level control, the evaporator salt inlet temperature control, the steam delivery temperature control, and the steam pressure (load) control. Tuning of the control loops was accomplished very efficiently and essentially without problems. The only problem incurred was receiving the feedback signal from the main salt flow transmitter FT-321. Initially this was thought to be a problem with the transmitter itself, and the transmitter was changed out for an identical spare transmitter available at CRTF. In changing out the transmitter it was determined that salt freezing in the standpipes was the cause of the erroneous salt flow signal to the control system. The freezing problem was corrected by altering the as-installed insulation in the area of the transmitter standpipes and adding a heat trace circuit to the standpipes, as described in Section 2.11. With molten salt in the transmitter standpipes, tuning of the steam pressure control loop was accomplished successfully.

The final, signed-off test procedure sheets for SGITP #1 and SGITP #2 are in Appendix D.

5.3 SGITP #3 - Diurnal Shutdown (No Salt Flow)

Beginning with SGITP #3, the remaining steam generator test procedures encompassed all the elements of the SGS acceptance testing. The purpose of SGITP #3 was to verify that the SGS could be maintained in the diurnal shutdown mode for a 12 hour overnight shutdown period. The diurnal shutdown mode is defined as maintaining the SGS water/steam system at a nominal pressure of 1100 psig (7584 kPa) during overnight shutdown using energy input from the circulation heater; the SGS salt system is drained in this mode with salt system temperatures maintained above 480°F (249°C) with heat tracing.

The original concept for steam pressure maintenance during diurnal shutdown using the circulation heater was to activate one or more of the five heater circuits at the start of the diurnal shutdown to maintain approximately 1100 psig (7584 kPa) steam pressure. The number of heater elements required to be activated was to be based on operating experience. There was no active control on heater element operation during diurnal shutdown. Operating experience indicated that the heat input required to have steam pressure reasonably close to 1100 psig (7584 kPa) at the end of the diurnal shutdown period tended to vary somewhat with ambient temperature and wind conditions and with the length of the diurnal shutdown period. An automatic pressure controller for diurnal shutdown (EHAC) was incorporated into the control system to maintain a nominal steam pressure of 1100 psig (7584 kPa). This automatic pressure controller is discussed in Section 2.12.8.2.1.

During diurnal shutdown, heat losses from the steam drum above the water level and from the water/steam system downstream of the drum are balanced by condensing saturated steam. The original procedure for diurnal shutdown called for removing this condensate through the HRFS steam trap T-482 located off the main steam piping near the HRFS/SGS interface point at the north end of the skid. Operating with this trap open resulted in unacceptable depletion of the SGS water inventory, to the point where the drum water level reached the low-low alarm point which tripped the BWCP and the circulation heater with subsequent reduction of steam pressure. It has never been clearly established whether the excessive water loss rate during diurnal shutdown with trap open was due to faulty trap operation which permitted steam leak-by along with condensate removal or to heat losses which were in excess of analytical predictions, or to a combination of both. To maintain an acceptable water inventory during diurnal shutdown, the operating procedure was altered to completely isolate the SGS water/steam system during diurnal shutdown by closing T-482. Using this procedure, condensate accumulates in the water/steam system downstream of the drum, which limits drum water level reduction to approximately 12 inches during diurnal shutdown. The initially conservative range of 13 inches between the high-high and the low-low steam drum water level alarms has been increased to 25 inches to permit more variation of water level during diurnal shutdown without causing BWCP and circulation heater trips. (Additional discussion of the performance of the SGS during diurnal shutdown is included in Section 6.0.) At the end of the diurnal shutdown period, the trap is opened to remove accumulated condensate and to permit steam to reheat the SGS water/steam system downstream of the steam drum.

From time to time excessive water loss during diurnal shutdown was experienced due to steam or water leaks at locations such as valve packing, instrument locations, or the pressure relief valve. For the most part, each of the leak sites was not a recurring problem; once fixed, leaks did not re-occur at most of the sites. Because of the relatively small size of the SGS, such extraneous leaks can have a more pronounced effect on water inventory during diurnal shutdown than might be the case in larger systems. While initial water inventory for diurnal shutdown is sufficient to tolerate a certain amount of such extraneous leakage, it is prudent to repair any leaks noted at the first opportunity to avoid excessive water loss with attendant trip of the BWCP and the circulation heater and the resultant reduction of steam pressure.

A catastrophic failure of the circulation heater pressure boundary on January 19, 1984 occurred during the diurnal shutdown operating mode. A review of the incident, the causes of the failure, and the corrective actions taken as a result of the failure is included in Appendix B of this report.

The final signed off test procedure sheets for SGITP #3 are in Appendix D.

5.4 SGITP #4 - Load Following Test

The purpose of SGITP #4 was to verify the SGS capability for increasing and decreasing load at the maximum specified rate of 10%/minute between the 30% load and 100% load steady-state conditions. Also, steady-state conditions at 30%, 50% and 100% loads were maintained for 30 minutes.

The load following acceptance test was completed with good results. The SGS operates in a boiler following mode over the normal operating range of 30% to 100% load. Load changes are initiated by changing the steam demand of the turbine (or in the case of testing, the deaerator). The four SGS automatic control loops responded well during 10%/minute power change transients; operation at the various steady-state loads was acceptable. Full load steam flow of 11530 lbm/hr (1.453 kg/sec) was not generated by the SGS due to low feedwater temperature. For reasons as yet undetermined the HRFS feedwater heater was unable to provide sufficient energy input to feedwater, resulting in feedwater temperatures on the order of 150^{o}F (83^{o}C) low. Maximum steam flow generated with the low feedwater temperature was on the order of 10000 lbm/hr (1.260 kg/sec). The steam generator subsystem did meet or exceed the rated heat load of 3.11 MWt with the low feedwater temperature conditions. Additional discussion of steam generator performance in the normal load range is included in Section 6.0.

The final signed-off test procedure sheets for SGITP #4 are in Appendix D.

5.5 SGITP #5 - Alternate Diurnal Shutdown (Salt Flow Cycling)

The purpose of SGITP #5 was to verify that the SGS could be maintained in the alternate diurnal shutdown mode for a 12 hour overnight shutdown period. The alternate diurnal shutdown mode is defined as maintaining the SGS water/steam system at a nominal prssure of 1100 psig (7584 kPa) during overnight shutdown by periodically cycling salt into the SGS from the cold salt sump. This was the mode of diurnal shutdown pressure maintenance called for in the SGS specification; however, this was subsequently changed to the method used in SGITP #3 for the reasons discussed in Section 2.9.

Because SGITP #5 was an alternate operating mode which would not be used at CRTF, it was ultimately dropped from the SGS acceptance testing by SNL to reduce the test span. Prior to deleting SGITP #5 from the testing, one attempt to perform this test was planned. Alternate diurnal shutdown was to be maintained for several hours subsequent to daily system operation. However, on the day in question the propane heater was used as the energy source for salt heating, rather than the receiver. When the propane heater was drained to the cold pump sump, the resulting salt temperature in the sump was well in excess of the normal cold salt temperature. Based on the operating procedure required for SGITP #5, a high cold salt temperature would have very likely caused high steam pressure in the SGS with attendant relief valve lift; therefore, the planned test was aborted.

Performance of alternate diurnal shutdown was planned for MSEE Phase II. Because of the similarity of operating conditions between alternate diurnal shutdown and warm standby, it is expected that the alternate diurnal shutdown mode should present no problems.

5.6 SGITP #6 - Feedwater Loss Safe Shutdown

The purpose of SGITP #6 was to demonstrate the safe shutdown of the SGS from both 50% and 100% loads subsequent to a loss of feedwater flow to SGS. This test demonstrated the control system performance of the Equipment Protection System, the Master Control System, and the Network 90 in response to a loss of feedwater conditions.

The original procedure was amended to perform the SGITP #6 safe shutdown only from the full load condition in the interest of reducing the test span. Loss of feedwater was simulated by placing the feedwater flow control valve FCV-411 in manual and allowing the steam drum water level to reduce to the low-low alarm point, which initiated the trip. (This simulation was performed to avoid having to re-start the feedwater pump.) The control system responded to the trip as expected and shut the system down in an orderly manner as required.

The final signed-off test procedure sheets for SGITP #6 are in Appendix D.

5.7 SGITP #7 - Salt Flow Loss Safe Shutdown

The purpose of SGITP #7 was to demonstrate the safe shutdown of the SGS from both 50% and 100% loads subsequent to a loss of salt flow to the SGS. This test demonstrated the control system performance of the Equipment Protection System, the Master Control System, and the Network 90 in response to a loss of salt flow condition.

The original procedure was amended to perform SGITP #7 safe shutdown only from the full load condition in the interest of reducing the test span. Loss of salt flow was initiated by introducing a high signal on the cold salt boost pump sump vent temperature (TE-181A), which initiated a loss of salt flow trip through the Equipment Protection System. The control system responded to the trip as expected and shut the system down in an orderly manner as required.

The final signed-off test procedure sheets for SGITP #7 are in Appendix D.

5.8 SGITP #8 - Manual Sequence Demonstration

The purpose of SGITP #8 was to perform the uninterrupted operation of the SGS from Diurnal Shutdown through Warm Standby to On-Line Operation, back to Warm Standby, and then to the Diurnal Shutdown condition. The test combined previously tested operating modes into a single sequence of events which permitted verification of all the operating steps required to be incorporated in the automatic sequence operation (see Section 5.10).

Performance of SGITP #8 was completed without any problems. Each of the individual sequences in the procedure, such as Diurnal Shutdown to Warm Standby, had been tested previously and any adjustments to operating procedures required based on operating experience had been incorporated prior to performing SGITP #8.

The final signed off test procedure sheets for SGITP #8 are in Appendix D.

5.9 SGITP #9 - MCS Control Demonstration

SGITP #1 through SGITP #8 were conducted with operation of the SGS from the Network 90 operator's console. The purpose of SGITP #9 was to retest SGITP #2 through SGITP #8 to demonstrate the Master Control System (MCS) capability of controlling the SGS by sending all operational commands from the EMCON operator's console to the SGS via the Network 90. There was no "hands-on" control activities from the Network 90 operator's console.

Because SGITP #2 was part of the operational checkout of the SGS, it was not necessary to repeat the entire procedure. Only the last portion of the procedure was repeated, in which low to medium amplitude pressure transients to main steam pressure were introduced and control response was verified. This procedure was successfully completed. SGITP #3, SGITP #4, and SGITP #8 were repeated with SGS control from the EMCON console and were successfully completed. Testing of SGITP #6 and SGITP #7 (Sections 5.6 and 5.7) was performed from the EMCON operator's console and as such the successful completion of these tests also fulfilled the requirements of performing the tests as part of SGITP #9.

The final signed-off test procedure sheets for SGITP #9 are in Appendix D.

5.10 SGITP #10 - Automatic Sequence Demonstration

The automatic sequence operation was designed to take the SGS, TSS, and HRFS from the diurnal shutdown mode to on-line operation and back to the diurnal shutdown mode with a minimum of operator input. Automatic sequences were programmed into the MCS to perform the following operations:

- SGS Fill-Start-up Sequence
- SGS On-Line Sequence
- SGS Off-Line Sequence
- SGS Warmdown Sequence
- SGS Drain Sequence

SGITP #10 was ultimately dropped from the SGS acceptance testing as all the necessary controls programming for automatic sequencing had not yet been completed by SNL. Performance of automatic sequencing was tested during MSEE Phase II. Automatic sequencing operation was not part of the required acceptance program as outlined in the specification (Reference 1) or the B&W Acceptance Test Plan (Reference 8). Completion of SGITP #10 was not required to verify steam generator subsystem performance.

6.0 SGS PERFORMANCE EVALUATION

6.1 Overview

Based on data selected from the Steam Generator Subsystem (SGS) acceptance testing, thermal/hydraulic performance of the system was evaluated. Areas of evaluation include:

- System Operating Characteristics
- Evaporator Performance
- Superheater Performance
- Mixing Tees
- Thermal Baffles
- Diurnal Shutdown

Data selected from the Steam Generator Subsystem acceptance testing on day 104 (4/13/84) and day 118 (4/27/84) was evaluated. Day 104 was the day the Electric Power Generation Subsystem was successfully synchronized with the commercial power grid. On day 118, 10% per minute power changes were run.

6.2 System Requirements

The function of the SGS is to transfer energy from molten nitrate salt to water/steam for subsequent use in a turbine-generator for electric power generation. The SGS is designed to supply superheated steam at the turbine at 1050 psig (7240 kPa) and 940^{o}F (504^{o}C) when supplied with feedwater at 550^{o}F (288^{o}C) from the feedwater heater. To satisfy these turbine inlet requirements, the SGS is rated at a power level of 3.109 MW_t to generate steam at 1100 psig (7584 kPa) and 950^{o}F (510^{o}C) at the superheater outlet. Additional requirements include:

- The evaporator salt inlet temperature shall be maintained at or below 850^{o}F (454^{o}C).
- The molten salt returning to the cold tank should be no cooler than 550^{o}F (288^{o}C) and no warmer than 600^{o}F (316^{o}C).

6.3 Conclusions

Conclusions based on the evaluation of the data are:

- Full load steady-state performance of the Steam Generator Subsystem meets specification requirements.
- The overall effective heat transfer coefficient of both the superheater and the evaporator is approximately 10% less than was predicted based on the 0% margin sizing calculations. A 30% margin sizing was used in the designs.
- The actual full load circulation ratio of 6-7 is well above the design circulation ratio of 3.7.
- During the 10% per minute up and down power changes, steam temperature and pressure, drum level, and salt inlet temperature to the evaporator were controlled at essentially constant values.
- The temperature gradients existing in salt mixing tee No. 2 (at the inlet to the superheater) during the cooldown to diurnal shutdown transient are structurally acceptable for the three year design life of the SGS.
- The temperature gradients existing in the thermal baffle region of the superheater steam outlet leg during the cooldown to diurnal shutdown transient are structurally acceptable for the three year design life of the SGS.

6.4 Subsystem Operating Characteristics

Figure 6.4-1 is the steam generator process flow schematic. Hot molten salt is pumped to the SGS from the hot salt thermal storage tank. The evaporator salt inlet temperature is controlled by mixing cold salt with the salt exiting the superheater. The cold salt exiting the evaporator is then returned to the Thermal Storage Subsystem cold tank.

Feedwater from the feedwater heater is pumped to the steam drum. In the drum, the feedwater is mixed with recirculated water and pumped to the evaporator where a steam/water mixture is produced. The steam/water mixture is returned to the drum where the steam and water phases are separated. The saturated steam is then superheated and sent to the turbine. Final adjustment of the superheated steam temperature flowing to the turbine is made by the steam attemperator which mixes saturated steam with the superheated steam exiting the superheater.

The design steam flowrate from the superheater is 11530 lbm/hr (1.453 kg/sec). The inlet salt temperature from the hot salt storage tank is 1050°F (566°C) at 62310 lbm/hr (7.851 kg/sec).

Data selected to assess performance of the SGS is listed in Table 6.4-1. A list of the instrumentation used to evaluate SGS performance is given in Table 6.4-2. SGS steady-state performance data is listed in Table 6.4-3. The data listed for day 104 is peak load performance on the day that the Electric Power Generation Subsystem was successfully synchronized with the commercial power grid. Steam side operating characteristics before and after the time selected (14:56:53) as being closest to full load performance requirements are also plotted in Figure 6.4-2.

Maximum steam flow from the SGS was limited to 11070 lbm/hr (1.395 kg/sec) compared to the full load rated steam flow of 11530 lbm/hr (1.453 kg/sec). This limitation resulted from the feedwater heater not being able to produce the specified feedwater temperature of $550^{o}F$ ($288^{o}C$). Feedwater temperatures were on the order of $100^{o}F$ ($56^{o}C$) below the specification value.

The overall system heat balance is calculated to be approximately 3.36 MWt compared to a specification requirement of 3.11 MWt, or 8% over required. A plot of temperatures versus heat load is shown in Figure 6.4-3.

A plot of the response of controlled parameters during an increasing power ramp is given in Figure 6.4-4. A plot of the response of controlled parameters during a decreasing power ramp is given in Figure 6.4-5. Both of these plots indicate that the Network 90 control system maintains subsystem set point parameters for the prescribed maximum rate power changes.

The method used to calculate the effective overall heat transfer coefficients for the evaporator and the superheater is as follows:

- o Use the recorded steam conditions to the turbine (flow rate, pressure and temperature) and recorded feedwater temperature to calculate the overall heat balance.
- o By attemperator heat balance equations, calculate steam flow to the superheater.
- o Calculate salt flow to the superheater using recorded inlet and outlet salt temperatures and an average salt specific heat of 0.367 Btu/lbm-F (1537 J/kg-C).

- Calculate salt flow to the evaporator using recorded inlet and outlet temperatures and an average salt specific heat of 0.360 Btu/lbm-F (1507 J/kg-C). Check salt side heat balances based on cold salt mixing with the salt exiting the superheater prior to entering the evaporator.

- Calculate log mean temperature differences, T_m.

$$T_m = \frac{(T_{in} - T_{out}) - (T_{out} - T_{in})}{\log_e \dfrac{(T_{in} - T_{out})}{(T_{out} - T_{in})}}$$

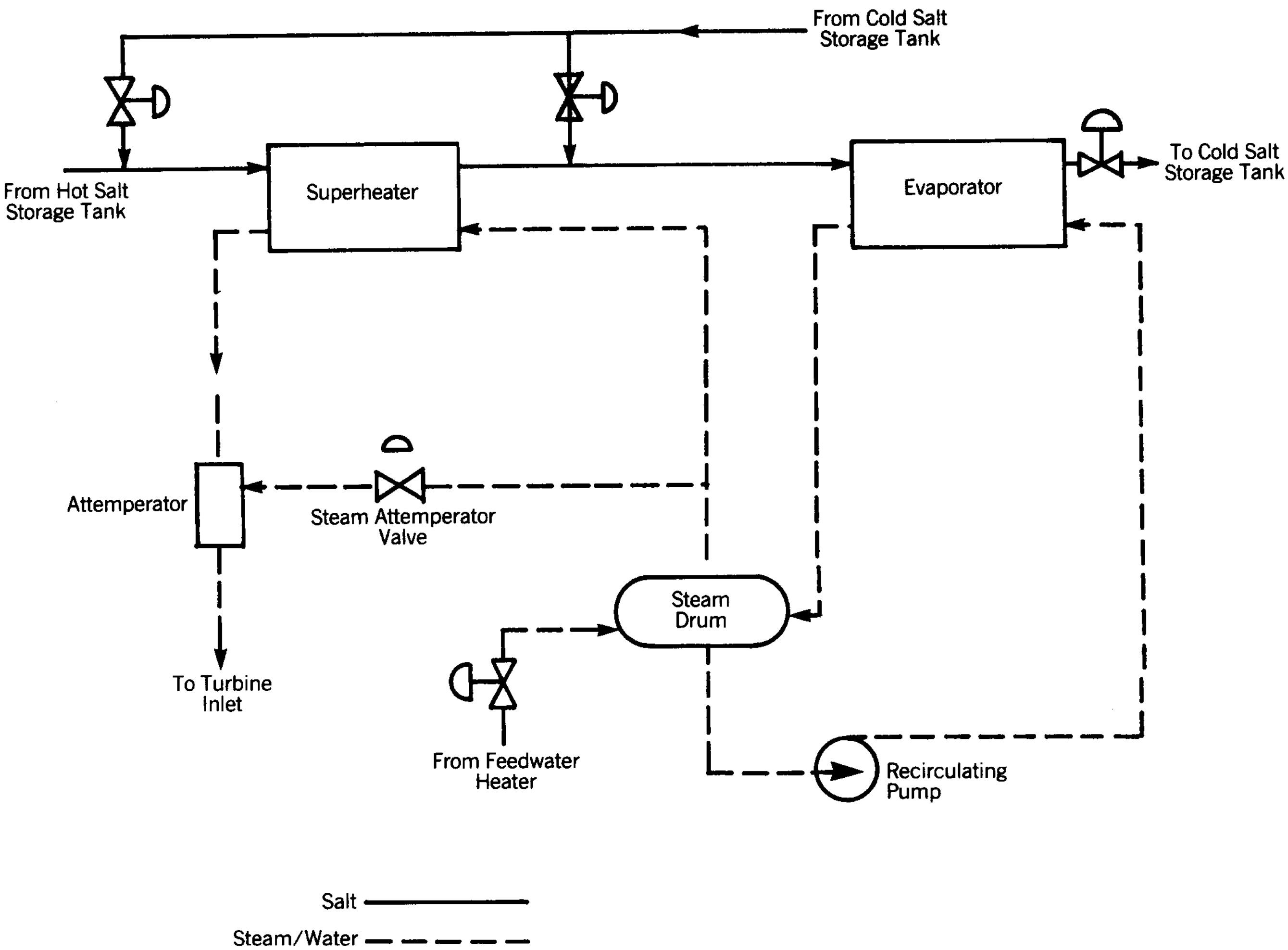
- Calculate effective overall heat transfer coefficients, U.

$$U = \frac{Q}{A \times T_m} \qquad \text{Btu/hr-ft}^2\text{-F}$$

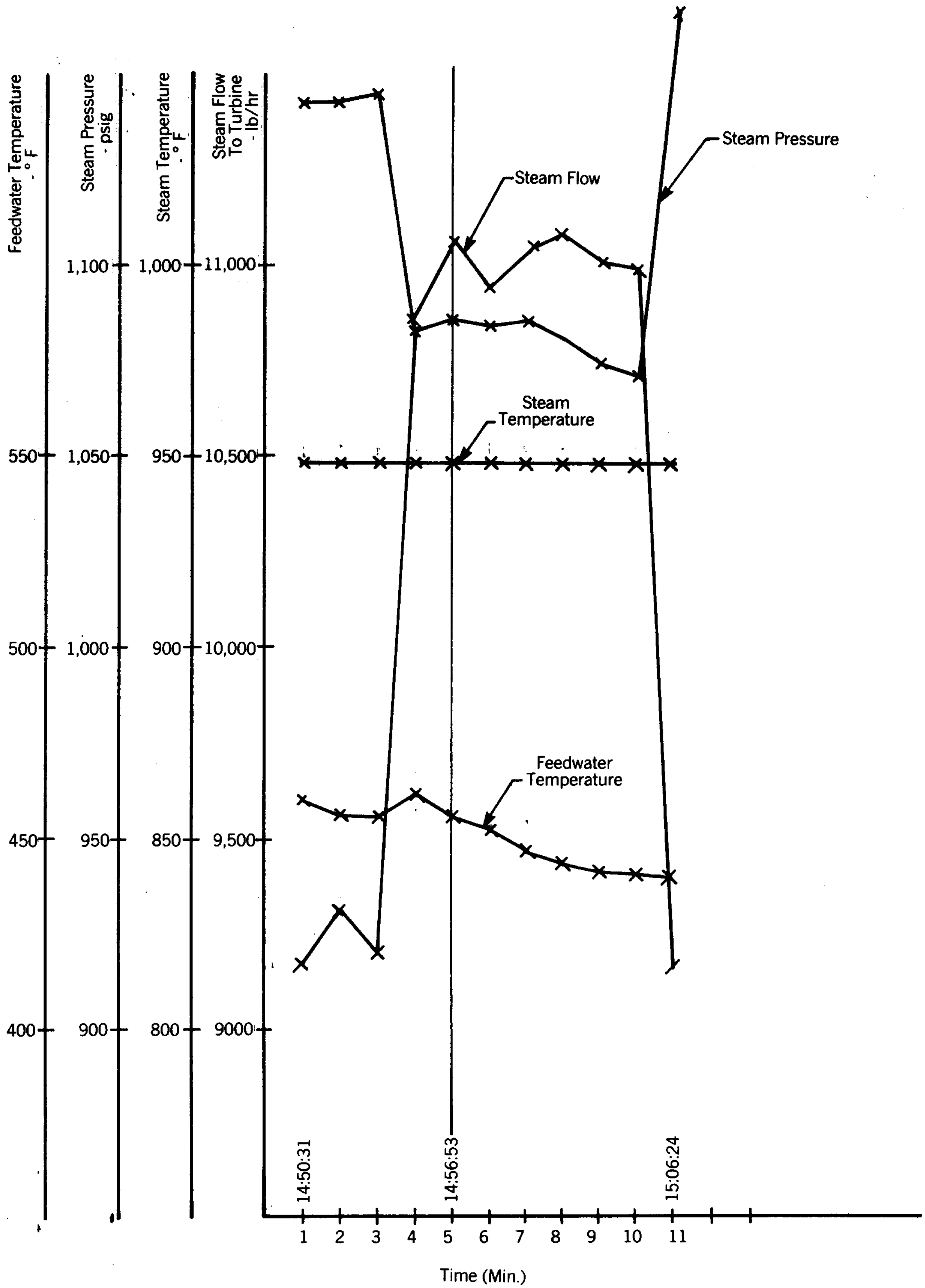
where:

Q is the heat load in Btu/hr

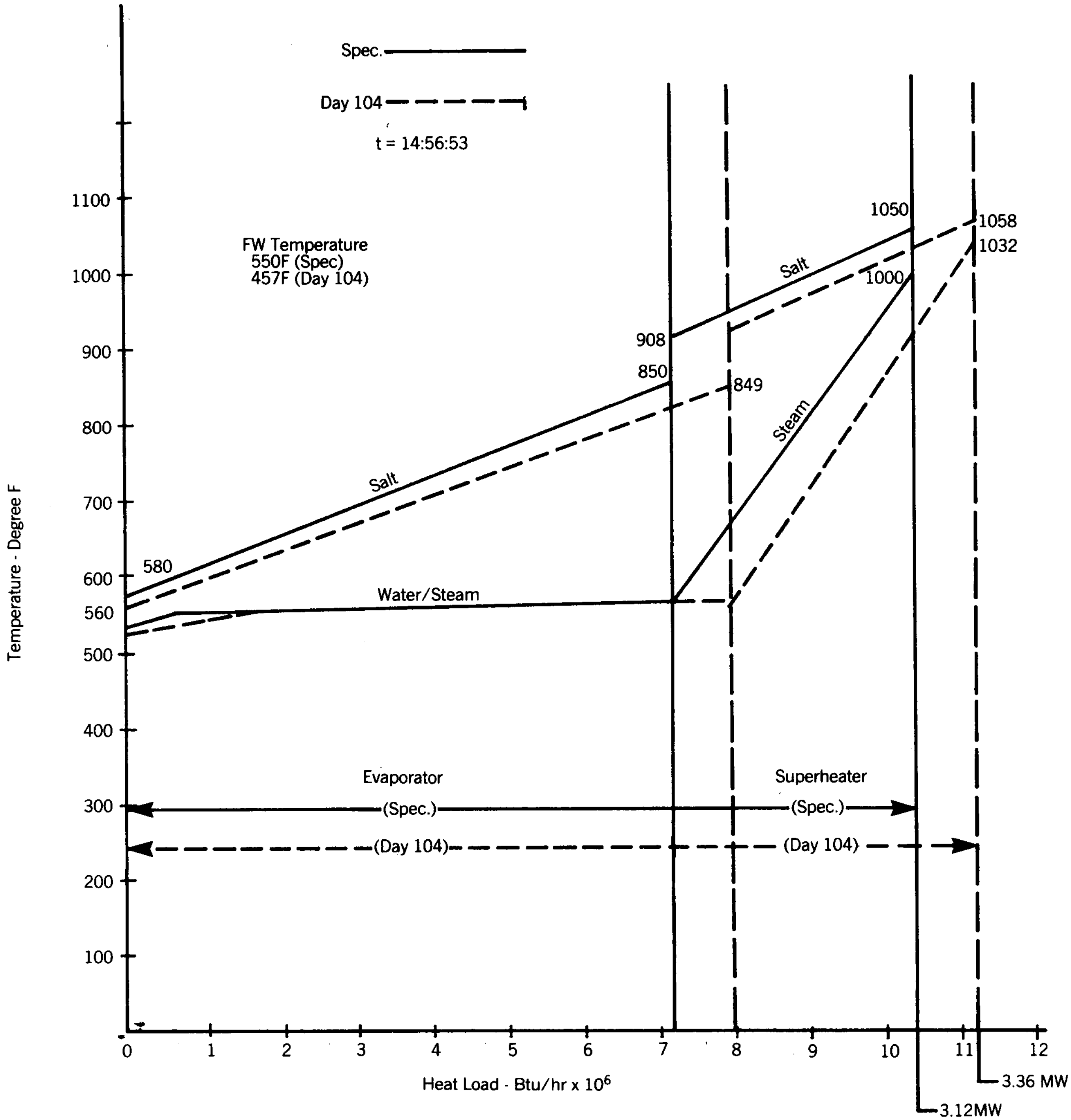
A is the heat transfer surface area, ft^2



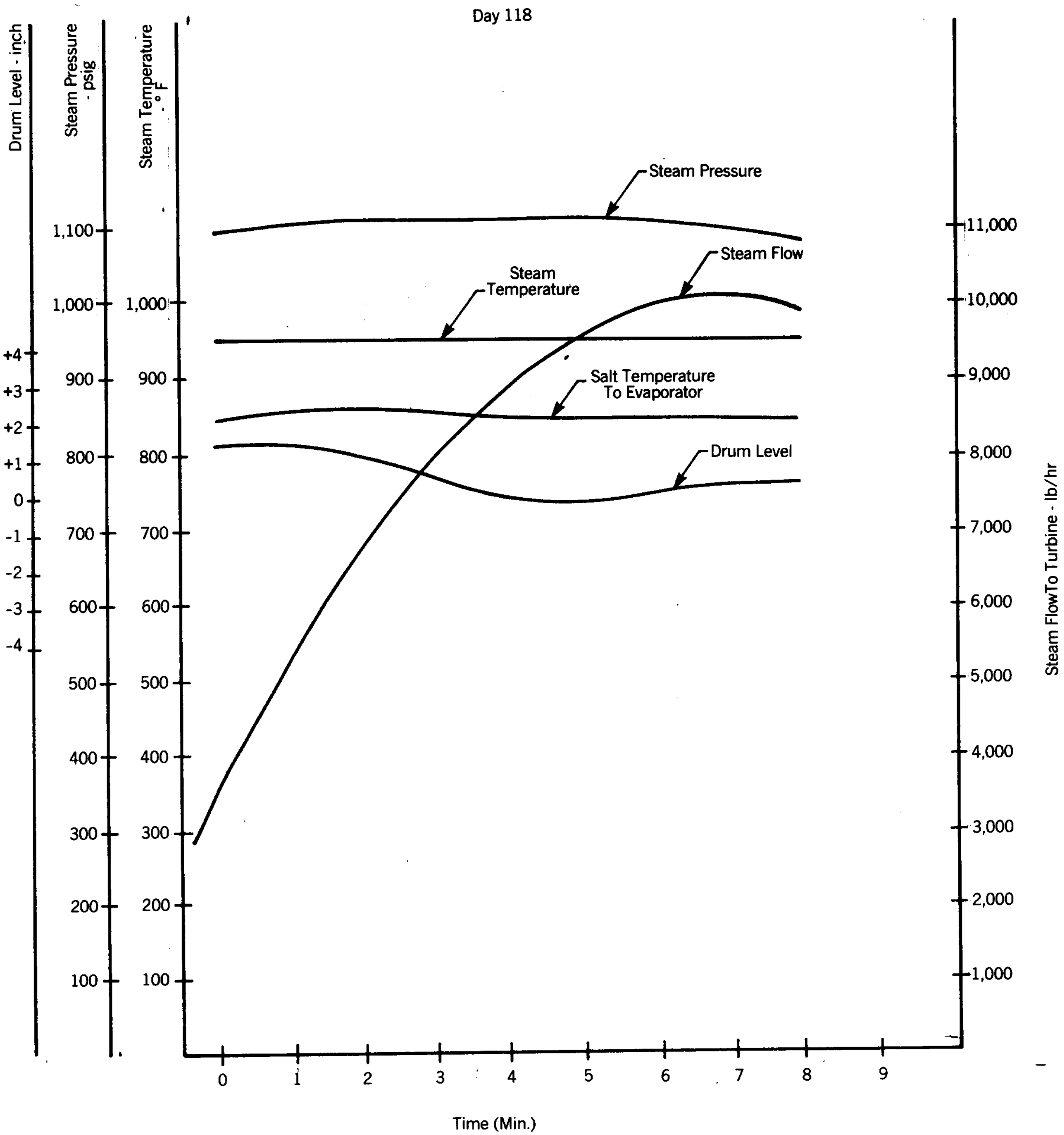
Steam Generator Flow Schematic
Figure 6.4-1



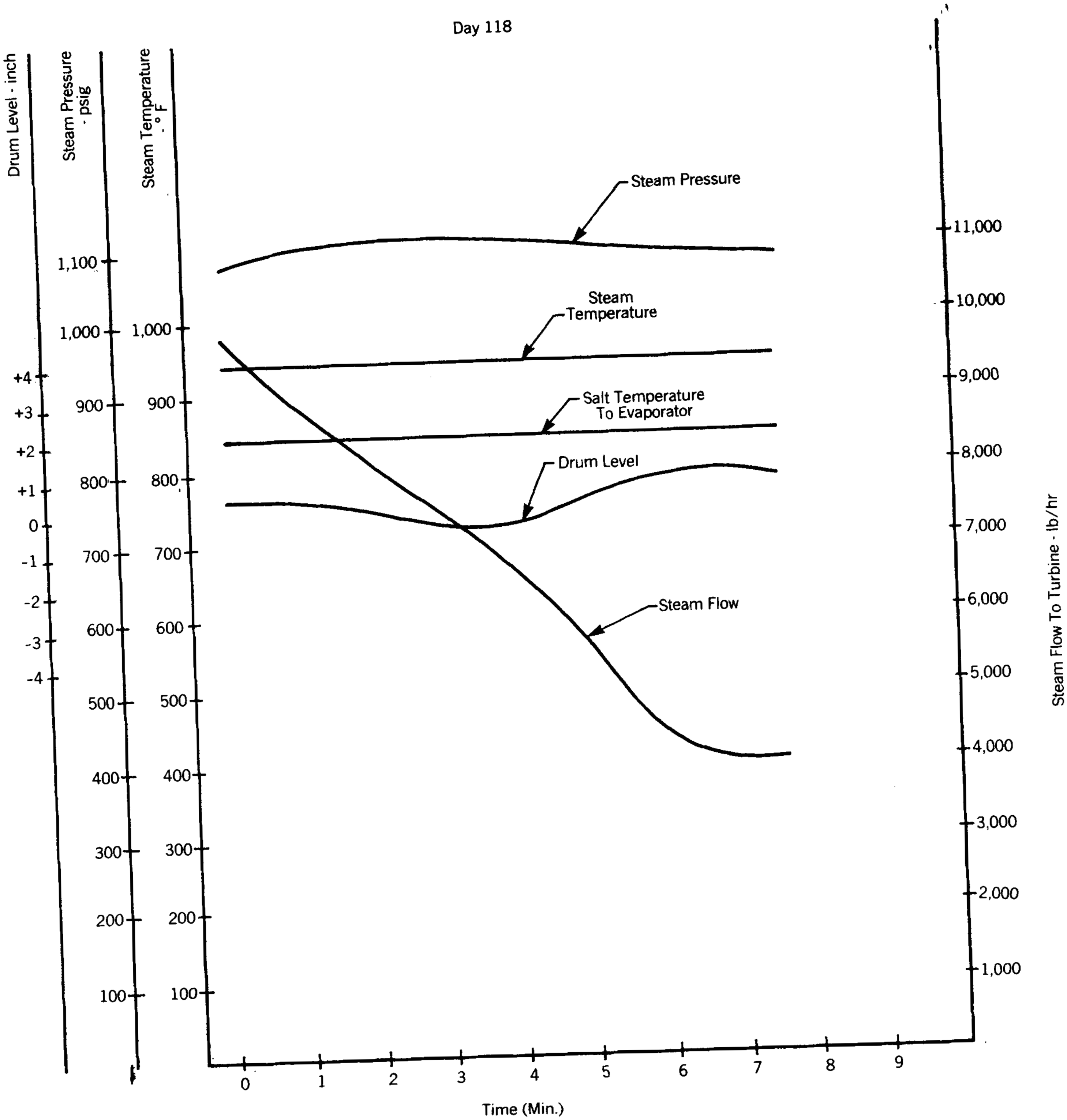
Performance Data On Day 104
"Getting On The Grid"
Figure 6.4-2



MSEE - SGS Performance
Figure 6.4-3



Increasing Power Ramp
Response of Controlled Parameters
Figure 6.4-4



Decreasing Power Ramp
Response of Controlled Parameters
Figure 6.4-5

TABLE 6.4-1

Selected MSEE - SGS Performance Data

Performance	Day	Time
100% Load	104 (4/13/84)	14:56:53
100% Load	118 (4/27/84)	13:54:35
Power Maneuvers Up/Down	118 (4/27/84)	11:13:38 through 11:29:7
Mixing Tees (Cooldown)	118 (4/27/84)	14:35:54 through 15:09:36
Thermal Baffles (Cooldown)	118 (4/27/84)	14:35:54 through 15:09:36

TABLE 6.4-2
MSEE - SGS List of Instrumentation

No.	Location	Unit
TE-382	Salt Inlet Temp. to SH	^oF
PT-382	Salt Inlet Press. to SH	psia
6007	Salt Outlet Temp. from SH	^oF
-	Salt Flow to SH	lb/hr
TE-331	SH Outlet Temp.	^oF
TE-301	Salt Inlet Temp. to Evap.	^oF
TE-384	Salt Outlet Temp. from Evap.	^oF
PT-384	Salt Outlet Press. from Evap.	psig
FT-321	Salt Flow from Evap.	lb/hr
FT-381	Steam Flow to Attemp.	lb/hr
FT-311	Steam Flow to Turbine	lb/hr
TE-332	Steam Temp. to Turbine	^oF
PT-321	Steam Press. to Turbine	psig
PT-383	Steam Drum Press.	psig
TE-383	Steam Temp. from Steam Drum to SH	^oF
FT-411	FW. Flow to Steam Drum	lb/hr
TE-386	FW. Temp. to Steam Drum	^oF
PT-386	FW Press. to Steam Drum	psig
FT-382	Cold Salt Flow to Mixing Tees (Evap.)	lb/hr
LT-311	Steam Drum Level	in.
6005	Sec. Downcomer Temp.	^oF
6032	Cold Salt Temp. from Attemp. to Evap. Inlet	^oF

Table 6.4-3
SGS Steady State Performance Data

	100% Load	
No.	Day 104 14:56:53	Day 118 13:54:35
TE-382	1058	1057
PT-382	76	68
6007	919	915
(1)	62,100	57,600
TE-331	1032	1030
TE-301	849	854
TE-384	560	562
PT-384	22	17
FT-321	(2)79,700	(2)74,900
FT-381	(2) 1,590	(2) 1,480
FT-311	11,070	10,480
TE-332	948	948
PT-321	1,087	1,120
PT-383	1,146	1,167
TE-383	560	564
FT-411	9,870	10,450
TE-386	457	452
PT-386	1,161	1,189
FT-382	(2)17,600	(2)17,300
LT-311	.24	-.33
6005	546	548
6032	569	596

(1) Salt flow (lb/hr) through SH based on heat balance
(2) Corrected value based on heat balance

6.5 Evaporator

To assess component performance, the calculated overall heat transfer coefficient for the evaporator is compared with 100% load sizing (0% and 30% margin). The results of this analysis are presented in Table 6.5-1.

As shown on day 104 the overall heat transfer in the evaporator is 8,291,500 Btu/hr (2.43 MW) compared to the 100% sizing requirement of 7,350,000 (2.15 MW) or about 13% over the specification value. The calculated overall heat transfer coefficient of 215 Btu/hr-ft^2-F (1436 w/m^2-C) is approximately 10% less than was predicted based on 0% sizing calculations. It should be noted that a direct comparison of overall heat transfer coefficients is difficult since the lower than design feedwater temperature results in a change in the overall operating parameters. The SGS circulation ratio is estimated by a steam drum heat balance using the following equation:

$$CR = \frac{T_{sat} - T_{fw}}{T_{sat} - T_{dc}}$$

where:

T_{sat} = Satuartion Temperature

T_{fw} = Feedwater Temperature

T_{dc} = Downcomer Temperature

The calculated circulation ratio of 6 to 7 is well above the design circulation ratio of 3.7 established to preclude departure from nucleate boiling in the evaporator (see Section 2.6).

Table 6.5-1
SGS Evaporator

Comparison of Full Load Sizing Parameters
and Operating Parameters

Item	100% Load Sizing 0% Margin	30% Margin	Day 104	Day 118
Salt Flow (lbm/hr)	72,136	74,217	79,700	74,900
T_{in} (^{o}F)	850	850	849	854
T_{out} (^{o}F)	567	575	560	562
Water Flow (lbm/hr)	56,000	53,250	-	-
T_{in} (^{o}F)	560	559	546	548
T_{out} (^{o}F)	563	563	560	564
Q (Btu/hr)	7,350,000	7,350,000	8,291,500	7,877,740
T_m (^{o}F)	75.4	93.8	90.8	91.1
A (ft^2)	406.7	406.7	406.7	406.7
U(Btu/hr-ft^2-F)	240	193	215	213

6.6 Superheater

A comparison of the effective overall heat transfer coefficient for the superheater with 100% load sizing (0% and 30% margin) is presented in Table 6.6-1.

As shown on day 104:

- o Steam flow is 11070 lbm/hr (1.395 kg/sec) or about 4% below the design value of 11530 lbm/hr (1.453 kg/sec). The steam flow to the superheater is dependent on steam generated in the evaporator; flow is less than design because of the low feedwater temperature(see Section 6.5).
- o The calculated overall heat transfer coefficient of 272 Btu/hr-ft^2-F (1817 w/m^2-C) is approximately 10% less than was predicted based on 0% sizing calculations.

Table 6.6-1
SGS Superheater

Comparison of Full Load Sizing Parameters
and Operating Parameters

Item	100% Load Sizing 0% Margin	30% Margin	Day 104	Day 118
Salt Flow (lbm/hr)	60,900	61,900	62,100	57,600
T_{in} (^oF)	1,050	1,050	1,058	1,057
T_{out} (^oF)	902	905	919	915
Steam Flow (lbm/hr)	9,922	10,375	9,480	9,000
T_{in} (^oF)	562	563	560	564
T_{out} (^oF)	1,030	1,004	1,032	1,030
Att. Flow (lbm/hr)	1,609	1,156	1,590	1,480
T (^oF)	562	563	560	564
Steam To Turbine(lbm/hr)	11,531	11,531	11,070	91.1
T (^oF)	950	950	948	948
P (psig)	1,100	1,100	1,087	1,120
Q (Btu/hr)	3,304,000	3,294,000	3,166,000	3,000,500
T_m (^oF)	113.1	147	126.6	126.3
A (ft^2)	92.1	92.1	92.1	92.1
U (Btu/hr-ft^2-F)	317	243	272	258

6.7 Mixing Tees

Salt mixing tees are located in the inlet piping to both the superheater and the evaporator to control the salt temperature entering these units as described in Section 2.10.1.7.

Mixing tee no. 2 is located in the hot salt piping at the superheater inlet. This tee permits increasing the salt temperature to the superheater inlet during start-up and decreasing the salt temperature during cooldown.

Four thermocouples are attached to mixing tee no. 2 to evaluate temperature profiles. Cooldown data for day 118 is listed in Table 6.7-1.

The two thermocouples shown in Figure 6.7-1 are located on the outside surface of the tee upstream of the holes in the hot salt pipe. As shown in Figure 6.7-1, temperature gradients (top to bottom) of up to 367°F (204°C) exist at this location in salt mixing tee no. 2 during cooldown

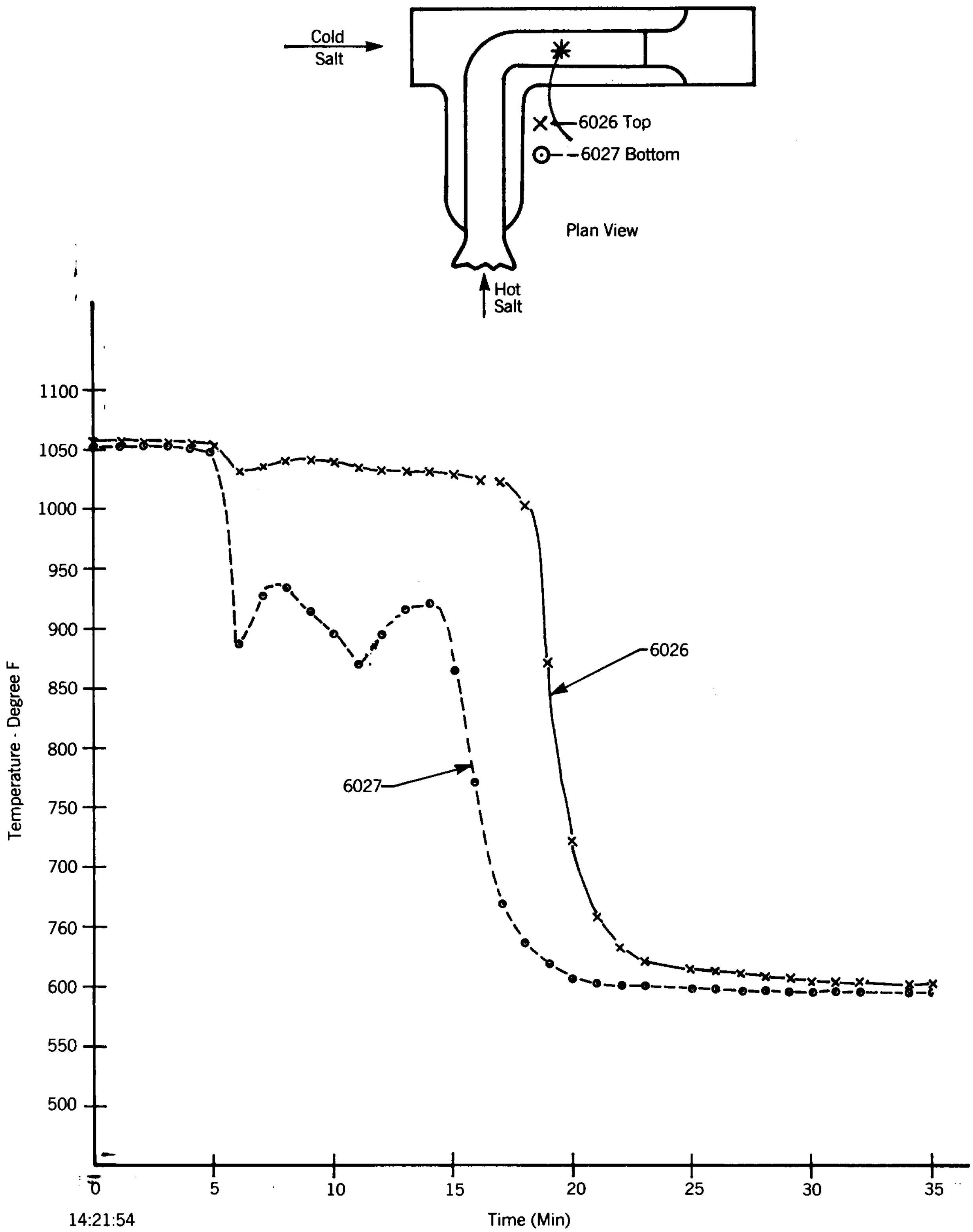
The two thermocouples shown in Figure 6.7-2 are located on the outside surface of the tee downstream of the holes in the hot salt pipe. As shown in Figure 6.7-2, temperature gradients of up to 82°F (46°C) exist at this location.

A structural evaluation was made of mixing tee no. 2 subjected to the temperature distributions shown on Figures 6.7-1 and 6.7-2. The maximum difference in temperatures occurs between TE-6026 (top) and TE-6027 (bottom) at time 14:39:54 (18 minutes on Figure 6.7-1).

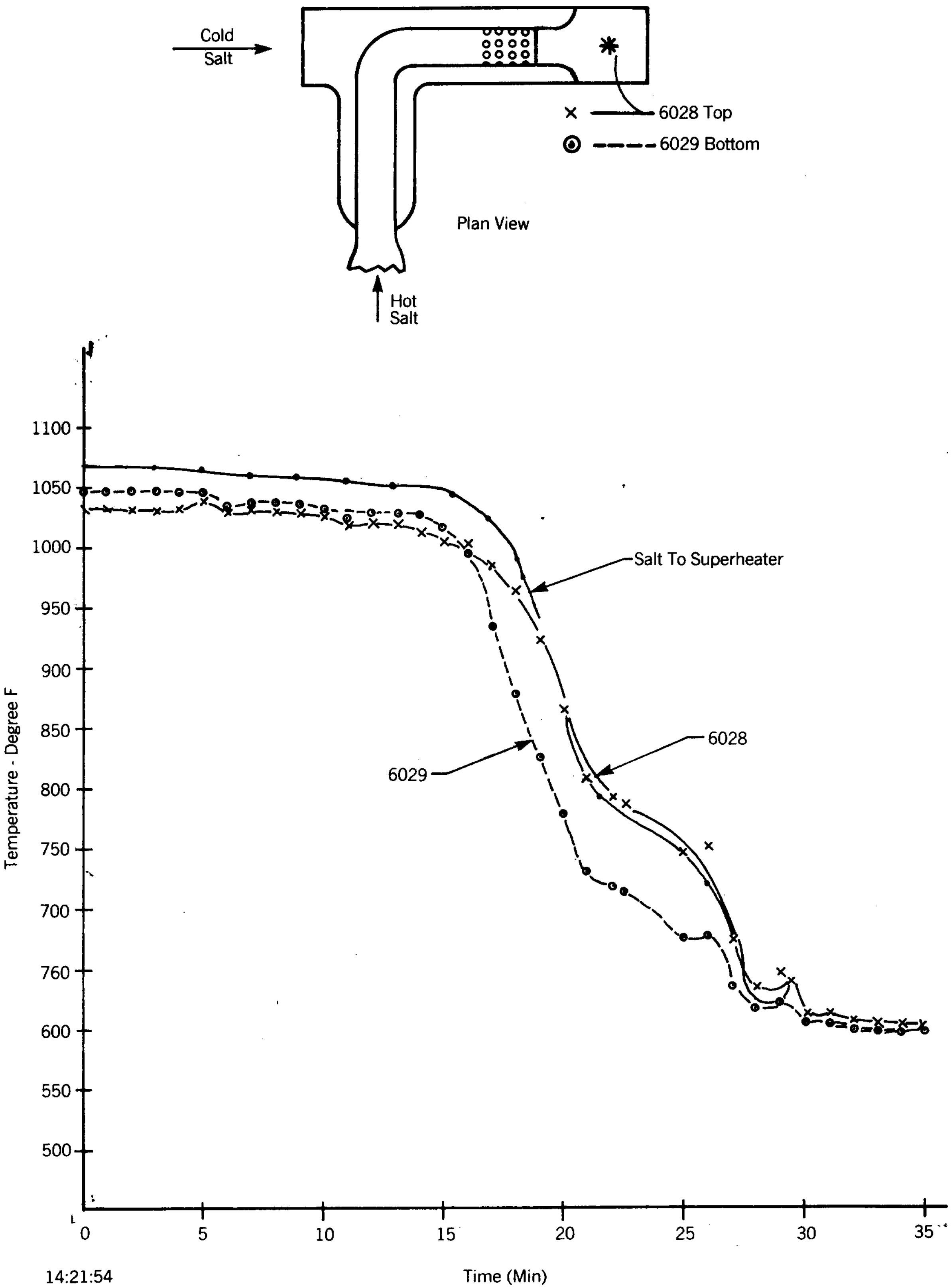
Thermocouples TE-6026 and TE-6027 are located near pipe hanger SL3-H2 (B&W Drawing 179936C) which is fixed in the vertical direction. At 14:39:54 the temperature difference between TE-6026 and TE-6027 is 367°F (204°C). At the same time the temperature difference between

TE-6028 and TE-6029, located 18 inches (0.457m) downstream, is $82^{o}F$ ($46^{o}C$).The structural evaluation assumed a beam supported at the superheater salt inlet nozzle and at hanger SL3-H2, with springs at the hot salt line branch (B&W Drawing 179936C) and at the cold salt control line branch (B&W Drawing 179938C). The adjacent supports in the branches are spring hangers, and the piping itself is relatively flexible in the vertical direction. The top-to-bottom temperature difference of $367^{o}F$ ($204^{o}C$) was assumed to exist over a length of 18 inches (0.457m) in the vicinity of hanger SL3-H2. A curvature was calculated for the pipe, and the moment which would produce that curvature was then calculated. The direction of curvature is such that the resistance to the curvature provided by the hot salt line and the cold salt control line is relatively low. An approximate spring constant was calculated for these lines, and bending stresses were calculated in the mixing tee line.

Using temperature response charts, stresses were calculated for the through-thickness temperature gradient induced by the rapid temperature change between 18 minutes and 21 minutes shown on Figure 6.7-1. These stresses were combined with the beam stresses discussed in the preceding paragraph and with the pressure stresses. Stress intensities were then calculated from the combined stresses. It should be noted that the piping flexibility stresses at the top and bottom of the mixing tee run are negligible. A stress intensification factor for a welding tee was applied to the maximum stress intensity, and a fatigue evaluation was made. The results indicate an acceptable fatigue damage factor on the basis of a daily cycle over the three year design life of the SGS.



**Temperatures (6026, 6027)
At Mixing Tee No. 2
During Cooldown - Day 118
Figure 6.7-1**



Temperatures (6028, 6029)
At Mixing Tee No. 2
During Cooldown - Day 118
Figure 6.7-2

Table 6.7-1
Day 118 Cooldown Data

No.	14: 35: 46	38: 46	41: 46	45: 25	48: 6	51: 16	53: 57	57: 7	15: 0: 59	4: 48	6: 36	9: 36
TE-382	1050	1024	878	767	723	639	601	600	600	669	689	704
TE-331	1014	1011	929	795	746	672	638	621	603	583	578	573
TE-301	849	851	843	756	725	661	639	621	608	592	581	576
TE-384	577	563	560	555	554	550	553	551	528	545	545	546
FT-311	1990	2500	2540	2060	1650	10	430	10	10	10	10	10
TE-332	948	948	944	848	798	733	709	681	669	670	667	661
PT-321	1093	1093	1098	1071	1068	1025	1035	1056	1016	1003	997	987
PT-383	1102	1107	1109	1082	1080	1032	1048	1071	1030	1013	1005	998
TE-383	574	567	564	559	559	551	555	555	552	548	546	545
TE-386	471	451	443	439	436	452	463	481	485	475	470	466
FT-382	4220	5440	9540	16000	16000	16000	16000	16000	16000	3770	3620	3680

Temperatures, ^{o}F

Pressures, psig

Flows, lbm/hr

6.8 Thermal Baffles

In the U-tube, U-shell superheater and evaporator, the 12-inch (.305m) length of each leg of the tube bundle closest to the tubesheet is provided with two thermal baffles spaced at 6 inches (.152m). The intent of these baffle plates is to form two adjacent regions of essentially stagnant salt on the shell side between the tubesheet and the salt path into (or out of) the heat exchangers (see Sections 2.5 and 2.6).

The six thermocouples shown in Figure 6.8-1 are located on the shell O.D. of the salt inlet leg in the thermal baffle region of the superheater. Superheater shell temperatures in this region during cooldown on day 118 are shown in Figure 6.8-1. Temperature gradients from top to bottom of the shell exist in the thermal baffle region, which likely indicates a salt stratification effect. Temperature gradients of up to 255°F (142°C) exist in the thermal baffle region closest to the salt inlet. Temperature gradients of up to 88°F (49°C) exist in the region of the tubesheet.

A structural analysis was performed on the superheater based on the temperature distributions shown on Figure 6.8-1. The effect of shell temperature gradients both in the vertical direction and in the longitudinal direction were evaluated.

The effect of the vertical temperature difference was evaluated first. The data on Figure 6.8-1 shows that the maximum temperature differences between the thermocouples located on top of the superheater and those on the bottom occur at 18 minutes past the initial time point on the plot of 14:34:55. If the steam outlet end of the superheater is considered as a free body, the vertical temperature difference causes the superheater shell to rotate downward in the region from the superheater support to the steam outlet nozzle. Resistance to this motion is provided by the salt inlet piping and the steam outlet piping. The salt inlet nozzle is located relatively close (18.0 inches) to the superheater support.

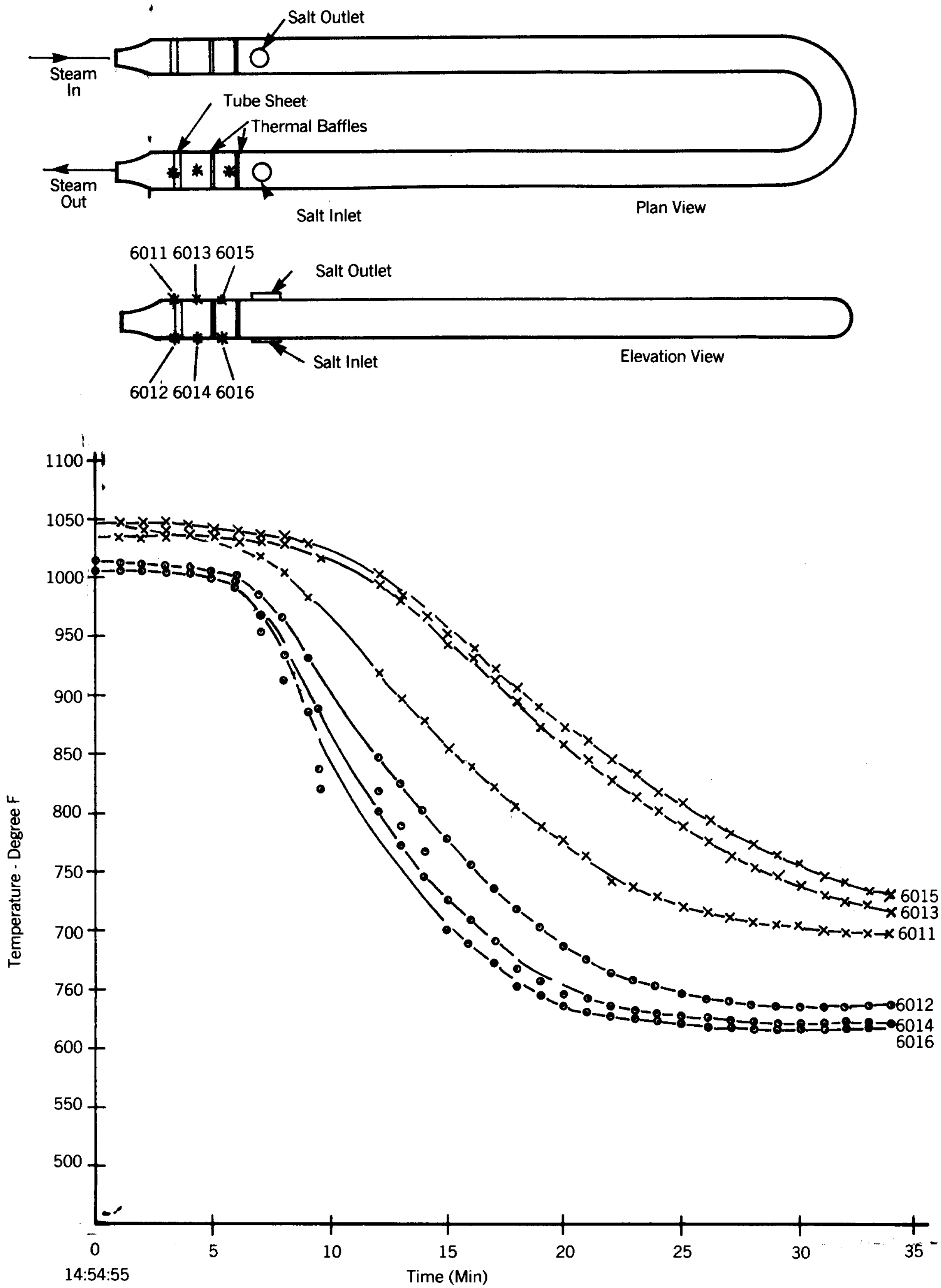
A conservative assumption was made that the maximum vertical temperature difference between TE-6015 and TE-6016 of 255°F (142°C) existed in the superheater shell from the salt inlet nozzle to the end of the superheater steam outlet nozzle, a distance of 39.0 inches (0.991m). The resulting free body displacements at the superheater outlet nozzle were calculated for this condition. Influence coefficients for loading in the vertical direction were calculated for the superheater and the steam outlet piping up to hanger WL5-H4 (B&W Drawing 139939C). The superheater was assumed to be fixed at its first support. Hanger WL5-H4 is fixed in the vertical direction; however, for this evaluation the steam outlet pipe was assumed to be totally fixed at hanger WL5-H4. An interaction analysis was made at the interface between the superheater and the steam outlet pipe with the deflection and rotation of the superheater due to superheater bowing imposed as free body displacements.

The results of the interaction analysis indicate that the superheater is substantially free to do whatever it wants to because the piping is much more flexible. Thus, the stresses induced in the superheater by this event are negligible. The stresses induced in the piping were conservatively combined with the flexibility stresses at full load operating conditions and were found to be acceptable. As a result of this event, the hanger load at WL5-H4 was found to increase by about 130 pounds, which is reasonable and acceptable.

The longitudinal temperature difference in the superheater shell adjacent to the tubesheet in the salt inlet leg was also evaluated for the structural effects of the cooldown on day 118. From Figure 6.8-1, the maximum longitudinal temperature differences are developed at 18 minutes past the intial plot point of 14:34:55. The maximum temperature difference between two adjacent thermocouples on the same surface is 88°F(49°C), which occurs between TE-6011 and TE-6013 on top of the shell. The corresponding temperature difference between TE-6012 and TE-6014 on the bottom surface is 37°F (21°C). An assumption was made that the 88°F (49°C) temperature difference existed around the entire circumference of the superheater shell. A further assumption was made that a linear longitudinal gradient existed between the location of TE-6013 and the tubesheet.

An interaction analysis was made between the salt side shell and the tubesheet. The results of the analysis show that the structural effects are minor for a daily occurrence over the three year design life of the SGS. As noted previously, the superheater shell is essentially unrestrained in the vertical direction so the structural effect of the vertical temperature difference in the shell is negligible.

In addition, an interaction analysis was made for the junction of the steam side shell and the tubesheet. In this evaluation, the average temperature of the tubesheet rim was taken as the average of thermocouples TE-6011 and TE-6012. The rate of change of the steam temperature was derived from the data at TE-331 in the steam outlet pipe. This steam temperature change was found to be -330°F (-183°C) in the interval between 5 minutes and 18 minutes following the start of cooldown. This rate of change of steam temperature was used to calculate the average steam side shell temperature at 18 minutes using the temperature response charts. The results of the interaction analysis indicate an acceptable structural condition for a similar daily cooldown over a period of three years.



Superheater Shell Temperatures
In Thermal Baffle Region
During Cooldown - Day 118
Figure 6.8-1

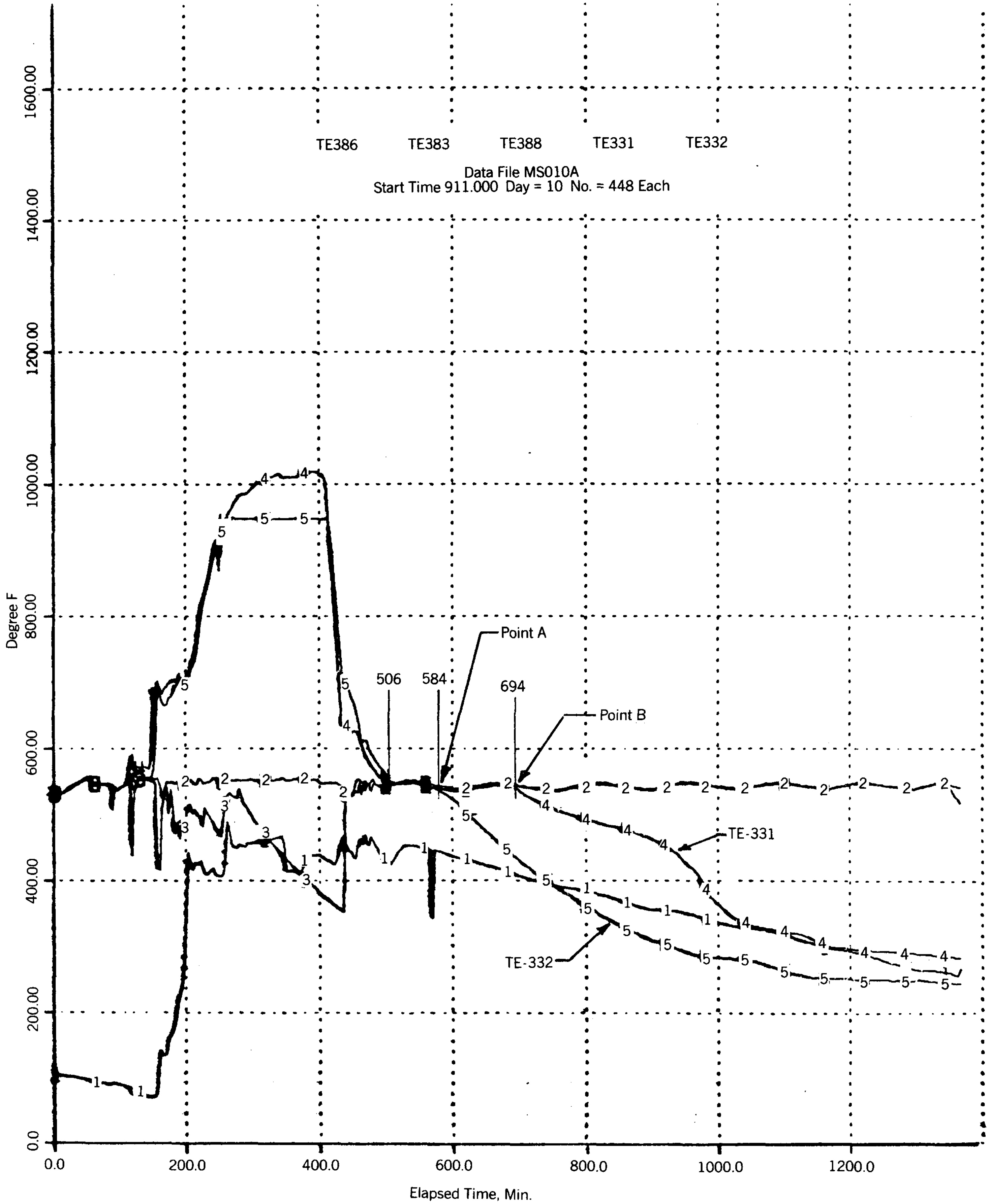
6.9 SGS Diurnal Shutdown

During diurnal shutdown heat losses from the steam drum above the water level and from the water/steam system downstream of the drum are balanced by condensing saturated steam. The original procedure for diurnal shutdown called for removing this condensate through the HRFS steam trap T-482 located off the main steam piping near the HRFS/SGS interface point at the north end of the skid. Operating with this trap open resulted in unacceptable depletion of the SGS water inventory, to the point where the drum water level reached the low-low alarm point which tripped the BWCP and the circulation heater with subsequent reduction of steam pressure. It has never been clearly established whether the excessive water loss rate during diurnal shutdown with trap open was due to faulty trap operation which permitted steam leak-by along with condensate removal or to heat losses which were in excess of analytical predictions, or to a combination of both. To maintain an acceptable water inventory during diurnal shutdown, the operating procedure was altered to completely isolate the SGS water/steam system during diurnal shutdown by closing T-482. Using this procedure, condensate accumulates in the water/steam system downstream of the drum, which limits drum water level reduction to approximately 12 inches during diurnal shutdown. The initially conservative range of 13 inches between the high-high and the low-low steam drum water level alarms has been increased to 25 inches to permit more variation of water level during diurnal shutdown without causing BWCP and circulation heater trips. At the end of the diurnal shutdown period, the trap is opened to remove accumulated condensate and to permit steam to reheat the SGS water/steam system downstream of the steam drum.

As noted above, with trap T-482 closed during diurnal shutdown, the drum water level reduction is limited to about 12 inches. This is equivalent to about 3 ft^3 ($0.085m^3$) of water which is the volume of the steam/water system between the high point in the superheater steam inlet pipe and trap T-482. Data from a number of diurnal shutdown periods have been reviewed to try to estimate the rate of heat loss from the steam/water system piping and to compare that heat loss with the calculated value. Steam line temperature values from TE-331 and TE-332 (B&W Drawing 179939C) can be used as an indication of both the rate of condensate accumulation in the piping and of the heat loss from piping. When each of these temperatures drops below the diurnal shutdown saturation temperature this provides an indication that condensate has accumulated to that location in the piping. Figure 6.9-1 (Day 10, January 10, 1984) shows a typical example. Points A and B on the figure indicate where TE-332 and TE-331 drop below the saturation temperature.

The review of the diurnal shutdown heat losses indicates that the "effective conductivity" of the pipe insulation is on the order of two and a half times higher than the "book value" for calcium silicate insulation, which is about 0.04 Btu/hr-ft-F (0.07 w/m-C) and on the order of one and a half times the value of 0.055 Btu/hr-ft-F (0.095 w/m-C) suggested by SNL for heat trace sizing (see Section 2.11).

A possible explanation for this difference is poor insulation installation at local spots, allowing air infiltration with attendant higher heat losses. This points out the need for the use of good installation techniques and suggests the use of a layer of blanket insulation between the piping and the rigid calcium-silicate insulation to eliminate potential air gaps. Also, the use of double layers of calcium silicate insulation with the joints of the two layers offset could help reduce air infiltration.



Diurnal Shutdown Temperature Data
Figure 6.9-1

7.0 CONCLUSIONS, RECOMMENDATIONS, AND LESSONS LEARNED

The Steam Generator Subsystem has performed well as an integral part of the Molten Salt Electric Experiment. The MSEE has verified the feasibility of a molten salt central receiver electric power generation system. The SGS successfully completed all steady-state and transient acceptance tests. The SGS Bailey Controls Network 90 system has performed well and interfaces well with the CRTF EMCON control system for total MSEE system control.

Throughout the period of SGS checkout and acceptance testing, a great deal of experience and information related to the design, the hardware, and the operation of the subsystem was accumulated. The following are conclusions, recommendations, and lessons learned from that experience.

1. Overall Subsystem Performance

    a. Full load steady-state performance of the steam generator subsystem meets specification requirements.

    b. The SGS exceeds the rated heat load of 3.11 MWt by 8% at design steam delivery temperature and pressure.

    c. The overall effective heat transfer coefficient of both the superheater and the evaporator is approximately 10% less than was predicted based on the 0% margin sizing calculations. A 30% margin sizing was used in the designs.

    d. The actual full load circulation ratio of 6 to 7 is well above the design circulation ratio of 3.7 established to preclude DNB in the evaporator.

e. During the 10% per minute up and down power changes, steam temperature and pressure, drum level, and evaporator salt inlet temperature were controlled at essentially constant values by the Network 90 control system.

2. Boiler Water Circulation Pump

The boiler water circulation pump (BWCP) is a canned pump designed and manufactured by Lawerence Pump and Engine Company. Lessons learned with regard to the BWCP resulted from two failures suffered in close succession near the beginning of operational testing.

The first failure was a failure of the BWCP bearings due to higher than normal temperatures at the front bearing. Contributing to this higher bearing temperature was the fact that the pump was not running during diurnal shutdown conditions, which stopped the flow of cooling water in the bearing cavity to the bearings. There was insufficient shaft/bearing clearance for these higher than normal temperatures, resulting in binding and ultimate failure of the bearings. Corrective action included increasing the bearing/shaft clearance and changing the bearing material from silicon-carbide to carbon to reduce the difference in thermal expansion coefficients between bearings and shaft. The external pump coolant piping was also revised to better assure adequate coolant supply to the pump.

The second BWCP failure was traced to a short in the motor stator windings. While the cause of the failure was not pinpointed, the most likely cause appeared to be a defective as-built stator which deteriorated over time, possibly aggravated by local overheating which might have occurred as a result of the previous problem with shaft/bearing binding. The BWCP was shipped back to the manufacturer for installation of a new stator. To better assure adequate cooling of the pump, operating procedures were modified to provide for pump operation during diurnal shutdown conditions.

Subsequent to these failures, the BWCP has operated without incident since November of 1983.

In future applications, better definition of all potential pump operating conditions must be made to assure a correct pump design and to provide correct system and pump operating procedures.

3. Circulation Heater

The circulation heater was supplied to the SGS program by SNL. The heater was designed and manufactured by the Pacific Chromalox Division of Emerson Electric Company. Two failures relative to the circulation heater occurred during operational checkout and acceptance testing.

The first failure occurred during the initial steam blow operation. All the circulation heater elements burned out due to steam formation in the heater and resulting excessive element temperature. Several factors contributed to the elements' failure:

a. There was no water flow through the heater because the heater inlet valve was inadvertently left closed by the operator.

b. Due to an incorrectly set trip point, the control system failed to cut off power on the high heater element temperature signal.

c. The heater element temperature thermocouple was incorrectly located near the bottom, rather than the top, of the heater bundle allowing the upper portion of the elements to overheat while the lower portion was still covered with water.

d. No formal test procedure had been established for this steam blow operation, and no individual had been assigned overall responsibilty for conducting the test.

Several corrective actions were taken as a result of this heater failure.

a. A control system interlock was added to prevent energizing the heaters unless the heater inlet valve was open to assure water flow to the heater.

b. SNL had the heater manufacturer locate the element temperature thermocouple near the top of the heated section of the heater bundle.

c. The power-off trip point for the thermocouple was reduced.

d. A formal test procedure for the steam blow operation was prepared by SNL, and a CRTF test engineer was assigned test conductor responsibility for the steam blow operation.

The second failure occurred during diurnal shutdown conditions. The circulation heater pressure boundary failed due to localized heating of the pressure boundary well in excess of its design temperature. Causes leading to the depletion of water inventory in the heater and subsequent overheating can be summarized as follows:

a. Improper location of the heater element high temperature thermocouple at the bottom rather than the top of the heater bundle. (It should be noted that at the time of the first heater bundle failure a cold lap was discovered on the surface of the heater vessel pressure boundary. The replacement heater bundle was inserted into that original heater vessel; the high element temperature thermocouple <u>was</u> located correctly on that heater bundle. Subsequently, the heater supplier replaced the entire circulation heater (vessel and heater bundle); on that replacement heater, the high element temperature thermocouple was again improperly located at the bottom of the heater bundle).

b. Freezing in some water/steam system instrumentation lines with resulting improper signals to the control system.

c. Insufficient control system interlocks on heater operation.

Several corrective actions were taken as the result of the second heater failure.

a. SNL had the heater manufacturer locate the element temperature thermocouple near the top end of the heated section of the heater bundle.

b. Improved freeze protection on the water/steam system instrument lines was incorporated in terms of higher heat trace power input and improved insulation.

c. Additional interlocks on heater operation were incorporated into the control system. In addition, a feature was incorporated requiring manual re-start of the heaters following any power-off trip.

Subsequent to the second failure, the circulation heater has operated without incident.

For future applications, additional care should be exercised with regard to the specification requirements, control, and inspection of such equipment.

4. <u>Salt System Valves</u>

With the exception of the two Kieley and Mueller valves on the heat exchangers' drain lines, all salt system valves were specified and purchased by SNL from Valtek. In general, all salt system valves associated with the SGS performed their basic function (i.e. control and/or isolation) as expected. However, several problems were noted which should be addressed in future designs.

a. Two of the Valtek valves developed leaks at the bonnet-to-body junction subsequent to field assembly of the valves by the vendor. These leaks were caused by improper field assembly. Any unnecessary field assembly of valves should be eliminated, and vendor field technicians should be closely monitored during field assembly work.

b. Valve position feedback indicators and limit switches functioned poorly. The signals could not be relied on for consistency, and the mounting hardware was of poor quality. The need to insulate the top of the valve bonnet in the region of the actuator yoke to reduce heat losses also caused problems with these mounting brackets. The need for better hardware for indicators and limit switches should be addressed in future programs.

c. Valve heat losses must be addressed in a manner which assures valve operating temperatures above the freezing point of the salt for the applicable ambient temperature and wind conditions. System designers should assure that valve suppliers are aware of the problems associated with valve operation in molten salt systems and should have those suppliers provide design information required for proper evaluation of valve heat losses. (See also Heat Trace recommendations following.)

5. <u>Water/Steam System Valves</u>

a. The remotely operated steam attemperator control, circulation heater isolation, and BWCP isolation valves performed as expected with no significant problems.

b. Several of the small, hand operated isolation valves developed leaks around the stem packing from time to time. Normally, tightening the packing gland was sufficient to eliminate the leakage. Such leaks, if allowed to become significant, can cause excess SGS water loss during diurnal shutdown conditions, resulting in shutdown of the circulation heater and reduction of system steam pressure. Such occurrences point out the need for a continuing program of daily inspection and preventative maintenance on the SGS.

c. Several of the small, hand operated isolation valves developed leaks at the threaded pipe-to-valve junctions. The teflon tape used to seal these connections is marginal or unacceptable at the SGS operating temperatures. As leaks of this type occurred, the valve-to-pipe joint was seal-welded. In the future, socket welded valves should be used in these applications.

6. Heat Trace

The heat tracing on the SGS is Nelson Electric Co. Inconel sheath, mineral insulated cable with nichrome conductors. Each heating zone has a primary cable, together with a back-up cable for use in the event of failure of the primary cable.

Overall, the heat trace system performed well in maintaining system temperature above the salt freezing point. At a couple of locations on the piping, re-work on the insulation was required after initial start-up to achieve the required temperatures. Some re-work on the bonnet insulation of the valves was required to increase the bonnet temperatures above the salt freezing temperature. This re-work achieved the desired results on all valves except FCV-341. On this valve, the back-up heat trace cable was wired to a separate 110 vac circuit which included a Variac to control cable power. The Variac was adjusted to increase power input to the valve bonnet such that its temperature exceeded 480^{o}F (249^{o}C). This proved to be a satisfactory fix.

Two cable failures occurred out of a total of 30 primary cables in the system. One cable was inoperative at initial start-up although it passed several megger and continuity tests during installation. The cable was apparently damaged at some time during the SGS erection. The second cable failed shortly after initial start-up. The failure was apparently due to insulation being packed around the cable in the area where the cable exited the insulation, resulting in overheating the cable. In both instances, the back-up cable was placed in service.

The experience with the SGS heat trace has suggested a number of recommendations for future heat trace systems.

a. Care must be exercised in specifying and carrying out installation requirements of the cable.

b. Improvements in insulating methods for piping and valves can improve heat trace effectiveness. Using an inner layer of blanket insulation over the piping and the heat trace may be effective in eliminating air gaps. When multiple outer layers of calcium-silicate insulation are used, the insulation joints should be staggered to reduce the potential for heat losses.

c. The MSEE heat trace uses passive control. Consideration should be given to active heat trace control as a potential for increasing cable life and for reducing power consumption. Both the "on-off" and the proportional types of active control should be considered.

d. Consideration should be given to trace heating valves independently from the adjacent piping. Such an approach will provide more flexibility in designing both the valve heat trace and the valve insulation.

e. For future installations, particularly those with relative long design life such as the proposed repowering plants, other types of heat trace hardware, other suppliers, and other installation techniques should be evaluated.

7. Controls And Instrumentation

Overall, the Bailey Network 90 control system performed well in controlling and monitoring the SGS and in interfacing with the CRTF EMCON control system. The following observations apply to the SGS control system:

a. During operational checkout and acceptance testing some differences in the operation of the SGS from the EMCON console compared to operation of the SGS from the Network 90 console became apparent, necessitating slightly different operating procedure wording for the two consoles.

b. The Network 90 system proved valuable in providing local, stand-alone operating capability during steam generator subsystem checkout, thus freeing the EMCON consoles for other tasks.

Lessons learned for future applications include the following:

a. The need for control system-based interlock and permissive signals should be carefully considered when designing the control system.

b. A reasonable margin of unused control system logic capacity should be provided to accommodate modifications to the control system based on experience gained during operation.

c. Control system equipment from a single supplier would simplify control system checkout and process operation.

d. When control system equipment from more than one supplier is used, as is often the case for a variety of reasons, this equipment can be successfully interfaced for total process operation.

8.0 REFERENCES

1. Sandia National Laboratories Document 81-5100, Attachment 1, Steam Generator Subsystem Specification dated March 18, 1982 as amended July 30, 1982.

2. ASME Boiler and Pressure Vessel Code, Section VIII, Division I, 1980 Edition and Addenda through Winter, 1981.

3. B&W Computer Program 09858 (VAGEN), Program Version 2.6.9, 8-29-83.

4. Thermal/Hydraulics Design Guide for an Advanced Design Thermal Mixer (Including Development/Testing Details), Argonne National Laboratories Report ANL-CT-79-4, October, 1978, by K. E. Kasza and J. P. Bobis.

5. Power Piping Code, ANSI B31.1, 1980 Edition.

6. Operating and Maintenance Manual, Molten Salt Electric Experiment Steam Generating Subsystem, B&W Contract No. 700-0027-45, SNL P.O. 81-5100.

7. MSEE SGS Checkout Plan, B&W Report No. 700-0027-45-1, Rev. 1, May 6, 1983.

8. MSEE SGS Acceptance Test Plan, B&W Report No. 700-0027-45-2, Rev. 2, May 9, 1983.

9. Integrated Test Procedures for the Steam Generator Acceptance Testing, Martin-Marietta Document MCR-83-548.

10. Steam Blow Procedures, prepared by CRTF, August 26, 1983.

APPENDIX A

B&W Drawings

<u>List of Drawings</u>

Dwg. No.	Title
179932C	Steam Piping - Downcomer Line - Assembly 4200
179933C	Steam Piping - Evaporator Water Inlet Line - Assembly 4300
179934C	Steam Piping - Riser Line - Assembly 4400
179935C	Steam Piping - Superheater Inlet Line - Assembly 4500/4900
179936C	Salt Piping - Hot Salt Inlet Line - Assembly 3100
179937C	Salt Piping - Evaporator Salt Inlet Line - Assembly 3200
179938C	Salt Piping - Cold Salt Control Lines - Assembly 3300
179939C	Steam Piping - Superheater Steam Outlet & Attemperator Lines - Assembly 4600
179940C	Salt Piping - Evaporator Salt Outlet & Over Pressure Lines - Assembly 3400
179941C	Salt Piping - Salt Drain Lines - Assembly 3500
179942C	Steam Piping - Blowdown Line - Assembly 4700
179943C	Steam Piping - Water Drain - Assembly 4800
179944C	Steam Piping - Feedwater Line - Assembly 4100
179945C	Water Heater Piping Inlet Sht. 1 of 2 - Assembly 4350

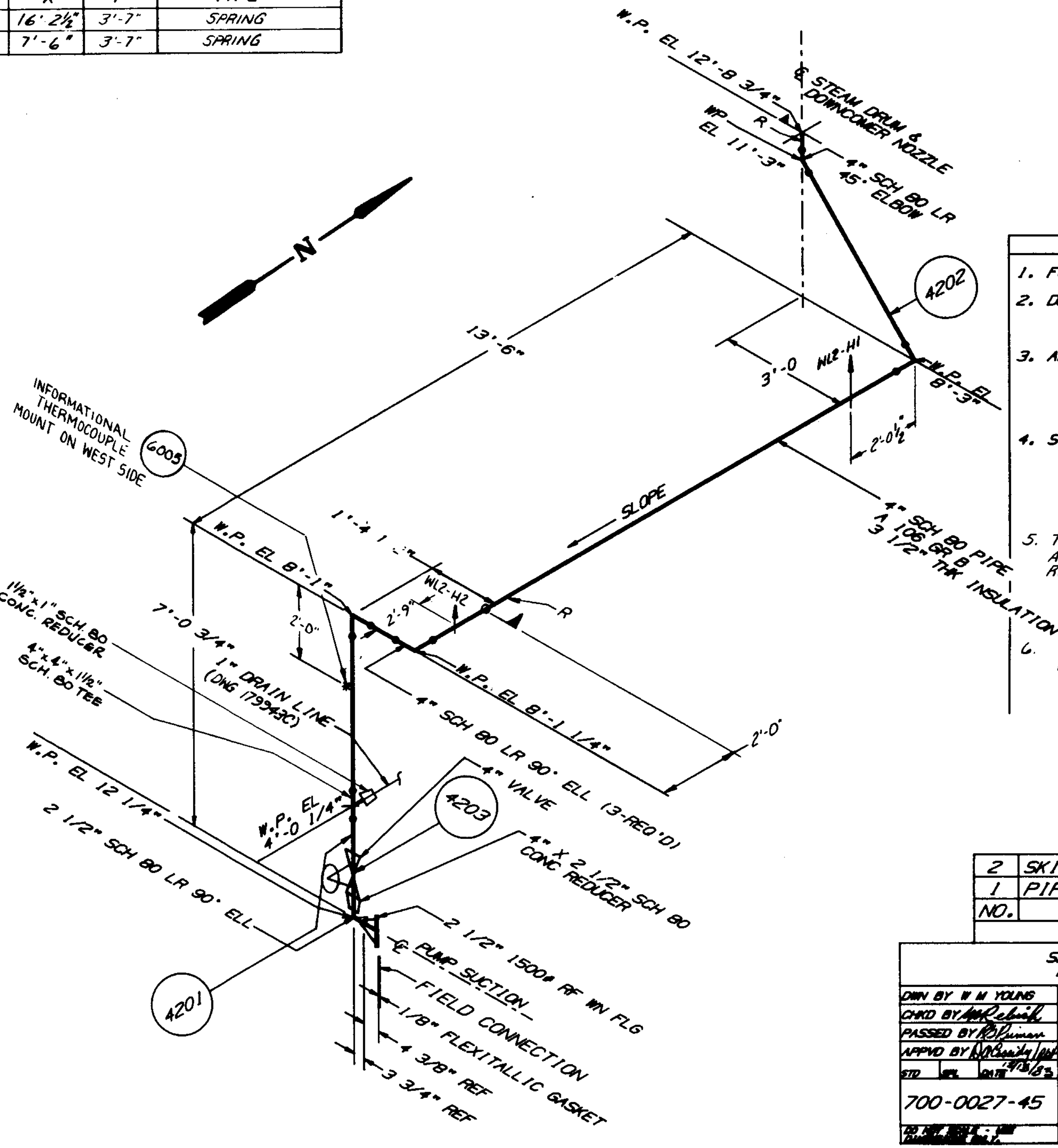
List of Drawings

Dwg. No.	Title
179946C	Water Heater Piping Outlet Sht. 2 of 2 - Assembly 4350
405325E	Superheater - Assembly 2100
405326E	Steam Drum Sht. 1 of 2 - Assembly 2300
405327E	Steam Drum Sht. 2 of 2 - Assembly 2300
405328E	Evaporator - Assembly 2200
405329E	Salt Mixing Tee
405330E	Pedestal Support and Foundation
405331E	Skid Assembly Sht. 1 of 5
405332E	Skid Assembly Sht. 2 of 5
405333E	Skid Assembly Sht. 3 of 5
405334E	Flow Restrictor
405335E	Tower Assembly - Plan View Sht. 1 of 3
405336E	Tower Assembly - Elevation Sht. 2 of 3
405337E	Tower Platform - Hand Rails Sht. 3 of 3
405338E	Skid Assembly Sht. 4 of 5
405339E	Steam Drum Accessories
405340E	Piping Arrangement Sht. 1 of 3
405341E	Piping Arrangement Sht. 2 of 3
405342E	Piping Arrangement Sht. 3 of 3
405343E	Control/Power Wiring - Schematic
405344E	Signal Wiring - Schematic
405345E	Skid Assembly Sht. 5 of 5

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
WL2-H1	16'-2½"	3'-7"	SPRING
WL2-H2	7'-6"	3'-7"	SPRING

REVISIONS

REV. NO.	DESCRIPTION	DATE	APPROVAL
1	(B-3) ADDED WL2-H1 (C-2) ADDED WL2-H2 (A-1) ADDED HANGER COORDINATES (B-3) REVISED NOTE #4. (B-1&2) ADDED INFORMATIONAL THERMOCOUPLE & NOTE 5 & 6.	9/17/83	RHP
2	ADDED NOTE TO DRAWING TO CONC. REDUCER. CHANGED TEE SIZE TO 4"x4"x1½" (C-1).	4/27/84	VT



NOTES

1. FOR GENERAL NOTES SEE REFERENCE #1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE= 1400 PSIA
   PIPING DESIGN TEMPERATURE= 600°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   O -FITTING TERMINALS.
   ▶ -FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. THE THERMOCOUPLES SHALL BE INSTALLED AND AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11.
6. INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE-700-0027-45-1.

NO.	TITLE	DWG. NO.
2	SKID ASSEMBLY SHEET #1	405331E
1	PIPING ARRANGEMENT SHEET #1	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN BY W M YOUNG
CHKD BY
PASSED BY
APPVD BY
STD | SPL | DATE 9/13/83

700-0027-45

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

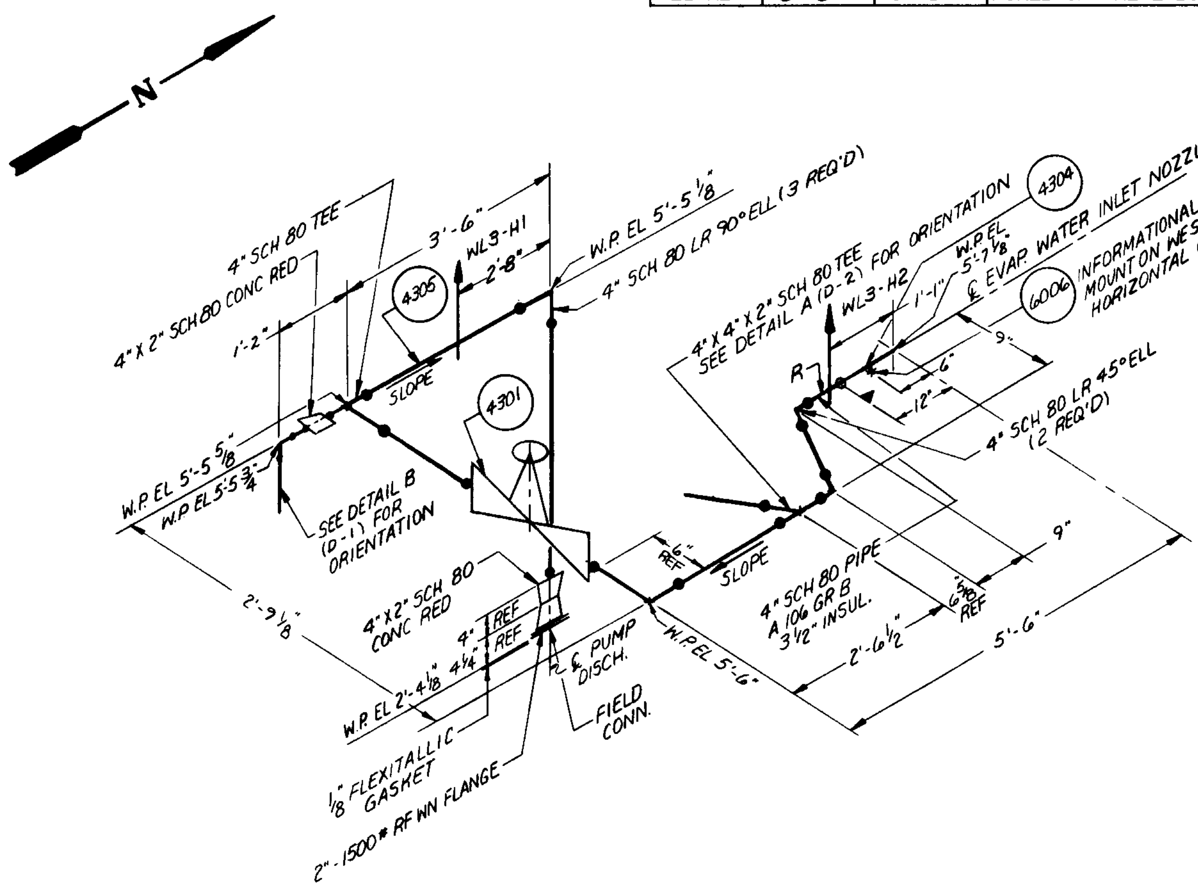
STEAM PIPING DOWNCOMER LINE ASSEMBLY - 4200

SCALE 1/24

DWG NO 179932C
REV 2

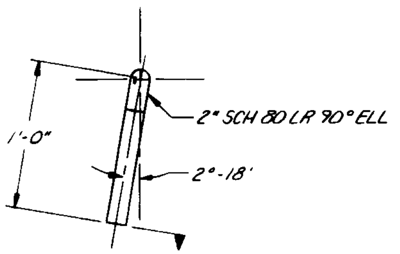
HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
WL3-H1	2'-1"	3'-5 1/8"	FIXED IN THE Z DIRECTION
WL3-H2	5'-8"	1'-5"	FIXED IN THE Z DIRECTION

REVISIONS			
REV. NO.	DESCRIPTION	DATE	APPROVAL
1	COMPLETELY REDRAWN TO RE-ROUT PIPING. ADDED HANGERS & THERMOCOUPLES MSWAR	3/17/83	

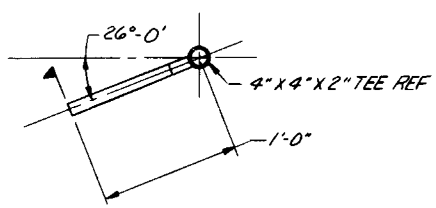


NOTES

1. FOR GENERAL NOTES SEE REFERENCE #1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE: 1400 PSIA
   PIPING DESIGN TEMPERATURE: 559°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   ● -FITTING TERMINALS.
   ⚑ - FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD 700-0027-45-11.
6. THE INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE 700-0027-45-1.



DETAIL B (B-1)
(LOOKING NORTH)
SCALE: NTS



DETAIL A (B-2)
(LOOKING NORTH)
SCALE: NTS

NO.	TITLE	DWG. NO.
2	SKID ASSEMBLY SHEET #1	405331E
1	PIPING ARRANGEMENT SHEET #1	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN BY W M YOUNG
CHKD BY MA REBISH
PASSED BY RG PIRMAN
APPVD BY DA CASSIDY
DATE 12-10-82

700-0027-45

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

STEAM PIPING EVAPORATOR WATER INLET LINE ASSEMBLY - 4300

DO NOT SCALE - USE DIMENSIONS ONLY.

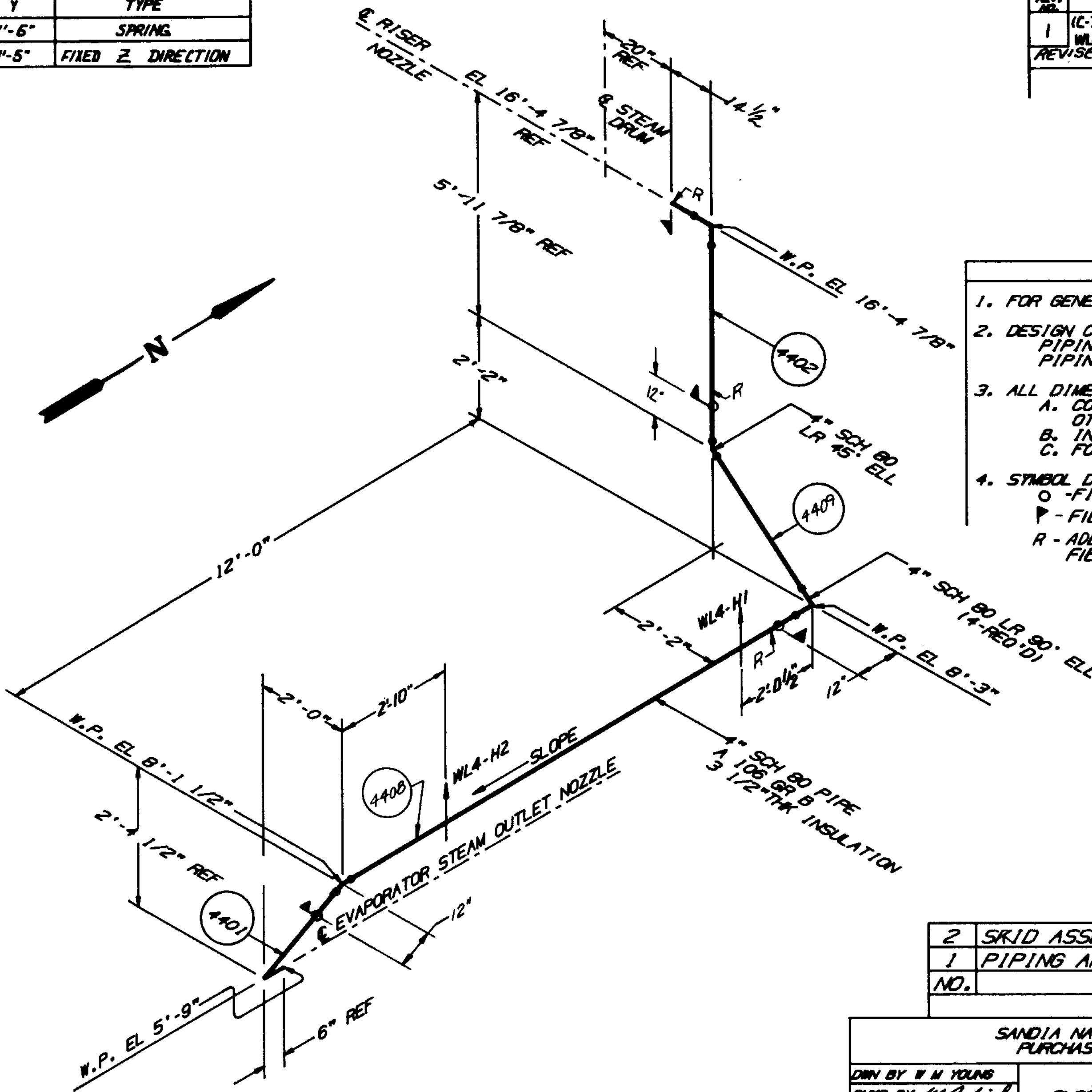
SCALE 1/24

DWG NO 179933C

REV 1

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
WL4-H1	16'-2 1/2"	1'-6"	SPRING
WL4-H2	9'-1"	1'-5"	FIXED Z DIRECTION

REVISIONS			
REV. NO.	DESCRIPTION	DATE	APPROVAL
1	(C-3) ADDED WL4-H1. (C-2) ADDED WL4-H2. (A-1) ADDED TABLE. (B-3) REVISED NOTE # 4. (A-3) 14½ WAS 16.	1/19/83	



NOTES

1. FOR GENERAL NOTES SEE REFERENCE #1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE: 1400 PSIA
   PIPING DESIGN TEMPERATURE: 600°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   O -FITTING TERMINALS.
   ▼ - FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.

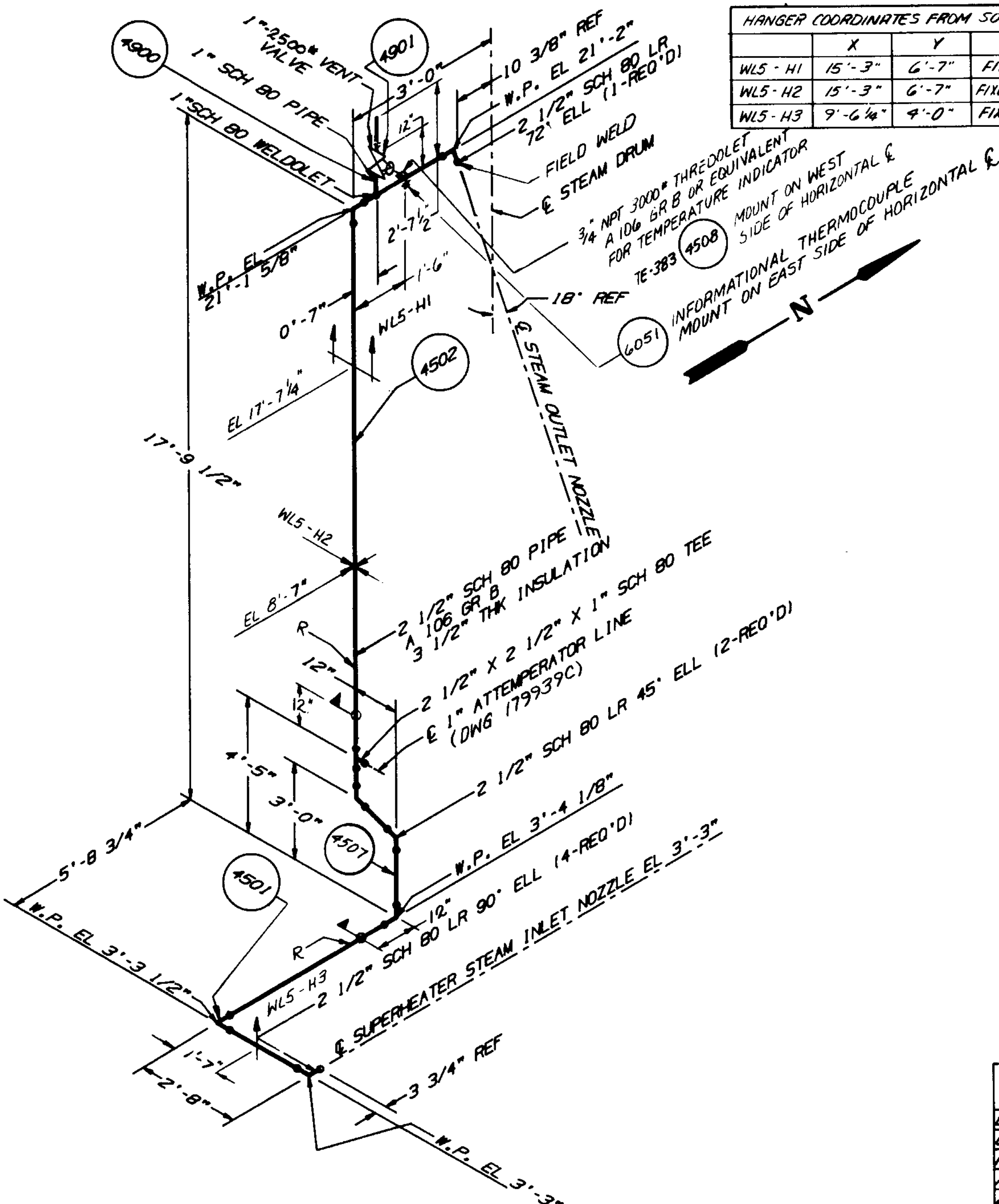
A-6

NO.	TITLE	DWG. NO.
2	SKID ASSEMBLY SHEET #1	405331E
1	PIPING ARRANGEMENT SHEET #1	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN BY W M YOUNG CHKD BY PASSED BY APPVD BY DATE 12/10/82	MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM	THIS DRAWING IS THE PROPERTY OF THE BABCOCK & WILCOX CO. POWER GENERATION GROUP AND IS LOANED UPON CONDITION THAT IT IS NOT TO BE REPRODUCED OR COPIED IN WHOLE OR IN PART, OR USED FOR FURNISHING INFORMATION TO OTHERS, OR FOR ANY OTHER PURPOSE DETRIMENTAL TO THE INTEREST OF THE BABCOCK & WILCOX COMPANY AND WILL BE RETURNED UPON REQUEST.
700-0027-45	STEAM PIPING RISER LINE ASSEMBLY - 4400	DWG NO 179934C — REV 1
DO NOT SCALE - USE DIMENSIONS ONLY.	SCALE 1/24	



HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
WL5 - H1	15'-3"	6'-7"	FIXED IN Z DIRECTION
WL5 - H2	15'-3"	6'-7"	FIXED IN X & Y DIRECTIONS
WL5 - H3	9'-6 1/4"	4'-0"	FIXED IN Z DIRECTION

REVISIONS				
REV. NO.	DESCRIPTION	DATE	APPROVALS	
1	(B-2) ADDED WL5-H1, (B-1) ADDED WL5-H2, (D-1) ADDED WL5-H3, (A-3) ADDED HANGER COORDINATES. (B-3) REVISED NOTE #4. (A-2) ADDED TEMPERATURE INDICATOR. (B-3) ADDED NOTE #5. (B-2) ADDED INFORMATIONAL THERMOCOUPLE, (C-4) ADDED NOTE #6 & #7.	2/17/83		
2	RELOCATED F.W.(C-1), CHANGED 1" 900# VENT VALVE TO 2500#(A-1)	4/27/84	VTJ	

NOTES

1. FOR GENERAL NOTES SEE REFERENCE #1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE: 1325 PSIA
   PIPING DESIGN TEMPERATURE: 600°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   O -FITTING TERMINALS.
   ▶ -FIELD WELD
   R -ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11.
6. THE INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE-700-0027-45-1.
7. HOLE IN PIPING AT THREDOLET TO BE FREE OF BURRS, ETC.

NO.	TITLE	DWG. NO.
2	SKID ASSEMBLY SHEET # 1	405331E
1	PIPING ARRANGEMENT SHEET # 1	405340E

REFERENCES

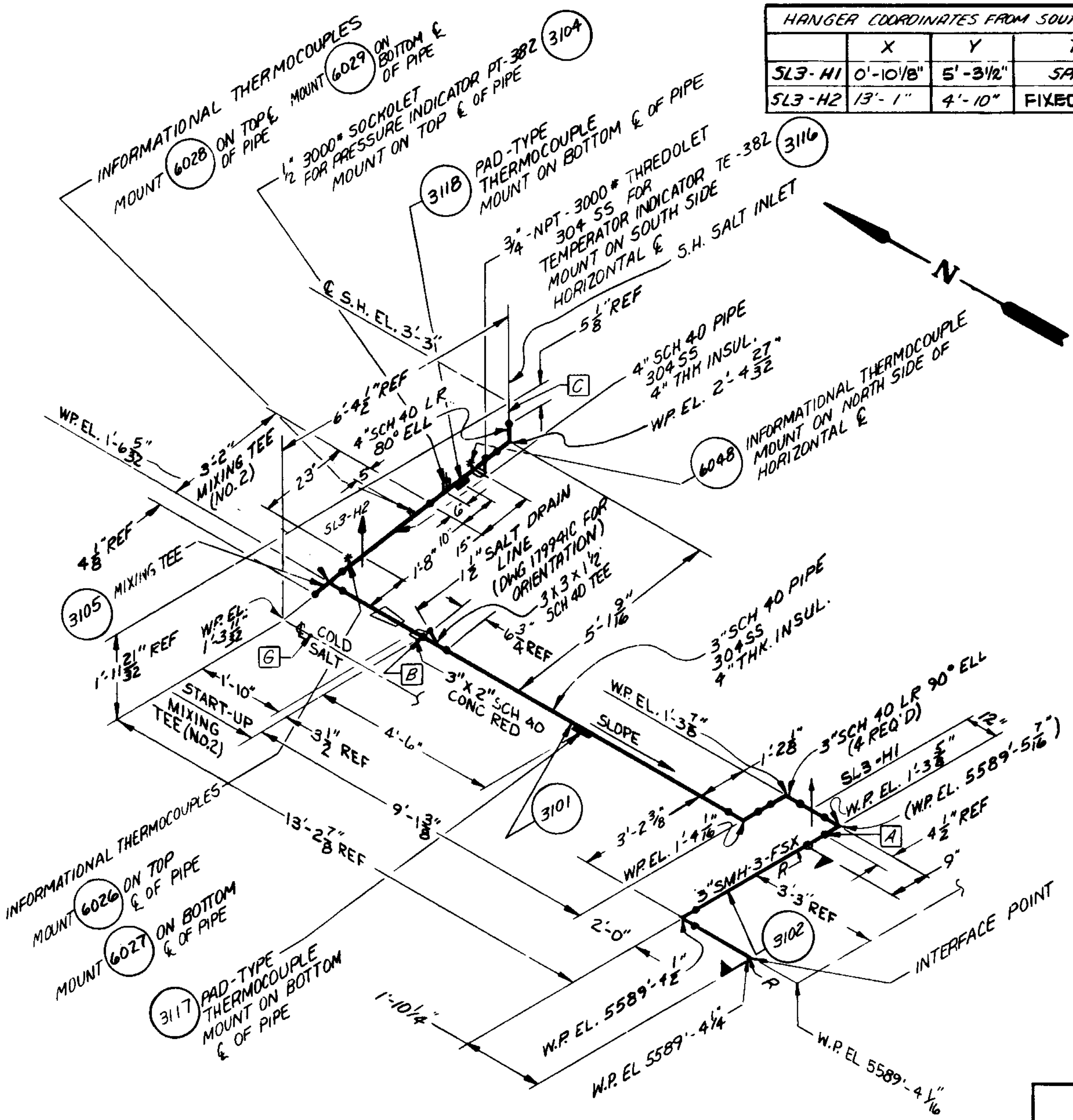
SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN BY W M YOUNG CHKD BY PASSED BY APPVD BY DATE 12/10/82	MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM	THIS DRAWING IS THE PROPERTY OF THE BABCOCK & WILCOX CO. POWER GENERATION GROUP AND IS LOANED UPON CONDITION THAT IT IS NOT TO BE REPRODUCED OR COPIED IN WHOLE OR IN PART, OR USED FOR FURNISHING INFORMATION TO OTHERS, OR FOR ANY OTHER PURPOSE DETRIMENTAL TO THE INTEREST OF THE BABCOCK & WILCOX COMPANY AND WILL BE RETURNED UPON REQUEST.
700-0027-45	STEAM PIPING SUPERHEATER INLET LINE ASSEMBLY-4500/4900	DWG NO 179935C — REV 2
DO NOT SCALE - USE DIMENSIONS ONLY.	SCALE 1/24	

HANGER COORDINATES FROM SOUTH END OF SKID	X	Y	TYPE
SL3-H1	0'-10 1/8"	5'-3 1/2"	SPRING
SL3-H2	13'-1"	4'-10"	FIXED IN Z DIRECT.

REVISIONS

REVISION NO.	DESCRIPTION	DATE	APPROVAL
1	(B & C-3) ADDED SL3-H1 & SL3-H2 (D-2) ADDED HANGER COORDINATES. (C-2) REVISED NOTE #4, PICTORIALLY REVISED SCHEMATIC PICTORIALLY & DIMENSIONS TO SUIT. (B-2) ADDED NOTE #5 & #6. (B & D-4) ADDED INFORMATIONAL THERMOCOUPLES (A-4) & (D-3) ADDED PAD-TYPE THERMOCOUPLES. (D-3) ADDED PRESSURE INDICATORS & TEMPERATURE INDICATOR (B-2) ADDED NOTE #7 & #8. (C-2) ADDED INFORMATIONAL THERMOCOUPLE. (C-1) 1050°F WAS 850°F.	4/29/82	
2	RELOCATED SL3-H1, ADDED REF. #3, REV. HNGR. TYPE (D-2)	4/27/84	VT



NOTES

1. FOR GENERAL NOTES SEE REFERENCE #1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE = 190 PSIA
   PIPING DESIGN TEMPERATURE = 1050°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68° F.
4. SYMBOL DESIGNATION:
   ● - FITTING TERMINALS.
   ▶ - FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. HEAT TRACING:
   TWO - 3112 CABLES TO BE INSTALLED FROM A TO B.
   TWO - 3113 DOUBLE CABLES TO BE INSTALLED FROM B TO G TO C. SEE HEAT TRACING WORKSCOPE B&W SPECIFICATION RLD 700-0027-45-9.
6. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11.
7. HOLES IN PIPING AT THREDOLET AND SOCKOLET FOR INSTRUMENTATION CONNECTIONS TO BE FREE OF BURRS, ETC.
8. INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE-700-0027-45-1.

NO.	TITLE	DWG. NO.
3.	SALT MIXING TEE	405829B
2.	SKID ASSEMBLY SH #1	405331E
1.	PIPING ARRANGEMENT SH #1	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN. BY R WILSON
CHKD. BY
PASSED BY
APPVD. BY
DATE 12-?-80

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

SALT PIPING
HOT SALT INLET LINE
ASSEMBLY - 3100

700-0027-45

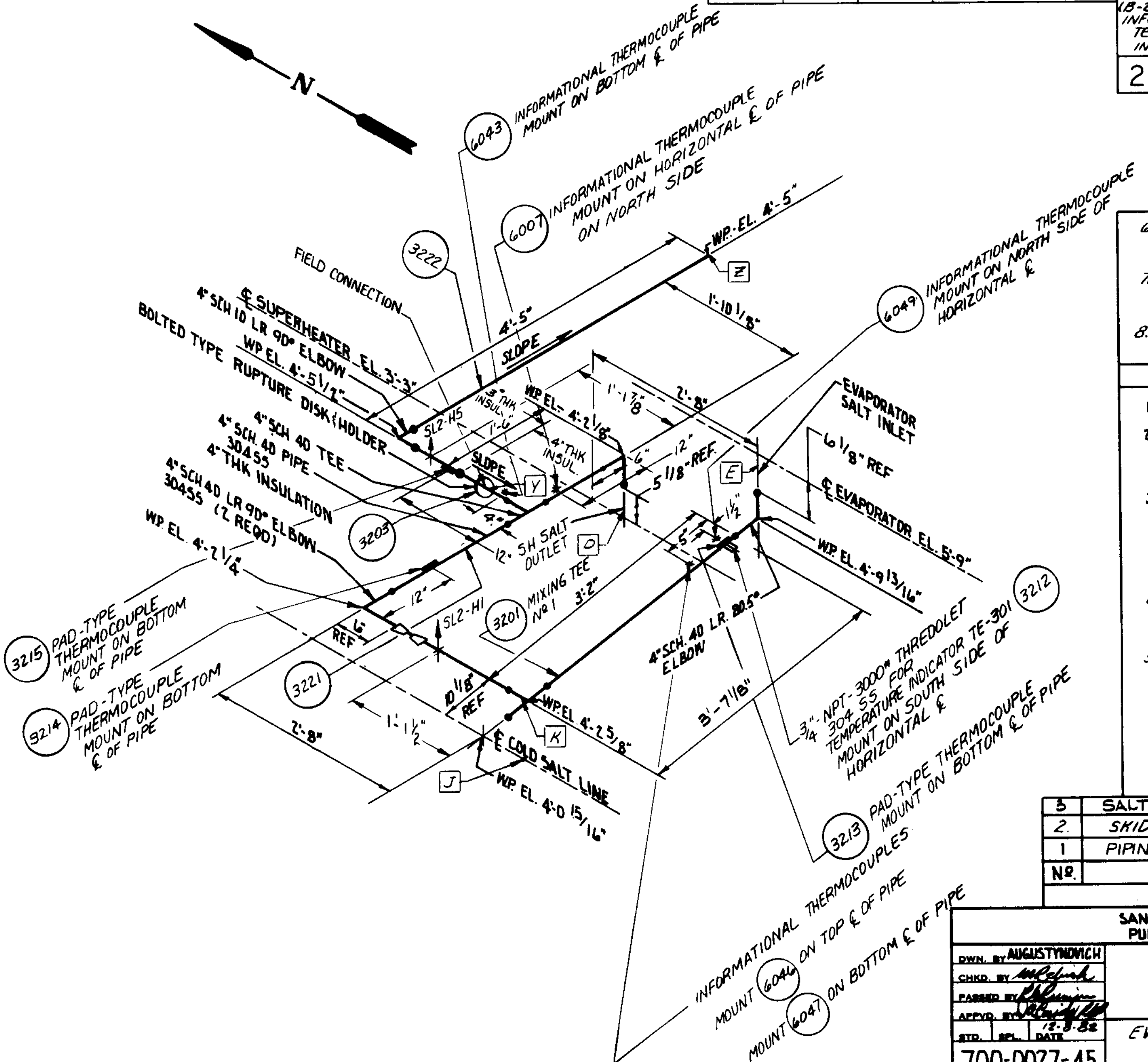
DO NOT SCALE - USE DIMENSIONS ONLY.

SCALE 1/24

DWG. NO. 179936 C
REV. 2

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
SL2-H1	11'-6½"	6'-11½"	SPRING
SL2-H5	14'-2½"	4'-5"	SPRING

REVISIONS			
REVISION NO.	DESCRIPTION	DATE	APPROVAL
1	(C-3) ADDED SL2-H5 (B-3) ADDED SL2-H1 (D-2) ADDED HANGER COORDINATES. (B&C-2) ADDED NOTE #5, #6, #7 & #8. (B-2 & 4) ADDED PAD-TYPE THERMOCOUPLES, (C-3) ADDED INFORMATIONAL THERMOCOUPLE. (B-2) ADDED TEMPERATURE INDICATOR. (A & C-2) ADDED INFORMATIONAL THERMOCOUPLES. NS/MAR	2/23/83	
2	REV. 3201 LENGTH NOW 3'-7⅛" (B-3) ADDED REF. #3.	4/27/84	VT



6. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11.
7. HOLE IN PIPING AT THREDOLET FOR INSTRUMENTATION TO BE FREE OF BURRS, ECT.
8. INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE 700-0027-45-1.

NOTES

1. FOR GENERAL NOTES SEE REF. 1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE: 190 PSIA.
   PIPING DESIGN TEMPERATURE: 900°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   ● - FITTING TERMINALS
5. HEAT TRACING:
   TWO -3208 DOUBLE CABLES TO BE INSTALLED FROM E TO J. TWO -3210 DOUBLE CABLES TO BE INSTALLED FROM K TO O. TWO 3211 DOUBLE CABLES TO BE INSTALLED FROM Y TO Z. SEE HEAT TRACING WORKSCOPE B&W SPECIFICATION RLD-700-0027-45-9.

NO.	TITLE	DWG. NO.
3	SALT MIXING TEE	405329E
2	SKID ASSEMBLY SH #1	405331E
1	PIPING ARRANGEMENT SH #1	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN. BY AUGUSTYNOVICH
CHKD. BY
PASSED BY
APPVD. BY
DATE 12-8-82
STD. SPL.
700-0027-45
DO NOT SCALE - USE DIMENSIONS ONLY.

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

EVAPORATOR SALT INLET LINE ASSEMBLY -3200

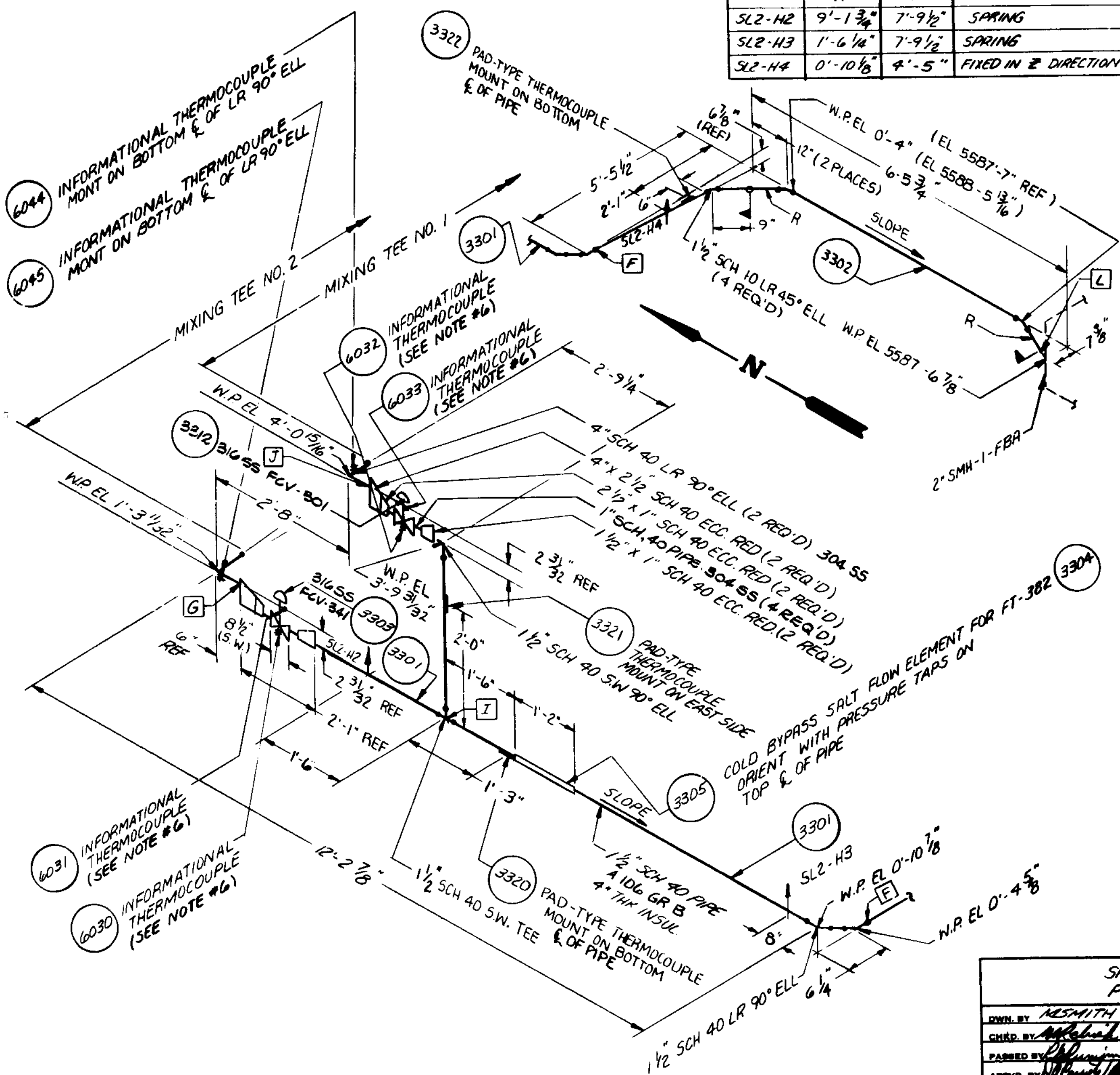
SCALE 1/12

DWG. NO. 179937 C REV. 2

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
SL2-H2	9'-1 3/4"	7'-9 1/2"	SPRING
SL2-H3	1'-6 1/4"	7'-9 1/2"	SPRING
SL2-H4	0'-10 1/8"	4'-5"	FIXED IN Z DIRECTION

REVISIONS

REVISION NO.	DESCRIPTION	DATE	APPROVAL
1	(B-2) ADDED SL2-H3 & SL2-H4, (B-4) ADDED SL2-H2, (D-2) ADDED HANGER COORDINATES. (C-2) REVISED NOTE #4. PICTORIALLY REVISED PIPING SCHEMATIC & DIMENSIONS TO SUIT. (B-2) ADDED NOTE #5 & #6. (A1B-4)(C-3) ADDED INFORMATIONAL THERMOCOUPLE A1B1D-3 ADDED PAD-TYPE THERMOCOUPLES. (C-2) ADDED NOTE #7. (D-4) ADDED INFORMATIONAL THERMOCOUPLES. (A-2) ADDED 1 1/2" SCH 40 LR 45° ELL.	4/29/83	
2	NOTED 1" SCH 40 PIPE NIPPLES, LABELED FCV # & TYPE (SS)	4/27/84	



7. INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE-700-0027-45-1.

NOTES

1. FOR GENERAL NOTES SEE REF #1.
2. DESIGN CONDITION:
   - PIPING DESIGN PRESSURE: 190 PSI
   - PIPING DESIGN TEMPERATURE:
     - < 750°F 1 1/2" LINES TO FCVS
     - > 850°F BEYOND FCVS
3. ALL DIMENSIONS ARE:
   - A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   - B. IN ACCORDANCE WITH ANSI Y14.5-1973
   - C. FOR PART TEMPERATURE OF 68°F
4. SYMBOL DESIGNATION:
   - ● - FITTING TERMINALS
   - ▶ - FIELD WELD
   - R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP
5. HEAT TRACING
   TWO - 3313 CABLES TO BE INSTALLED FROM F TO G. TWO - 3315 CABLES TO BE INSTALLED FROM I TO J. TWO - 3317 CABLES TO BE INSTALLED FROM F TO L. SEE HEAT TRACING WORKSCOPE SPECIFICATION RLD-700-0027-45-9.
6. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11. LOCATION OF THERMOCOUPLES 6030, 6031, 6032 & 6033 IN B&W SPECIFICATION RLD-700-0027-45-11.

NO.	TITLE	DWG NO.
2.	SKID ASSEMBLY SH #1	405331E
1.	PIPING ARRANGEMENT	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

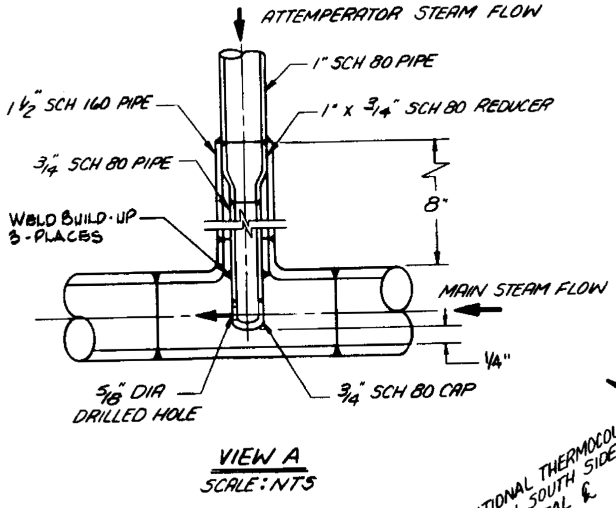
DWN. BY	M SMITH
CHKD. BY	
PASSED BY	
APPVD. BY	
STD. / SPL. / DATE	12-14-82
700-0027-45	
DO NOT SCALE - USE DIMENSIONS ONLY.	

MOLTEN SALT
ELECTRIC EXPERIMENT
STEAM GENERATOR
SUBSYSTEM

SALT PIPING
COLD SALT CONTROL LINES
ASSEMBLY - 3300

SCALE

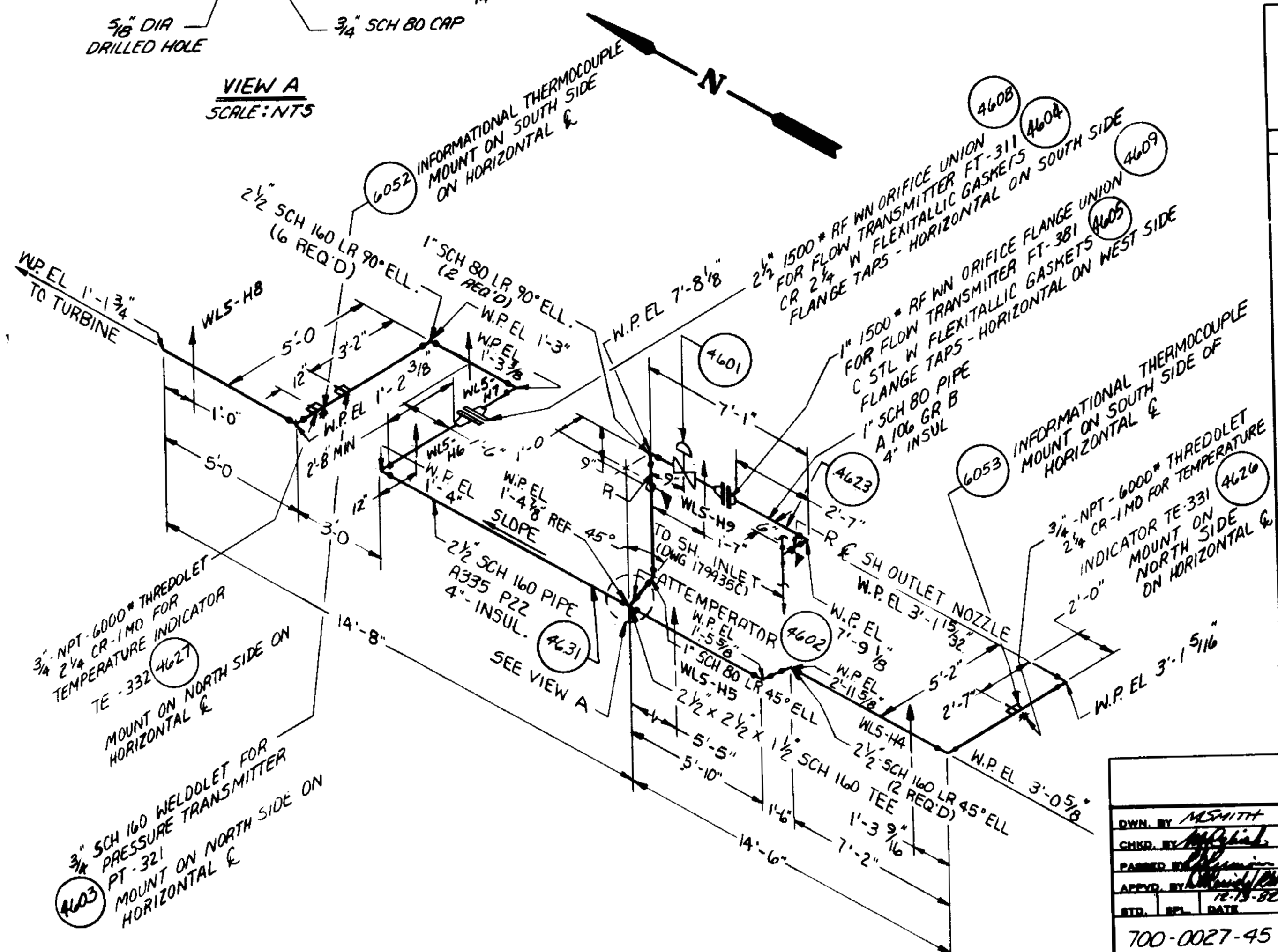
DWG. NO. 179938 C — REV. 2



VIEW A
SCALE: NTS

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
WL5-H4	9'-1 9/16"	6'-7"	FIXED IN Z DIRECTION
WL5-H5	16'-11"	6'-7"	SPRING
WL5-H6	29'-0"	5'-7"	SPRING
WL5-H7	30'-6"	1'-7"	FIXED IN Z DIRECTION
WL5-H8	36'-0"	6'-7"	ANCHOR
WL5-H9	20'-9"	5'-7"	SPRING

REVISIONS			
REVISION NO.	DESCRIPTION	DATE	APPROVALS
1	(B-1) ADDED WL5-H8 & WL5-H6. (B-2) ADDED WL5-H7. (B-3) ADDED WL5-H9 & WL5-H5. (A-3) ADDED WL5-H4. (D-2) ADDED HANGER COORDINATES. (B-2) REVISED NOTE #4. (B-4&2) ADDED TEMPERATURE INDICATOR. (A-4) ADDED PRESSURE TRANSMITTER (C-2) ADDED FLOW TRANSMITTER. ADDED NOTE 5. (B-2)&(C-3) ADDED INFORMATIONAL THERMOCOUPLES (C-1) ADDED NOTE #6 & #7 ADDED (2) 2 1/2" SCH 160 LR 45° ELL. REVISED LOCATION OF ATTEMPERATOR & DIMENSIONS TO SUIT.	4/1/83	
2	CHANGED DIMENSION OF WL5-H5 TO 5'-5", ADDED WELD BUILD-UP NOTE IN VIEW A, 1/4"	4/12/84	VT



6. THE INSULATION SHALL BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE-700-0027-45-1.
7. HOLES IN PIPING AT THREDOLETS AND WELDOLETS TO BE FREE OF BURRS, ECT.

NOTES

1. FOR GENERAL NOTES SEE REF #1.
2. DESIGN CONDITIONS:
   - PIPING DESIGN PRESSURE: 1325 PSI
   - PIPING DESIGN TEMPERATURE: 1000°F
3. ALL DIMENSIONS ARE:
   - A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   - B. IN ACCORDANCE WITH ANSI Y14.5-1973
   - C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   - ● - FITTING TERMINALS
   - ▶ - FIELD WELD
   - R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11.

NO.	TITLE	DWG NO.
2.	SKID ASSEMBLY SH #1	405331E
1.	PIPING ARRANGEMENT SH #1	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN. BY	M SMITH
CHKD. BY	
PASSED BY	
APPVD. BY	
STD. / SPL. / DATE	12-13-82
	700-0027-45

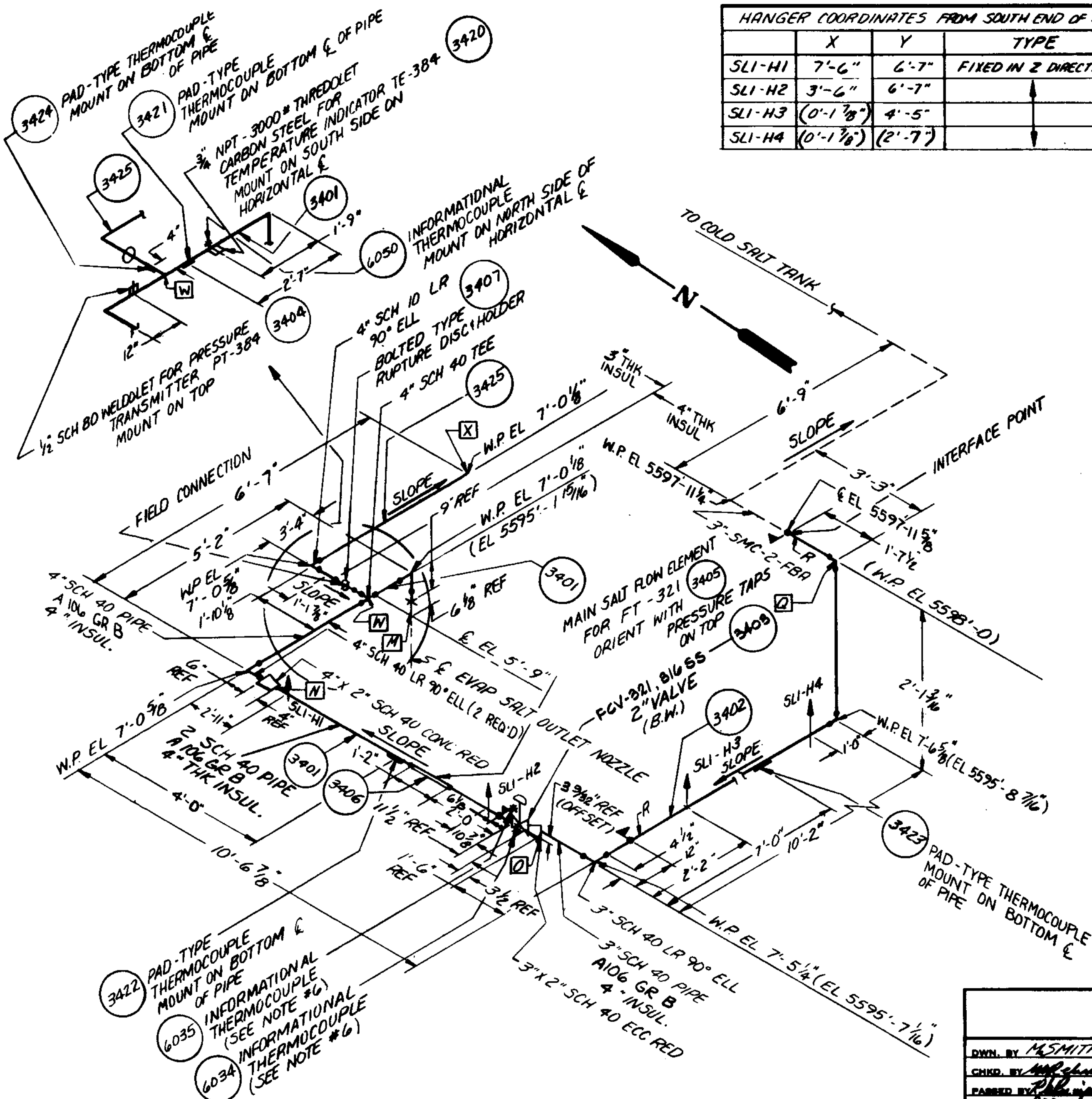
MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM
STEAM PIPING SUPERHEATER STEAM OUTLET & ATTEMPERATOR LINES ASSEMBLY - 4600

DWG. NO. 179939 C
REV. 2

DO NOT SCALE - USE DIMENSIONS ONLY.
SCALE NTS

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
SLI-H1	7'-6"	6'-7"	FIXED IN Z DIRECTION
SLI-H2	3'-6"	6'-7"	↕
SLI-H3	(0'-1 7/8")	4'-5"	↕
SLI-H4	(0'-1 7/8")	(2'-7")	↕

REVISIONS			
REVISION NO.	DESCRIPTION	DATE	APPROVAL
1	(B-3) ADDED SLI-H2 & SLI-H3, (B-2) ADDED SLI-H4, (C-4) ADDED SLI-H5, (B-4) ADDED SLI-H1, (D-2) ADDED HANGER COORDINATES (B-2) REVISED NOTE #4, PICTORIALLY REVISED PIPING SCHEMATIC & DIMENSIONS TO SUIT. (C-2) ADDED NOTE #6, (B-2) ADDED NOTE #5, (A-4) ADDED INFORMATIONAL THERMOCOUPLES (A & D-4) & (A-2) ADDED PAD-TYPE THERMOCOUPLES, (C & D-4) ADDED PRESSURE TRANSMITTER & TEMPERATURE INDICATOR. (C-2) ADDED NOTE #7 & 8, (D-3) ADDED INFORMATIONAL THERMOCOUPLE. MS/	3/22/83	
2	ADDED FIELD WELD LINE 3401, ADDED MAT'L TYPE TO VA. 3403, REMOVED SLI-H5 (C-4)	4/27/84	VTJ



6. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11. LOCATIONS OF THERMOCOUPLES 6034 AND 6035 IN B&W SPECIFICATION RLD-700-0027-45-11.
7. HOLES IN PIPING AT WELDOLET AND THREDOLET FOR INSTRUMENTATION TO BE FREE OF BURRS, ETC.
8. INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE-700-0027-45-1.

NOTES

1. FOR GENERAL NOTES SEE REF #1.
2. DESIGN CONDITION:
   PIPING DESIGN PRESSURE: 190 PSI
   PIPING DESIGN TEMPERATURE: 750°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   ● - FITTING TERMINALS
   ▶ - FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. FOUR-3412 CABLES TO BE INSTALLED FROM M TO W. TWO-3413 CABLES TO BE INSTALLED FROM W TO Q. TWO-3414 CABLES TO BE INSTALLED FROM Q TO Q. TWO 3418 TO BE INSTALLED FROM W TO X. SEE HEAT TRACING WORKSCOPE B&W SPECIFICATION RLD-700-0027-45-9.

NO.	TITLE	DWG NO.
2.	SKID ASSEMBLY SH #1	405331E
1.	PIPING ARRANGEMENT SH #1	405340E

REFERENCES

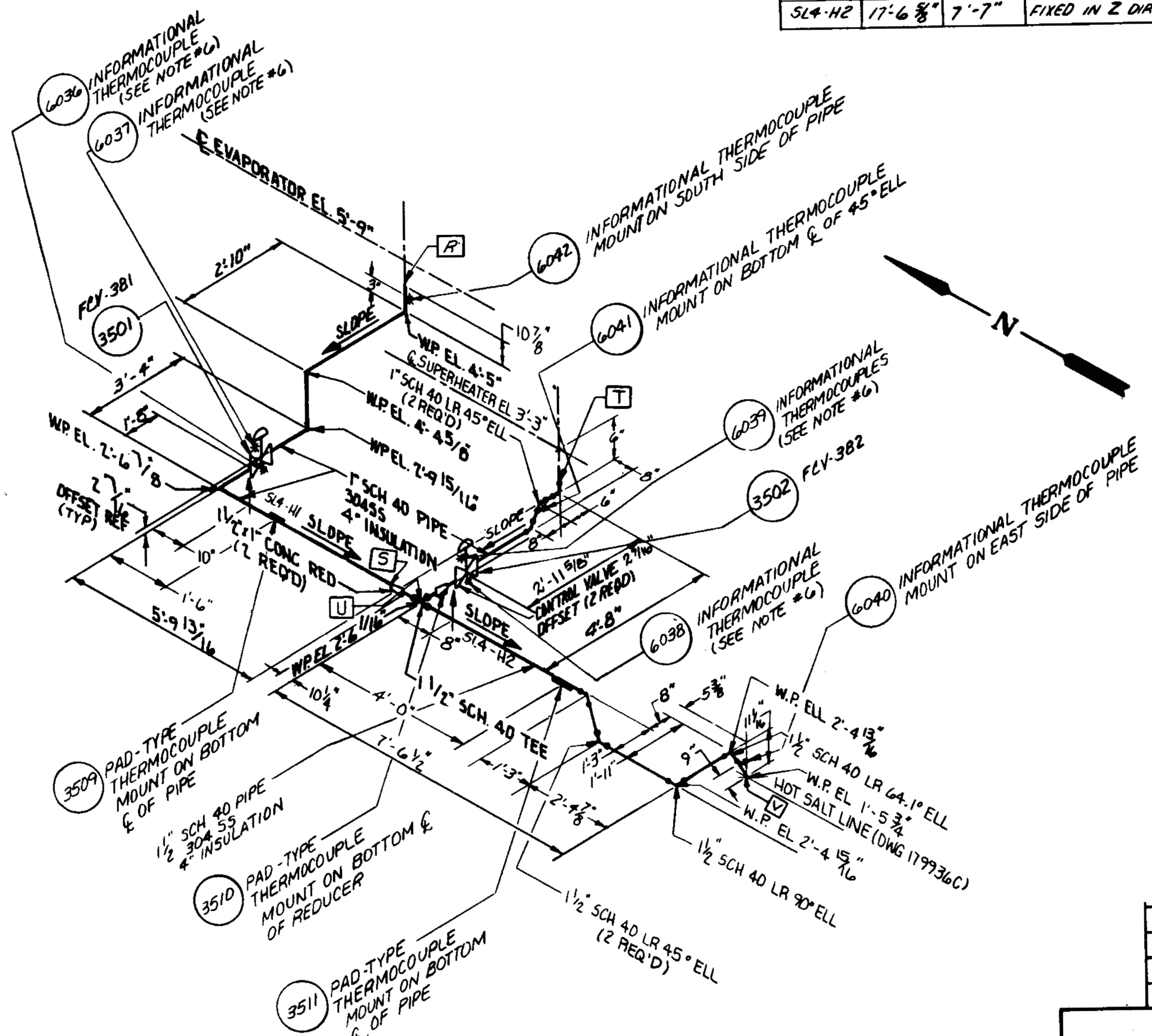
SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN. BY M SMITH	MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM
CHKD. BY	
PASSED BY	
APPVD. BY	DATE 12-18-82
STD. / SPL.	EVAPORATOR SALT OUTLET & OVERPRESSURE LINES ASSEMBLY-3400
700-0027-45	DWG. NO. 179940 C — REV. 2
DO NOT SCALE - USE DIMENSIONS ONLY.	SCALE NTS

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
SL4-H1	23'-10 7/16	7'-7"	FIXED IN Z DIRECTION
SL4-H2	17'-6 3/8"	7'-7"	FIXED IN Z DIRECTION

REVISIONS

REVISION NO.	DESCRIPTION	DATE	APPROVAL
1	(B-3) ADDED SL3-H2 (C-4) ADDED (D-2) ADDED HANGER COORDINATES. (B-2) REVISED NOTE #4. (C-2) ADDED NOTE 5 & 6. (C & B-3) & (D-4) ADDED INFORMATIONAL THERMOCOUPLES (B & A-4) ADDED PAD TYPE THERMOCOUPLE (C-3) 10 7/8" WAS 14 3/8" REF. (C-2) ADDED NOTE #7 & 8. (B-3) ADDED 1 1/2" SCH 40 LR 64.1° ELL, 1 1/2" SCH 40 LR 45° ELL & INFORMATIONAL THERMOCOUPLE. (C-3) ADDED INFORMATIONAL THERMOCOUPLE REVISED PICTORIALLY WITH DIMENSIONS TO SUIT.	8/23/83	
2	ADDED C.VA. OFFSET SIZE (2'/16") ADDED [V] TO HEAT TRACING CHANGED DIM. LOCATION OF 3502	4/27/84	



6. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11.
7. INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE-700-0027-45-1.
8. LOCATION OF THERMOCOUPLES 6036, 6037, 6038 & 6039 IN B&W SPECIFICATION RLD-700-0027-45-11.

NOTES

1. FOR GENERAL NOTES SEE REF 1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE: 190 PSIA.
   PIPING DESIGN TEMPERATURE: 900°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   ● - FITTING TERMINAL
   ▶ - FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. HEAT TRACING:
   TWO - 3505 CABLES TO BE INSTALLED FROM [R] TO [S]. TWO - 3506 CABLES TO BE INSTALLED FROM [U] TO [T]. TWO - 3507 CABLES TO BE INSTALLED FROM [S] TO [V]. SEE HEAT TRACING WORKSCOPE B&W SPECIFICATION RLD 700-0027-45-9.

2	SKID ASSEMBLY SH #1	405331E
1	PIPING ARRANGEMENT SH #1	405340E
NO.	TITLE	DWG. NO.

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500.

DWN. BY AUGUSTYNOVICH
CHKD. BY
PASSED BY
APPVD. BY
DATE 12-3-82

700-0027-45

DO NOT SCALE - USE DIMENSIONS ONLY.

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

SALT PIPING
SALT DRAIN LINES
ASSEMBLY - 3500

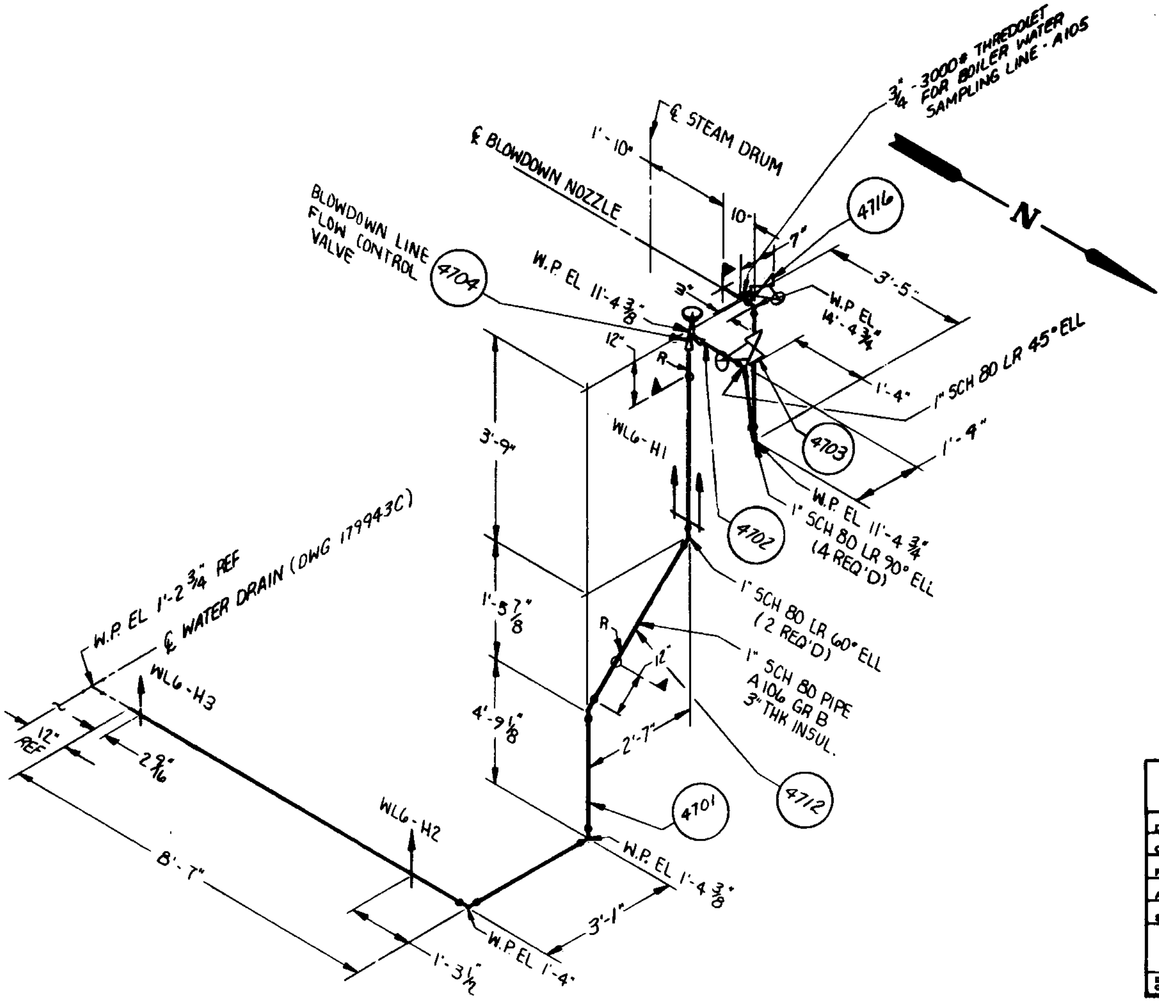
SCALE 1/24

DWG. NO. 179941 C REV. 2

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
WL6-H1	17'-6"	7'-11"	SPRING
WL6-H2	16'-2½"	2'-3"	FIXED IN Z DIRECTION
WL6-H3	9'-1 9/16"	2'-3"	FIXED IN Z DIRECTION

REVISIONS

REVISION NO.	DESCRIPTION	DATE	APPROVAL
1	(C-2) REVISED NOTE #2, (B-2) ADDED NOTE #5, (D-2) ADDED ¾"-3000# THREDOLET, (C-3) ADDED VALVE 4716, (B-3) ADDED 4712. REVISED PICTORIALLY, DIMENSIONS TO SUIT	3/4/83	



NOTES

1. FOR GENERAL NOTES SEE REF #1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE: 1400 PSI
   PIPING DESIGN TEMPERATURE: 600°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   ● - FITTING TERMINALS
   ⚑ - FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE-700-0027-45-1.

NO.	TITLE	DWG NO.
2.	SKID ASSEMBLY SH #1	405331E
1.	PIPING ARRANGEMENT	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO 81-500

DWN. BY	M SMITH
CHKD. BY	
PASSED BY	
APPVD. BY	
STD. / SPL. / DATE	2-8-83

700-0027-45

DO NOT SCALE - USE DIMENSIONS ONLY.

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

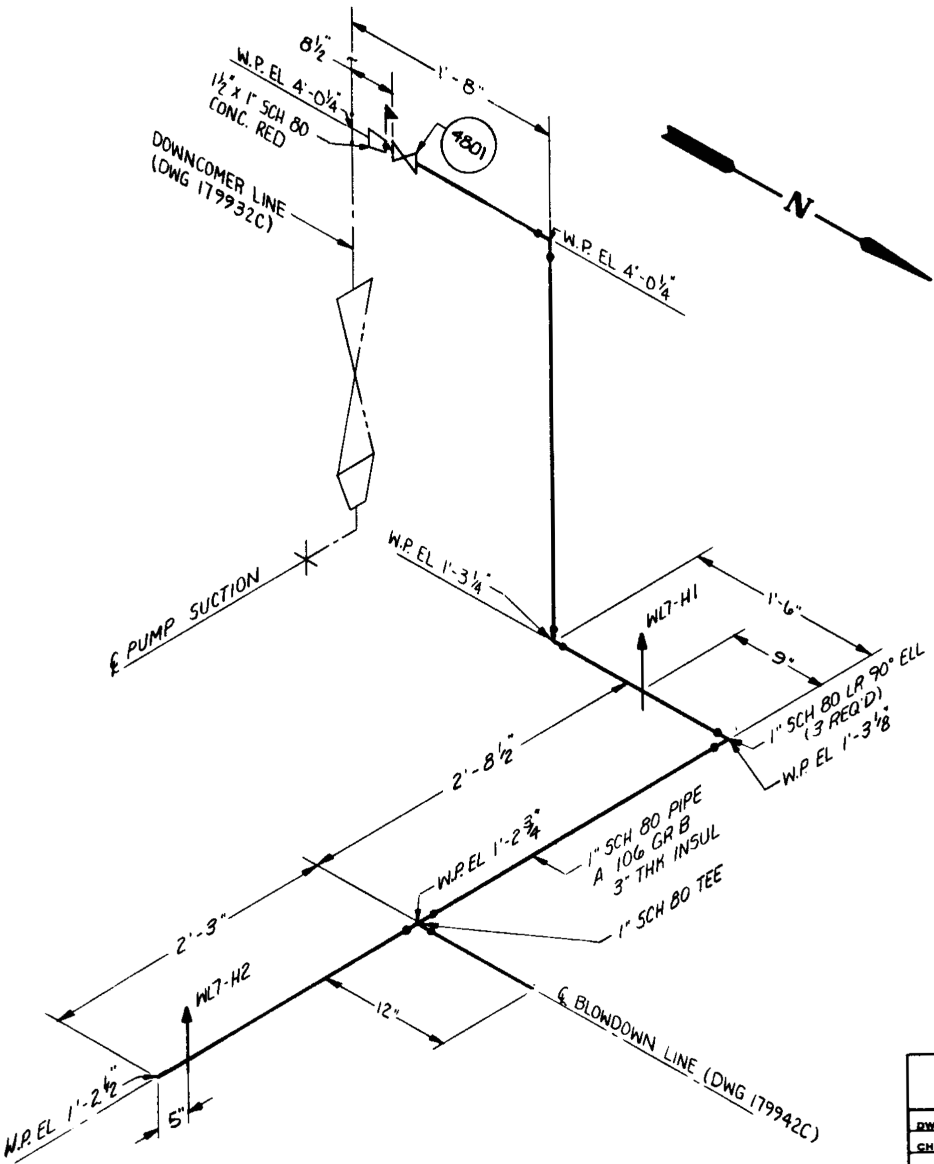
STEAM PIPING BLOWDOWN LINE ASSEMBLY - 4700

SCALE ½" = 1'-0"

DWG. NO. 179942 C REV. 1

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
WL7-H1	7'-2"	4'-11½"	FIXED IN Z DIRECTION
WL7-H2	7'-11"	0'-5"	ANCHOR

REVISIONS			
REVISION NO	DESCRIPTION	DATE	APPROVAL
1	CHANGED DIMENSION TO 5" FOR LOCATION OF WL7-H2 (A-4)	4/27/84	VTX



NOTES

1. FOR GENERAL NOTES SEE REF #1.
2. DESIGN CONDITION:
   PIPING DESIGN PRESSURE: 1325 PSI
   PIPING DESIGN TEMPERATURE: 566° F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68° F.
4. SYMBOL DESIGNATION:
   ● - FITTING TERMINAL
   ▶ - FIELD WELD

NO.	TITLE	DWG NO.
2.	SKID ASSEMBLY SH #1	405331E
1.	PIPING ARRANGEMENT	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN. BY M.SMITH
CHKD. BY
PASSED BY
APPVD. BY
DATE 2-8-83
STD. SPL.
700-0027-45
DO NOT SCALE - USE DIMENSIONS ONLY.

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

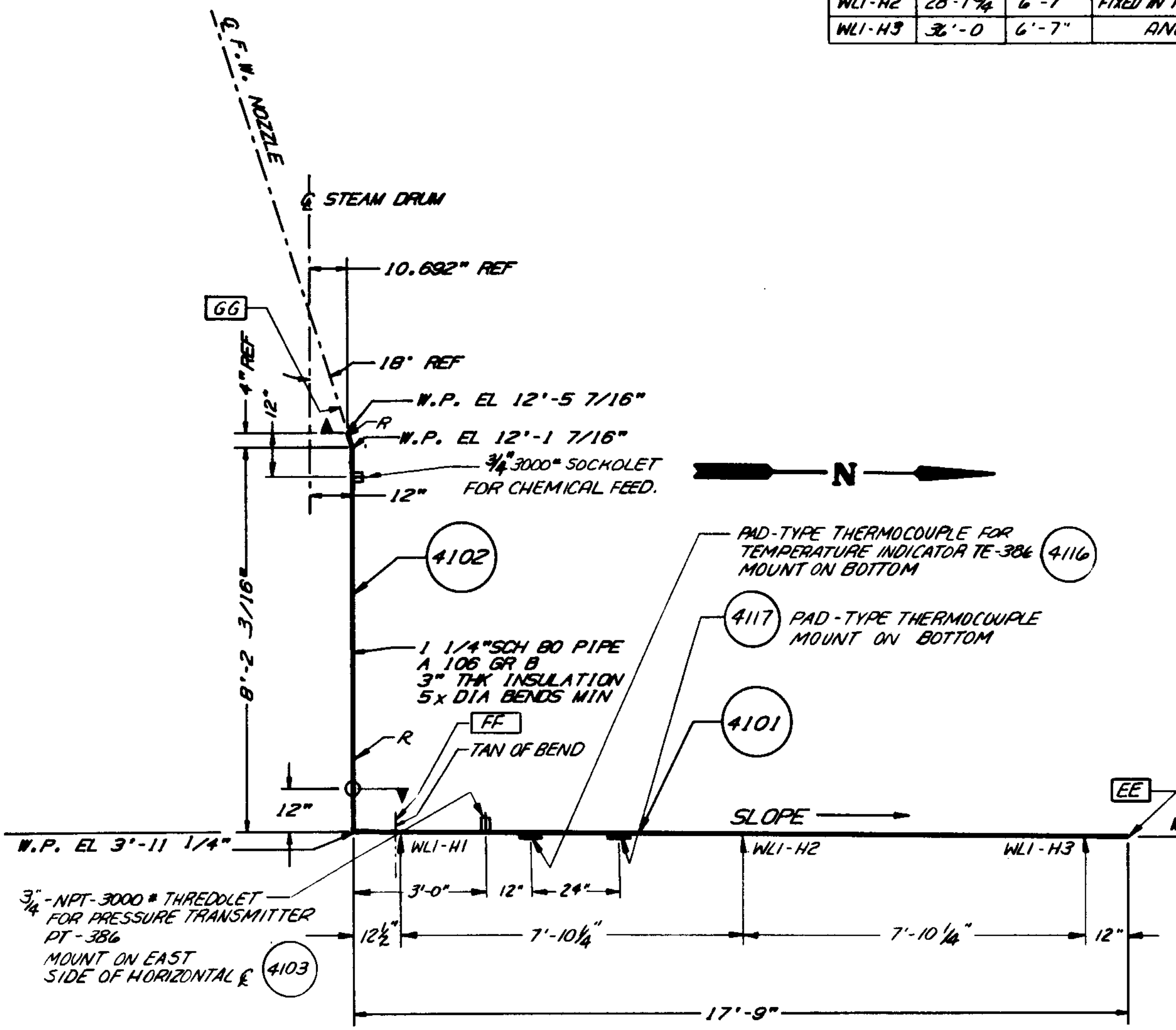
STEAM PIPING WATER DRAIN ASSEMBLY - 4800

SCALE ¾" = 1'-0"

DWG. NO. 179943 C REV. 1

HANGER COORDINATES FROM SOUTH END OF SKID			
	X	Y	TYPE
WL1-H1	20'-3½"	6'-7"	SPRING
WL1-H2	28'-1¾"	6'-7"	FIXED IN Y & Z DIRECTION
WL1-H3	36'-0	6'-7"	ANCHOR

REVISIONS				
REV. NO.	DESCRIPTION	DATE	APPROVAL &	
1	(C-2) ADDED WL1-H1 & WL1-H2, (C-3) ADDED WL1-H3, (A-3) ADDED HANGER COORDINATES. B-2 REVISED NOTE #4 ADDED ¾ 3000# SOCKOLET. ADDED NOTE #5, #6 & #7. (C-1) ADDED PRESSURE TRANSMITTER. (B & C-3) ADDED PAD-TYPE THERMOCOUPLES. (B-3) ADDED NOTE #8.	7/28/86		



NOTES

1. FOR GENERAL NOTES SEE REFERENCE #1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE: 1400 PSIA
   PIPING DESIGN TEMPERATURE: 600°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   O - FITTING TERMINALS.
   ▶ - FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. HEAT TRACING:
   TWO 4113 CABLES TO BE INSTALLED FROM EE TO GG. SEE HEAT TRACING WORKSCOPE B&W SPECIFICATION RLD-700-0027-45-9.
6. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11.
7. HOLE IN PIPING AT THREDOLET FOR INSTRUMENTATION CONNECTION TO BE FREE OF BURRS, ETC.
8. INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE-700-0027-45-1.

NO.	TITLE	DWG. NO.
2	SKID ASSEMBLY SHEET #1	405331E
1	PIPING ARRANGEMENT SHEET #1	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN BY W M YOUNG
CHKD BY
PASSED BY
APPVD BY
DATE 12/10/86

700-0027-45

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

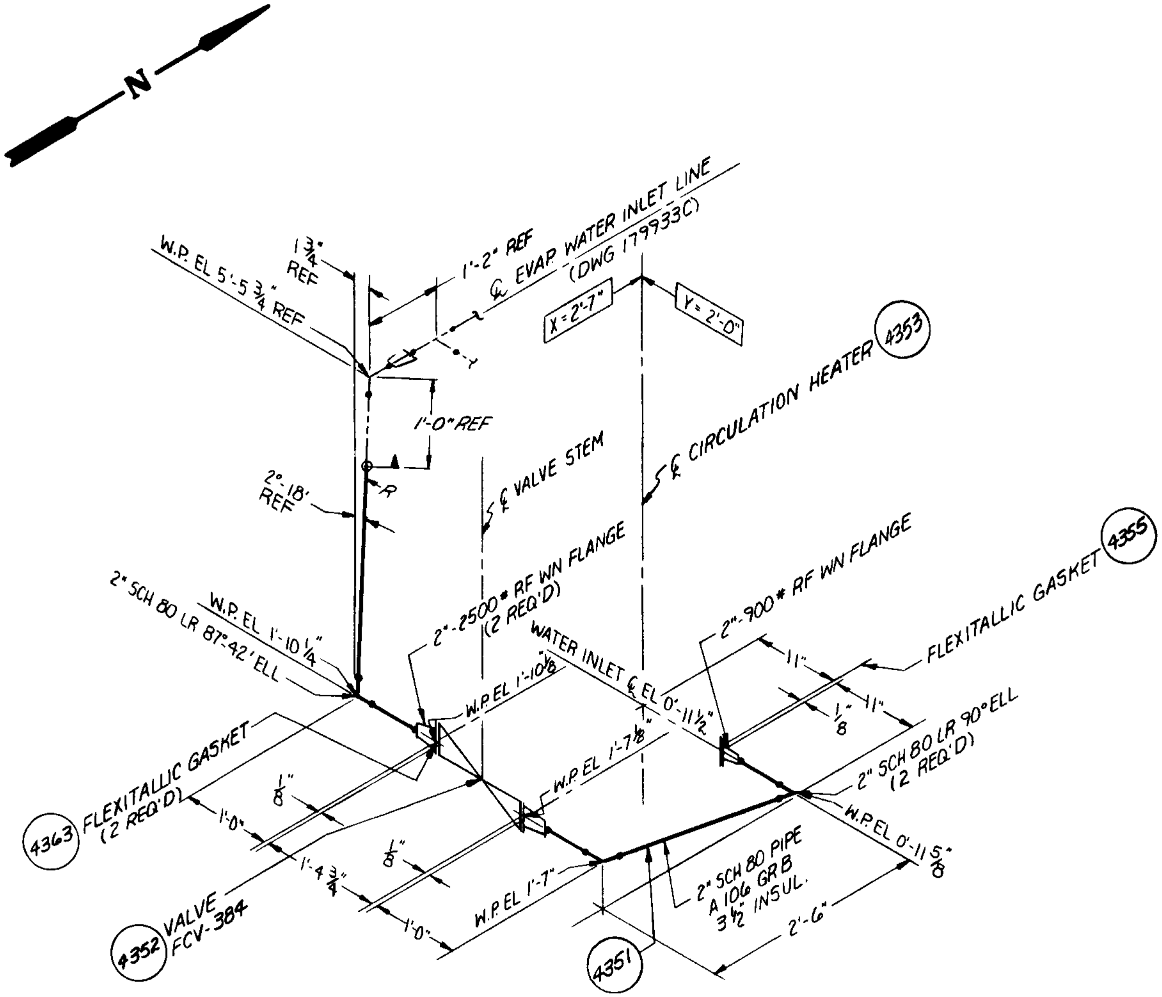
STEAM PIPING FEEDWATER LINE ASSEMBLY - 4100

SCALE 1/24

DWG NO 179944C

REV 1

REVISIONS				
REV. NO.	DESCRIPTION	DATE	APPROVALS	D F



NOTES

1. FOR GENERAL NOTES SEE REFERENCE #1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE = 1400 PSIA
   PIPING DESIGN TEMPERATURE = 600°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   O - FITTING TERMINALS.
   ⚑ - FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. THE INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE 700-0027-45-1.

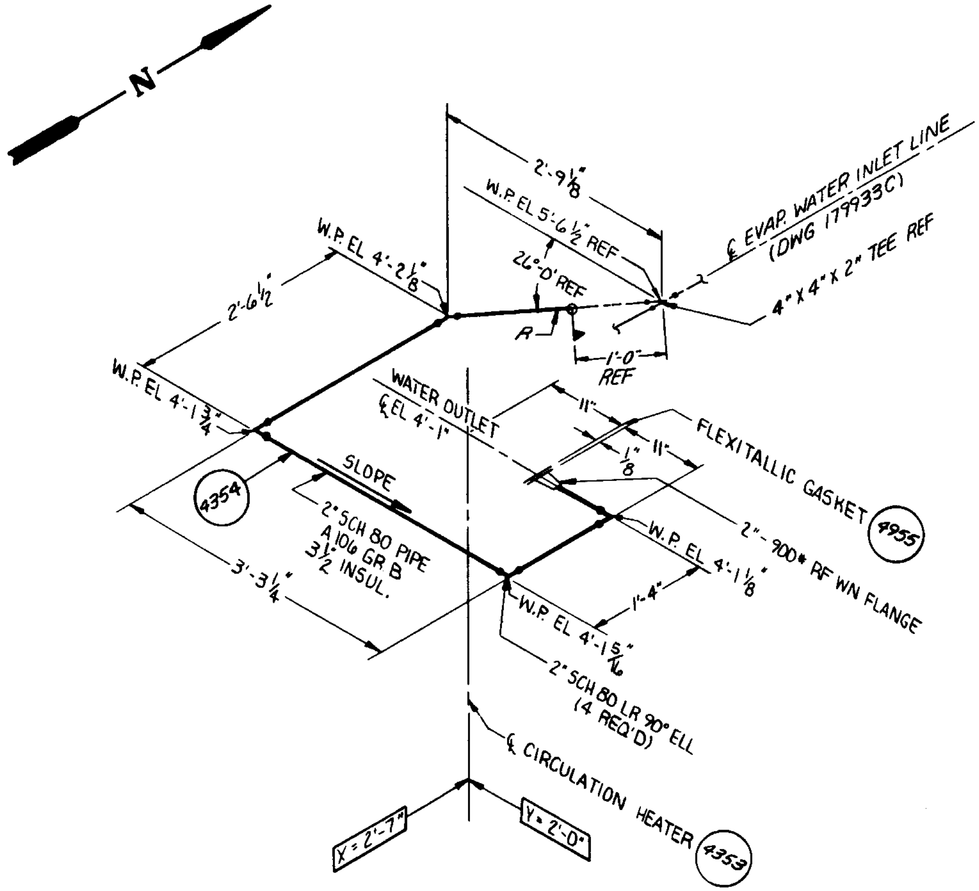
NO.	TITLE	DWG. NO.
2	SKID ASSEMBLY SHEET #1	405331E
1	PIPING ARRANGEMENT SHEET #1	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN BY M.Q.SMITH CHKD BY [signature] PASSED BY [signature] APPVD BY D.A.Smith STD SPL DATE 3/15/83	MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM	THIS DRAWING IS THE PROPERTY OF THE BABCOCK & WILCOX CO. POWER GENERATION GROUP AND IS LOANED UPON CONDITION THAT IT IS NOT TO BE REPRODUCED OR COPIED IN WHOLE OR IN PART, OR USED FOR FURNISHING INFORMATION TO OTHERS, OR FOR ANY OTHER PURPOSE DETRIMENTAL TO THE INTEREST OF THE BABCOCK & WILCOX COMPANY AND WILL BE RETURNED UPON REQUEST.
700-0027-45	CIRCULATION HEATER PIPING INLET ASSEMBLY 4350-SHT 1 OF 2	DWG NO 179945C — REV 0
DO NOT SCALE - USE DIMENSIONS ONLY.	SCALE 1/24	

REVISIONS				
REV. NO.	DESCRIPTION	DATE	APPROVAL	D F



NOTES

1. FOR GENERAL NOTES SEE REFERENCE #1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE = 1400 PSIA
   PIPING DESIGN TEMPERATURE = 600°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE OF 68°F.
4. SYMBOL DESIGNATION:
   O - FITTING TERMINALS.
   ▼ - FIELD WELD
   R - ADD 12" RANDOM LENGTH TO ALLOW FOR FIELD FITUP.
5. THE INSULATION TO BE INSTALLED IN ACCORDANCE WITH B&W SPECIFICATION DAE 700-0027-45-1.

NO.	TITLE	DWG. NO.
2	SKID ASSEMBLY SHEET #1	405331E
1	PIPING ARRANGEMENT SHEET #1	405340E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN BY M SMITH
CHKD BY
PASSED BY
APPVD BY
STD | SPL | DATE 3/15/83

700-0027-45

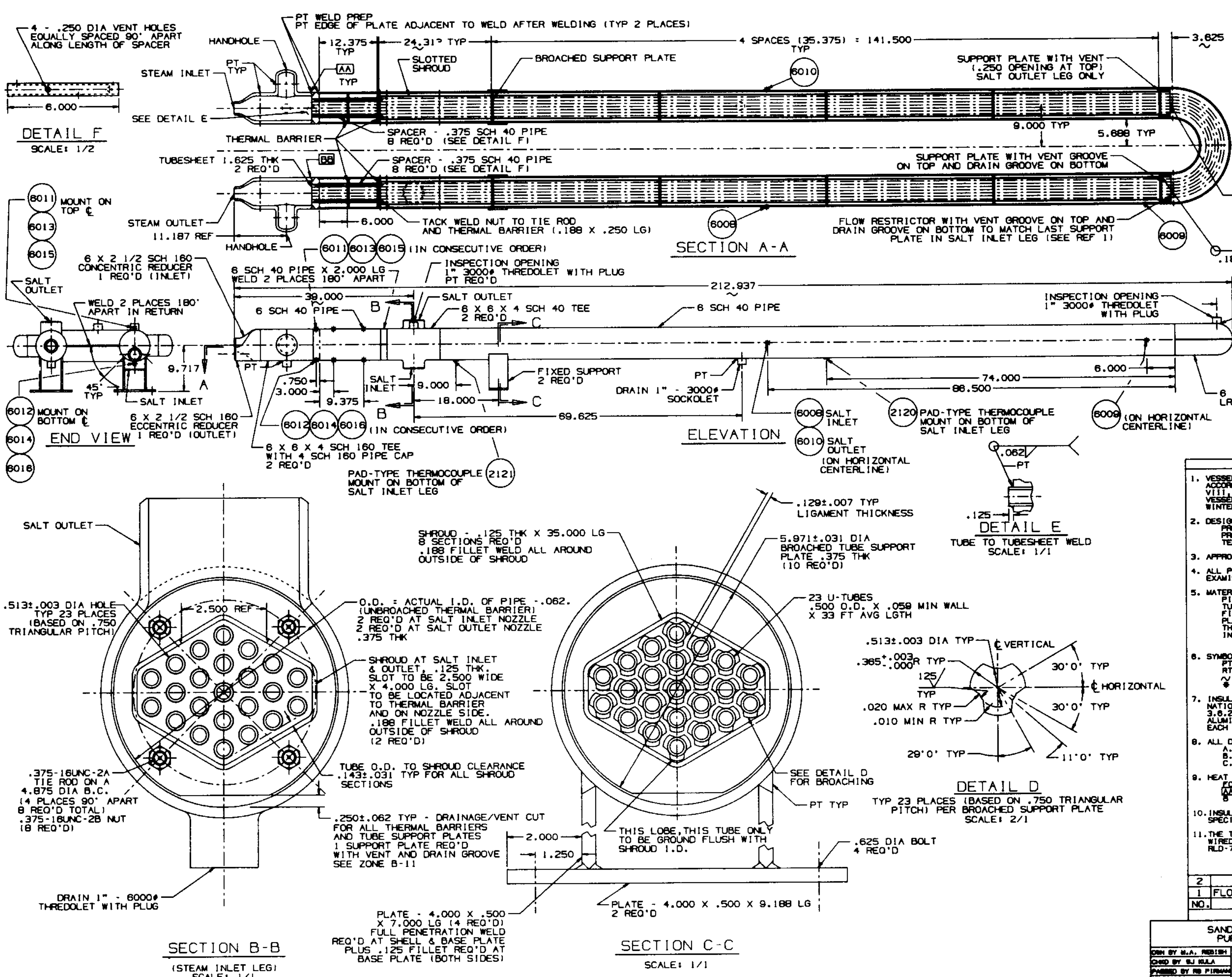
DO NOT SCALE - USE DIMENSIONS ONLY.

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

CIRCULATION HEATER PIPING OUTLET
ASSEMBLY 4350 - SHT 2 OF 2

SCALE 1/24

DWG NO 179946C | REV 0



REVISIONS

	DESCRIPTION	DATE	APPROVAL
1	ADDED: (C-4) 8 SCH 40 X 2.000 PIPE; (D-3) DRAIN; (A,C-10) FLOW RESTRICTOR REDESIGN; NOTE 8 REF; (B-3) 11.187 DIM. REVISED; NDE REQUIREMENTS; THERMAL BARRIERS & SUPPORT PLATES FOR VENT/DRAIN GROOVES; (F-4) O.D. NOTE FOR THERMAL BARRIER; NOTES 3 THRU 7; VESSEL SUPPORTS; DETAIL E. DELETED TOLERANCE BLOCK & ADDED TOLERANCES WHERE REQ'D. MAR/WMY		RB PIRMAN
2	ADDED: ALL THERMOCOUPLES; NOTES 9, 10 & 11; (1-12) ASSEMBLY-2100; (E-7) .129±.007 TYP DIM. (A-4) DELETED RT TYP. REVISED NOTE 6. MAR/WMY		
3	RELOCATED 6011 THRU 6016 IN ZONES B&C-2		

NOTES

1. VESSEL TO BE DESIGNED AND FABRICATED IN ACCORDANCE WITH THE REQUIREMENTS OF SECTION VIII, DIVISION 1 OF THE ASME BOILER & PRESSURE VESSEL CODE, 1980 EDITION & ADDENDA THROUGH WINTER 1981.
2. DESIGN CONDITIONS:
   PRESSURE TUBE-SIDE = 1325 PSIA
   PRESSURE SHELL-SIDE = 190 PSIA
   TEMPERATURE = 1075°F
3. APPROXIMATE DRY WEIGHT = 1400 LBS.
4. ALL PRESSURE BOUNDARY WELDS TO BE VISUALLY EXAMINED IN ADDITION TO THE NDE AS NOTED.
5. MATERIALS:
   PIPE - SA 312, TYP 304 (SST)
   TUBE - SA 213, TYP 304 (SST)
   FITTINGS - SA 403, WP 304
   PLATE - A240, TYP 304 (SST)
   THREDOLET, SOCKOLET - SA 182, F 304
   INSULATION - 5" THK CALCIUM SILICATE W/ALUMINUM JACKET (.016" THK)
6. SYMBOL DESIGNATION:
   PT - LIQUID PENETRANT INSPECTION
   RT - RADIOGRAPH INSPECTION
   ∿ - OUT OF SCALE DIMENSION
   ◉ - INFORMATIONAL THERMOCOUPLE
7. INSULATION SHALL BE IN ACCORDANCE WITH SANDIA NATIONAL LABORATORY DOCUMENT #81-5100, PARA. 3.6.2. INSULATION PLUGS WITH REMOVABLE ALUMINUM JACKET COVERS SHALL BE PROVIDED AT EACH INSPECTION AND DRAIN WITH PLUG OPENING.
8. ALL DIMENSIONS ARE IN INCHES AND:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED
   B. IN ACCORDANCE WITH ANSI Y14.5-1973
   C. FOR PART TEMPERATURE OF 68°F
9. HEAT TRACING:
   FOUR 2203 CABLES TO BE INSTALLED FROM AA TO BB. SEE HEAT TRACING WORKSCOPE B & W SPECIFICATION RLD-700-0027-45-9
10. INSULATION TO BE INSTALLED ACCORDING TO B&W SPECIFICATION DAE-700-0027-45-1.
11. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11.

REFERENCES

NO.	TITLE	DWG. NO.
2		
1	FLOW RESTRICTOR	405334E

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DRN BY M.A. REDISH
CHKD BY BJ KULA
PASSED BY RB PIRMAN

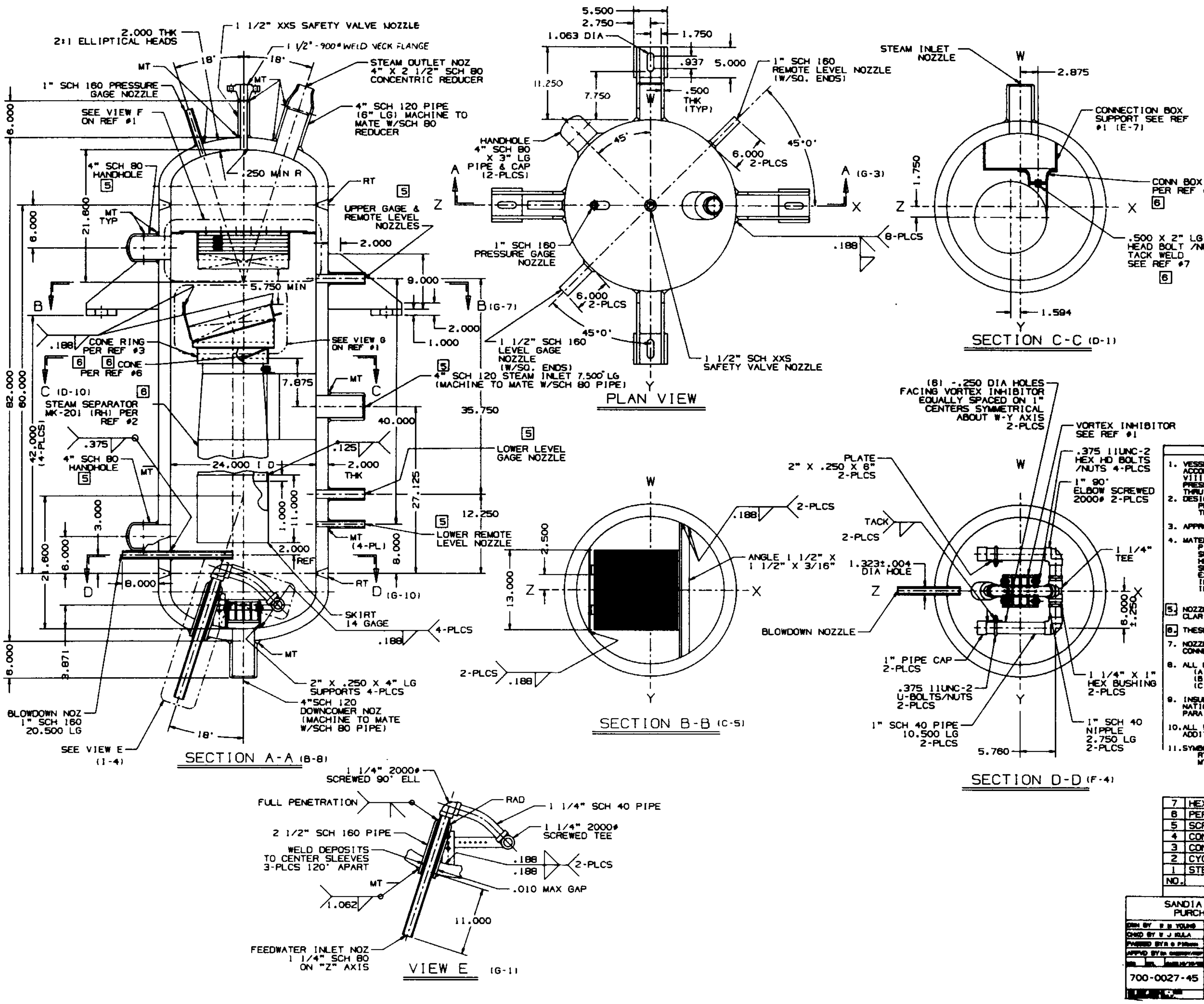
MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

700-0027-45

SUPERHEATER
ASSEMBLY-2100

SCALE 1/8

DWG NO 405325 E REV 3



REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL
1	REVISED NOTE #4. ADDED NOTES #9, 10 & 11. (A-7) ADDED .500 THK (TYP). (B-7) ROTATED NOZ FROM 30° TO 45°. (C-8&7) MOVED NOZ FROM 30° OFF "X" AXIS TO 45° BETWEEN "Y"-"Z" AXIS. 6.000 WAS 16.000. IN SECTION A-A ADDED SYMBOL DESIGNATIONS MT AND RT TO ALL WELDS. (D-4) 40.000 WAS 33.000. (D&E-5) ADDED DIM'S 12.250 & 35.750 AND MOVED UPPER GAGE & REMOTE LEVEL NOZZLES. (D-3) ADDED DIM 7.875. (B-3 ADDED .250 MIN RAD. (A-2) DELETED "HOLD". REDESIGNED FEEDWATER INLET NOZZLE (F-3 & 10 AND H-5).	[illegible]	[illegible]
2	(A-6) 11.250" WAS 12.000", 7.750" WAS 8.000"; (D-6) 7.5" WAS 6"; (A-3) ADDED 1 1/2" - 900# WELD NECK FLANGE (I-12) ADDED ASSEMBLY-2300.	[illegible]	[illegible]
3	REVISED NOTE #4. ADDED WORD "NOZZLE" TO SAFETY VALVE NOTE (SECTION A-A)	[illegible]	[illegible]

NOTES

1. VESSEL TO BE DESIGNED AND FABRICATED IN ACCORDANCE WITH THE REQUIREMENTS OF SECTION VIII, DIVISION 1, OF THE ASME BOILER AND PRESSURE VESSEL CODE, 1980 EDITION & ADDENDA THRU WINTER 1981.
2. DESIGN CONDITIONS:
   PRESSURE = 1325 PSIA
   TEMPERATURE = 600°F
3. APPROXIMATE DRY WEIGHT = 4500#
4. MATERIALS:
   PIPE - SA 106 GR B
   SUPPORTS - A 36
   HEADS - SA 516 GR 70
   SHELL - SA 106 GR B
   EXT FITTINGS - A 234
   INT FITTINGS - A-105 GR II
   INSULATION - 6" THK CALCIUM SILICATE W/ALUMINUM JACKET (.016" THK)
5. NOZZLES ARE ROTATED INTO SECTION FOR CLARITY.
6. THESE ITEMS ARE FURNISHED BY B & W TO VENDOR.
7. NOZZLES TO HAVE TERMINALS FOR STANDARD WELD CONNECTIONS UNLESS OTHERWISE NOTED.
8. ALL DIMENSIONS ARE IN INCHES AND:
   (A) CONSIDERED NOMINAL UNLESS OTHERWISE NOTED
   (B) IN ACCORDANCE WITH ANSI Y14.5 -1973
   (C) FOR PART TEMPERATURE OF 68°F
9. INSULATION SHALL BE IN ACCORDANCE WITH SANDIA NATIONAL LABORATORY DOCUMENT # 81-5100, PARA.3.8.2.
10. ALL WELDS REQUIRE VISUAL EXAMINATION IN ADDITION TO THE NDE AS NOTED.
11. SYMBOL DESIGNATION:
    RT - RADIOGRAPHIC INSPECTION
    MT - MAGNETIC PARTICLE INSPECTION

NO.	TITLE	DWG. NO.
7	HEX BOLT	154856A
6	PERFORATED CONE	758218-1
5	SCRUBBER ELEMENTS	783850-15
4	CONNECTION BOX	118782C-7
3	CONE RING	118812C-2
2	CYCLONE STEAM SEPARATOR	148217E-6
1	STEAM DRUM SHEET 2 OF 2	405327E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DRN BY R B YOUNG
CHKD BY W J KULA
PASSED BY R G PIRAM
APPVD BY

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

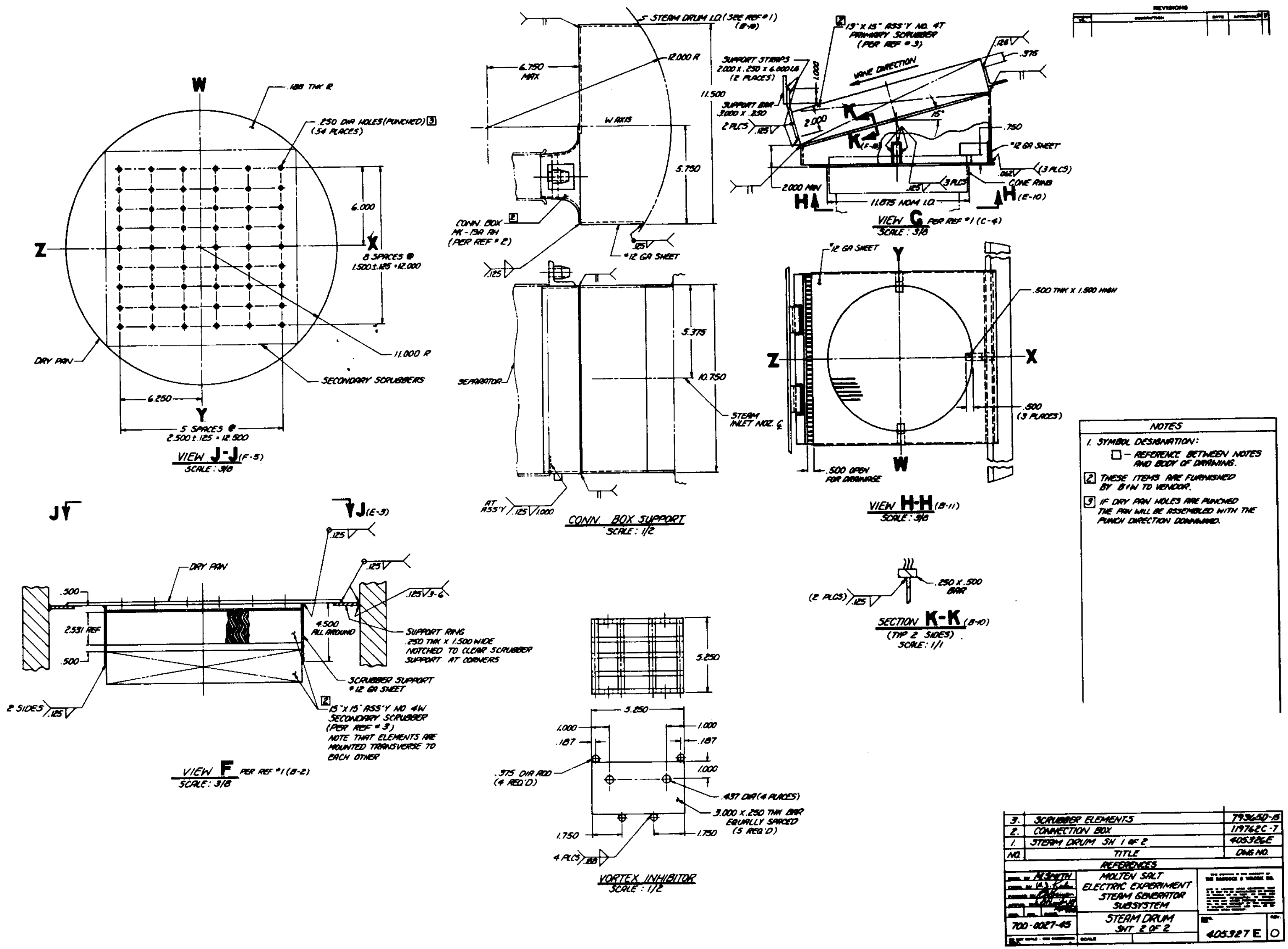
ASSEMBLY -2300

STEAM DRUM SHEET 1 OF 2

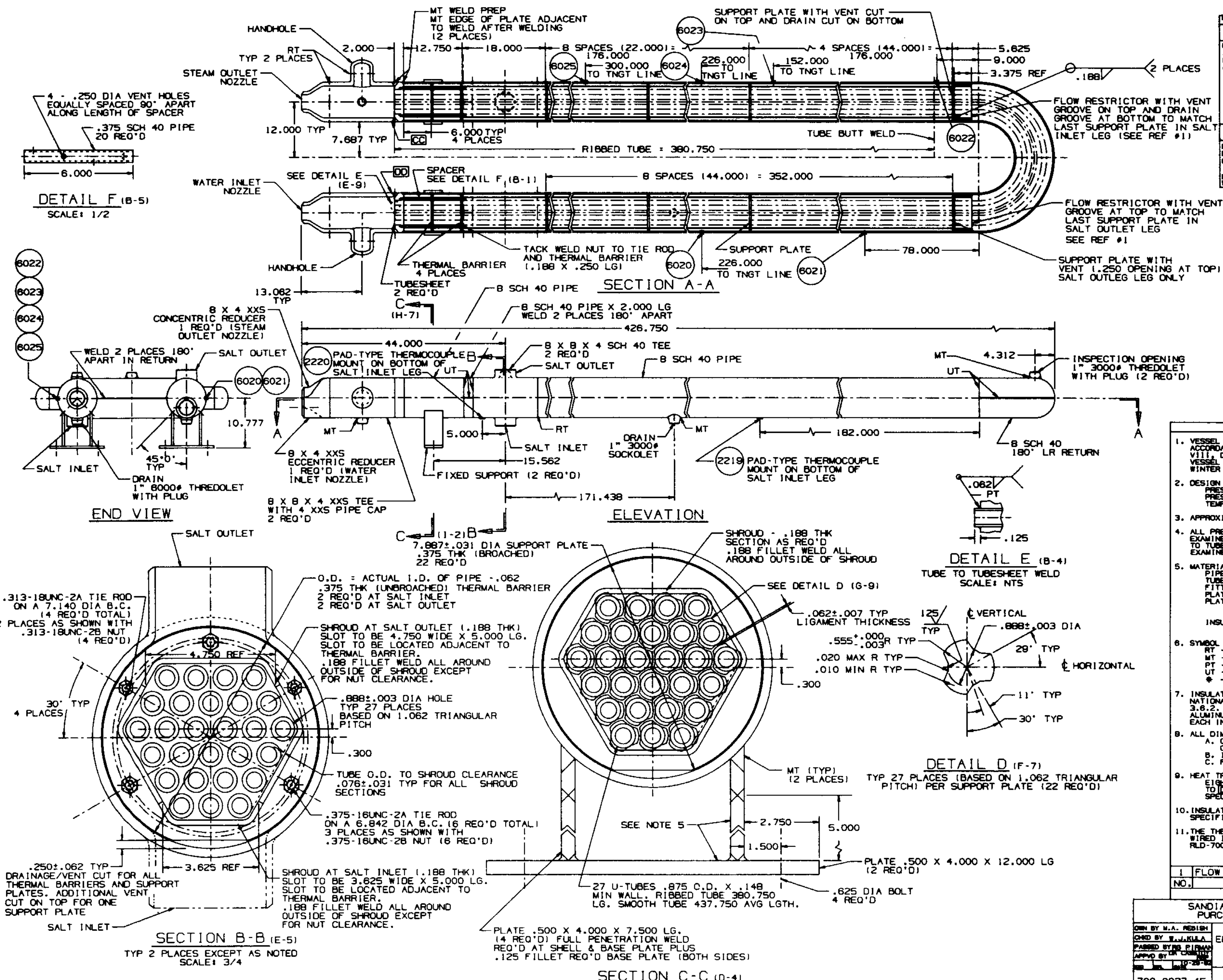
700-0027-45

SCALE 1/8

DWG NO 405326E REV 3



VIEW J-J (F-5)
SCALE: 3/8
.188 THK R
.250 DIA HOLES (PUNCHED) 3
(54 PLACES)
6.000
8 SPACES @ 1.500±.125 = 12.000
11.000 R
DRY PAN
SECONDARY SCRUBBERS
6.250
5 SPACES @ 2.500±.125 = 12.500
W
X
Y
Z
VIEW F PER REF #1 (B-2)
SCALE: 3/8
DRY PAN
.500
2.531 REF
.500
4.500 ALL AROUND
SUPPORT RING
.250 THK x 1.500 WIDE
NOTCHED TO CLEAR SCRUBBER
SUPPORT AT CORNERS
SCRUBBER SUPPORT
#12 GA SHEET
2 15" x 15" ASS'Y NO 4W
SECONDARY SCRUBBER
(PER REF # 3)
NOTE THAT ELEMENTS ARE
MOUNTED TRANSVERSE TO
EACH OTHER
2 SIDES .125
J (E-3)
5" STEAM DRUM I.D. (SEE REF #1) (B-10)
6.750 MAX
12.000 R
11.500
W AXIS
5.750
CONN. BOX 2
MK-19A RH
(PER REF # 2)
#12 GA SHEET
CONN. BOX SUPPORT
SCALE: 1/2
SEPARATOR
5.375
10.750
STEAM INLET NOZ. ℄
AT ASS'Y .125 1.000
2 13" x 15" ASS'Y NO. 4T
PRIMARY SCRUBBER
(PER REF # 3)
SUPPORT STRAPS
2.000 x .250 x 6.000 LG
(2 PLACES)
SUPPORT BAR
3.000 x .250
2 PLCS .125
VANE DIRECTION
2.000
1.000
15°
.375
.750
#12 GA SHEET
.062 (3 PLCS)
CONE RING
H (E-10)
2.000 MIN
11.875 NOM I.D.
VIEW G PER REF #1 (C-4)
SCALE: 3/8
#12 GA SHEET
.500 THK x 1.500 HIGH
.500 (3 PLACES)
.500 OPEN FOR DRAINAGE
VIEW H-H (B-11)
SCALE: 3/8
.250 x .500 BAR
(2 PLCS) .125
SECTION K-K (B-10)
(TYP 2 SIDES)
SCALE: 1/1
5.250
1.000
.187
.375 DIA ROD
(4 REQ'D)
.437 DIA (4 PLACES)
3.000 x .250 THK BAR
EQUALLY SPACED
(5 REQ'D)
1.750
4 PLCS .188
VORTEX INHIBITOR
SCALE: 1/2
REVISIONS
NOTES
1. SYMBOL DESIGNATION:
☐ - REFERENCE BETWEEN NOTES AND BODY OF DRAWING.
2 THESE ITEMS ARE FURNISHED BY B&W TO VENDOR.
3 IF DRY PAN HOLES ARE PUNCHED THE PAN WILL BE ASSEMBLED WITH THE PUNCH DIRECTION DOWNWARD.
3. SCRUBBER ELEMENTS 793650-B
2. CONNECTION BOX 119762C-7
1. STEAM DRUM SH 1 OF 2 405326E
NO. TITLE DWG NO.
REFERENCES
M. SMITH
MOLTEN SALT
ELECTRIC EXPERIMENT
STEAM GENERATOR
SUBSYSTEM
700-0027-45
STEAM DRUM
SHT 2 OF 2
405327 E 0



REVISIONS

REV.	DESCRIPTION	DATE	APPROVAL
1	IN ELEVATION ADDED RT, MT & UT, (E-5) ADDED 15.562, (E-6) ADDED 171.438, (E-5&7) DELETED 161.000 & 195.000, (E-8) DELETED 80.000, DELETED 4 SLIDING SUPPORTS, IN SECTION A-A, (C-3) ADDED 13.062 TYP, (A&C-5) DELETED .062, (A-5&8) REVISED FLOW RESTRICTOR NOTE, (E-10) REVISED DETAIL E, IN SECTION C-C (I-6) (4 REQ'D) WAS (12 REQ'D), (I-8) (2 REQ'D) WAS (6 REQ'D) (H-8) ADDED MT NOTE & WELD CONFIG., IN SECTION B-B (H-1) REVISED DRAIN / VENT NOTE, (H-11) ADDED REFERENCES, REVISED NOTE #4, #5 & #6. MAS/		RB PIRMAN
2	ADDED: ALL THERMOCOUPLES (F-8) .062±.007 TYP DIM; NOTES 9, 10 & 11; (I-12) ASSEMBLY-2200. REVISED: (D-5) LOCATION OF (1) INSPECTION OPENING; (E-2) DRAIN 1" 6000# WAS 1" 3000#; (H-8) 2.750 WAS 2.000, 1.500 WAS 1.250; NOTE #6, (A-4) DELETED RT TYP. (D-5) UT WAS RT FOR SHELL WELD. MAR/		

NOTES

1. VESSEL TO BE DESIGNED AND FABRICATED IN ACCORDANCE WITH THE REQUIREMENTS OF SECTION VIII, DIVISION I OF THE ASME BOILER & PRESSURE VESSEL CODE, 1980 EDITION & ADDENDA THROUGH WINTER 1981.
2. DESIGN CONDITIONS:
   PRESSURE TUBE-SIDE = 1400 PSIA
   PRESSURE SHELL-SIDE = 190 PSIA
   TEMPERATURE = 900°F
3. APPROXIMATE DRY WEIGHT = 5400 LBS.
4. ALL PRESSURE BOUNDARY WELDS TO BE VISUALLY EXAMINED IN ADDITION TO THE NDE AS NOTED. TUBE TO TUBE BUTT WELDS TO BE RADIOGRAPHICALLY EXAMINED.
5. MATERIALS:
   PIPE - SA335, P22
   TUBE - SA213, T22
   FITTINGS - SA182, F22
   PLATE - A387 GR22,CL1
   PLATE - A240,TP 304 (SST) (BOTTOM PORTION OF VERTICAL SUPPORT & BASE PLATE ONLY)
   INSULATION - 5" THK CALCIUM SILICATE W/ALUMINUM JACKET (.016" THK)
6. SYMBOL DESIGNATION:
   RT - RADIOGRAPH INSPECTION
   MT - MAGNETIC PARTICLE INSPECTION
   PT - LIQUID PENETRANT INSPECTION
   UT - ULTRASONIC INSPECTION
   * - INFORMATIONAL THERMOCOUPLE
7. INSULATION SHALL BE IN ACCORDANCE WITH SANDIA NATIONAL LABORATORY DOCUMENT #81-5100, PARA. 3.6.2. INSULATION PLUGS WITH REMOVABLE ALUMINUM JACKET COVERS SHALL BE PROVIDED AT EACH INSPECTION AND DRAIN PLUG OPENING.
8. ALL DIMENSIONS ARE IN INCHES AND:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED
   B. IN ACCORDANCE WITH ANSI Y14.5-1973
   C. FOR PART TEMPERATURE OF 68°F
9. HEAT TRACING:
   EIGHT 2103 CABLES TO BE INSTALLED FROM CC TO DD. SEE HEAT TRACING WORKSCOPE B&W SPECIFICATION RLD-700-0027-45-9.
10. INSULATION TO BE INSTALLED ACCORDING TO B&W SPECIFICATION DAE-700-0027-45-1.
11. THE THERMOCOUPLES SHALL BE INSTALLED AND WIRED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11.

NO.	TITLE	DWG. NO.
1	FLOW RESTRICTOR	405334E

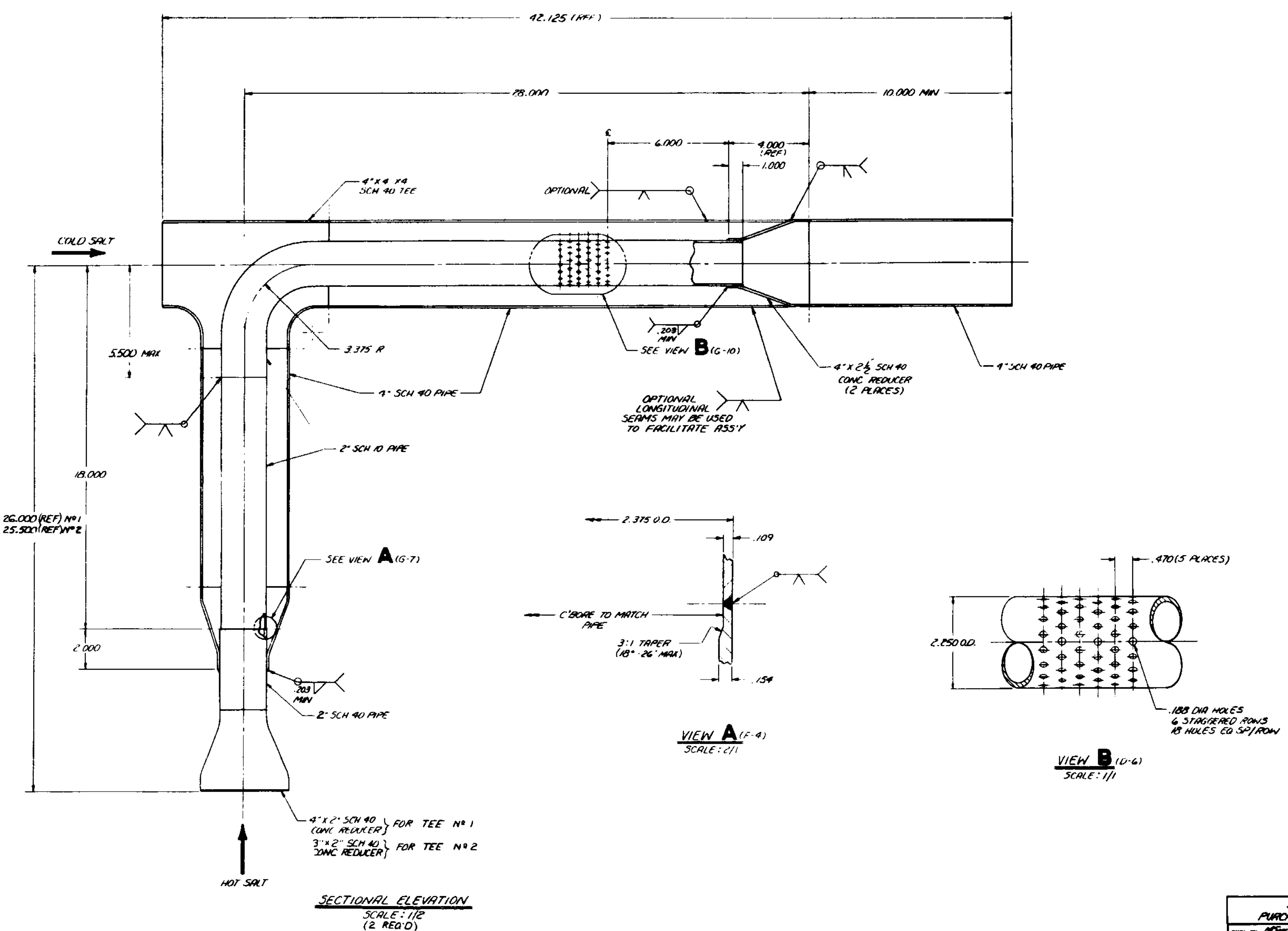
REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN BY M.A. REDISH CHKD BY W.J.KULA PASSED BY RB PIRMAN APPVD BY DR CASSIDY 10-29-82	MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM	
700-0027-45	EVAPORATOR ASSEMBLY-2200	DWG NO 405328 E — REV 2
	SCALE 1/8	

REVISIONS

NO.	DESCRIPTION	DATE	APPROVAL
1	(G-6) REVISED VIEW A, (G-3) & (D-6) ADDED .203 TO WELD SYMBOL. (E-3) 2" SCH 10 PIPE WAS 2.250 O.D. X .095 TUBE. (F-1) & (H-3) DELETED "HOLD"	1/31/85	



NOTES

1. COMPONENT TO BE DESIGNED AND FABRICATED TO POWER PIPING CODE ANSI/ASME B31.1-1980 EDITION INCLUDING SUMMER 1980 ADDENDA.
2. ALL DIMENSIONS ARE IN INCHES AND:
   (A) CONSIDERED NOMINAL UNLESS OTHERWISE NOTED.
   (B) IN ACCORDANCE WITH ANSI Y14.5-1973
   (C) FOR PART TEMPERATURE OF 68° F.
3. ALL MATERIAL TO BE A-213 TP-304

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500, PROJECT NO.

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

THE BABCOCK & WILCOX CO.

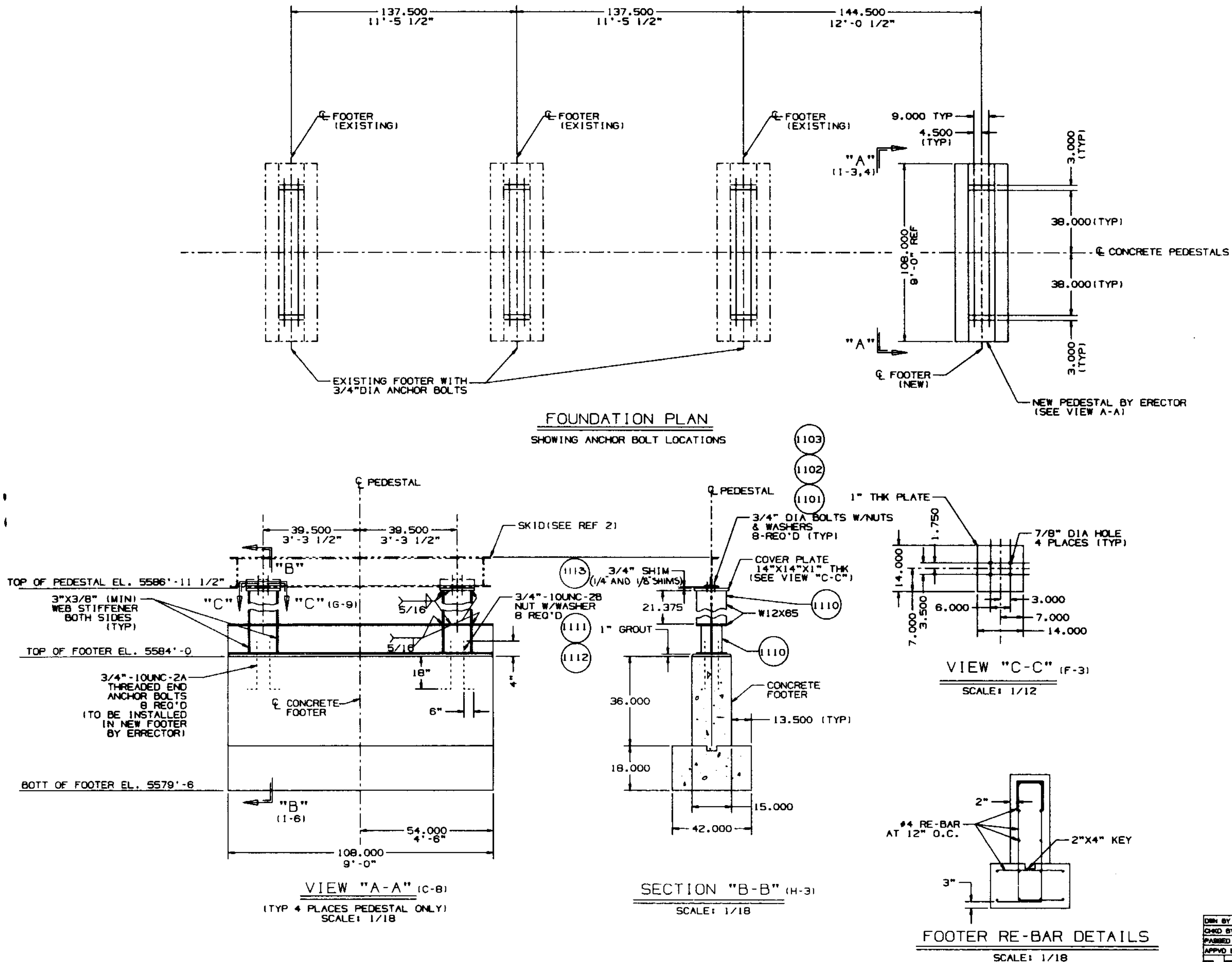
700-0027-45

SALT MIXING TEE

SCALE NOTED

405329 E

REV. 1



REVISIONS			
REV. NO.	DESCRIPTION	DATE	APPROVAL
1	ADDED IDENTIFICATION NO'S. (F-2) 5586'-11 1/2 WAS 5586'-11 13/16. (F-6) 21.375 WAS 21.687. (F-7) ADDED W/NUTS & WASHERS. (8) WAS (4). WMY/		

NOTES

1 STEEL AND FABRICATION OF PEDESTAL TO CONFORM WITH AISC STANDARDS.

2 MATERIALS:
STRUCTURAL STEEL : A-36
BOLTS AND NUTS : A-307
CONCRETE - MIN COMPRESSIVE STRENGTH: 3000 PSI AT 28 DAYS MAX. W/C RATIO: 6 GAL /94# SACK CEMENT MAX. SLUMP: 6" AIR ENTRAINMENT FOR WORKABILITY PER ACI SPECS.
CURE EXPOSED SURFACES AGAINST LOSS OF MOISTURE FOR 7 DAYS MIN.
REINFORCING STEEL - ASTM A615 OR A617, GR.40.
ANCHOR BOLT - A36 BAR

3 ALL WELDS TO BE E70XX ELECTRODES WITH VISUAL INSPECTION.

NO.	TITLE	DWG. NO.
2	SKID ASSEMBLY SHEET #2	405332E
1	PIPING ARRGT-PLAN VIEW	405340E

REFERENCES

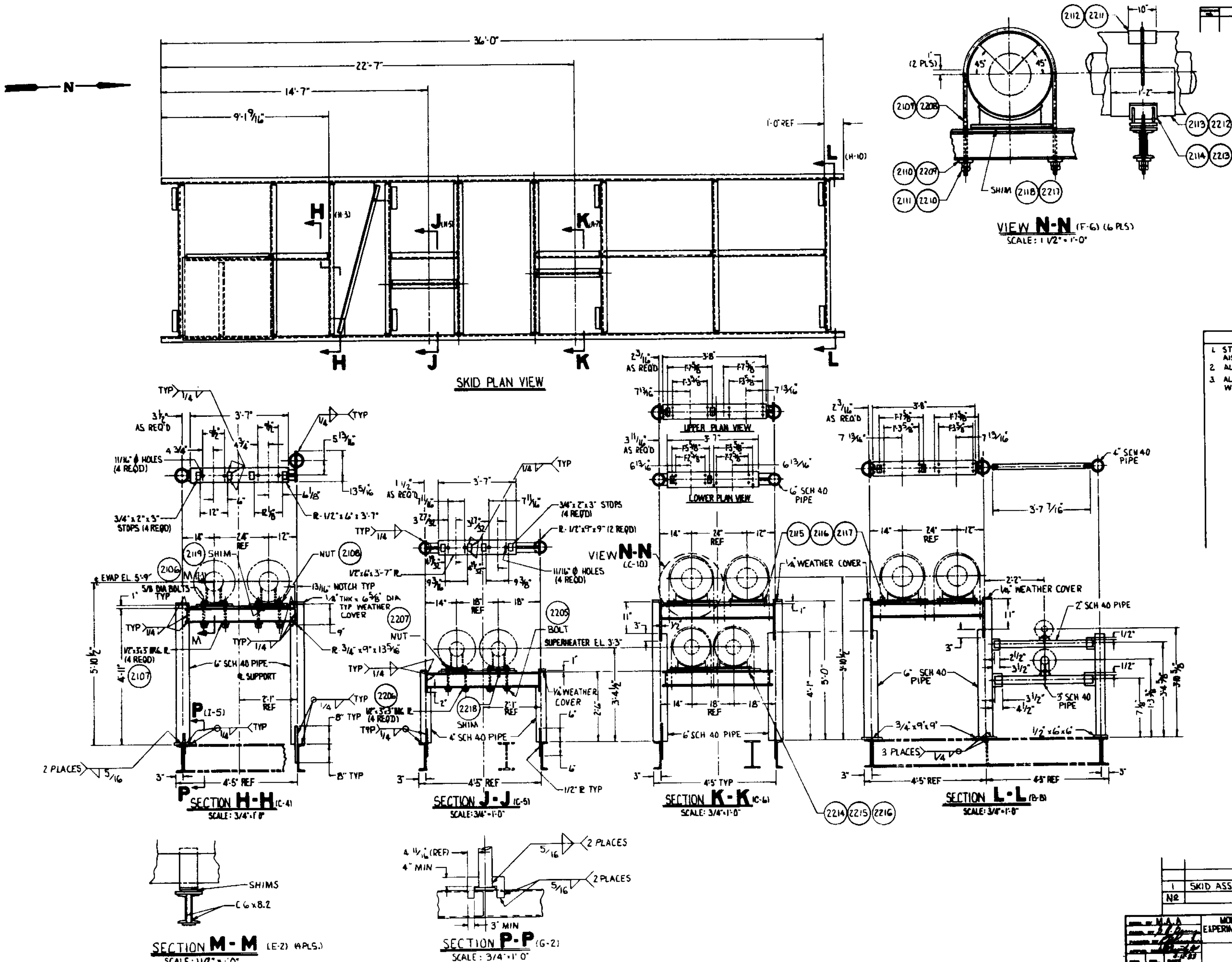
DWN BY M.A.A.
CHKD BY W M YOUNG
PASSED BY R G PIRMAN
APPVD BY

700-0027-45

PEDESTAL SUPPORT
&
FOUNDATION PLAN

SCALE 1/24

DWG NO 405330E REV 1



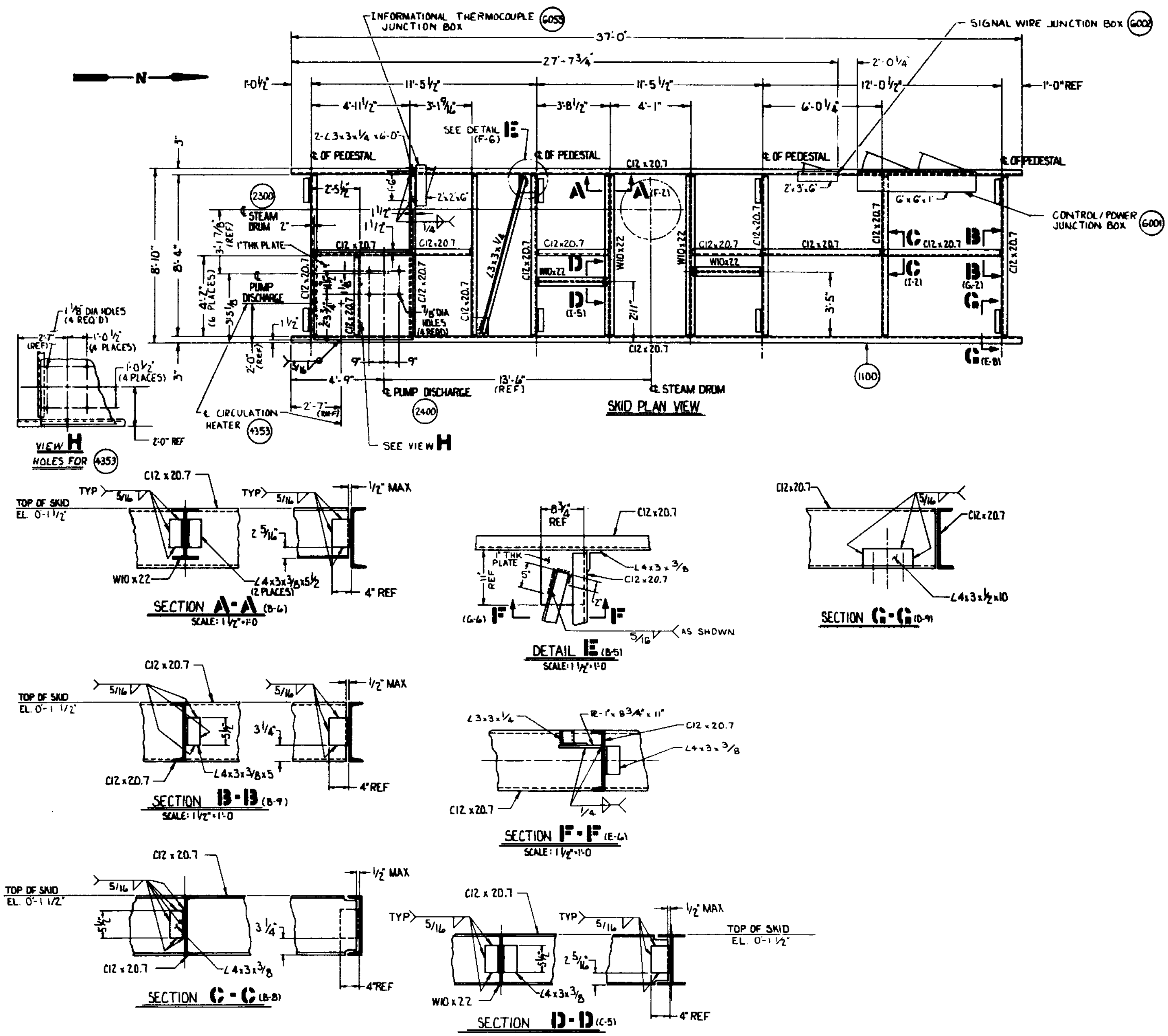
A-25

NOTES
1. STEEL & FABRICATION TO CONFORM WITH AISC STANDARDS
2. ALL MATERIAL TO BE A36
3. ALL WELDS TO BE E70XX ELECTRODES WITH VISUAL INSPECTION

Nº	TITLE	DWG. NO.
1	SKID ASSEMBLY SHEET 2 OF 5	405332E

REFERENCES

M.A.A.	MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM	THE BABCOCK & WILCOX CO.	
700-0027-45	SKID ASSEMBLY SHEET 1 OF 5	405331	E
	SCALE 1/2" = 1'-0"		0



NOTES

1. STEEL & FABRICATION OF SKID TO CONFORM WITH AISC STANDARDS.
2. ALL MATERIAL TO BE A36.
3. ALL WELDS TO BE E70XX ELECTRODES WITH VISUAL INSPECTION.

REFERENCES

Nº	TITLE	DWG. NO.
6	SKID ASSEMBLY SHEET 5 OF 5	405345E
5	SKID ASSEMBLY SHEET 4 OF 5	405338E
4	SKID ASSEMBLY SHEET 3 OF 6	405333E
3	TOWER ASSEMBLY ELEVATION SHEET 2 OF 3	405336E
2	PEDESTAL SUPPORT & FOUNDATION PLAN	405330E
1	SKID ASSEMBLY SHEET 1 OF 5	405331E

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

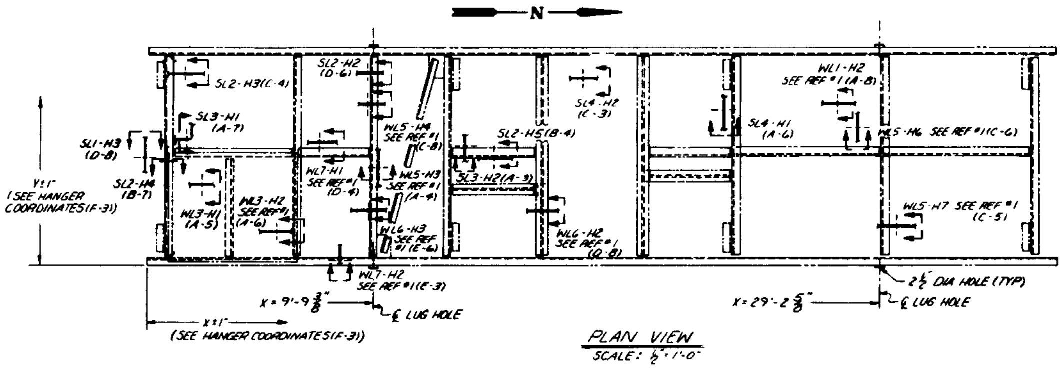
SKID ASSEMBLY
SHEET 2 OF 5

700-0027-45

SCALE 1/24

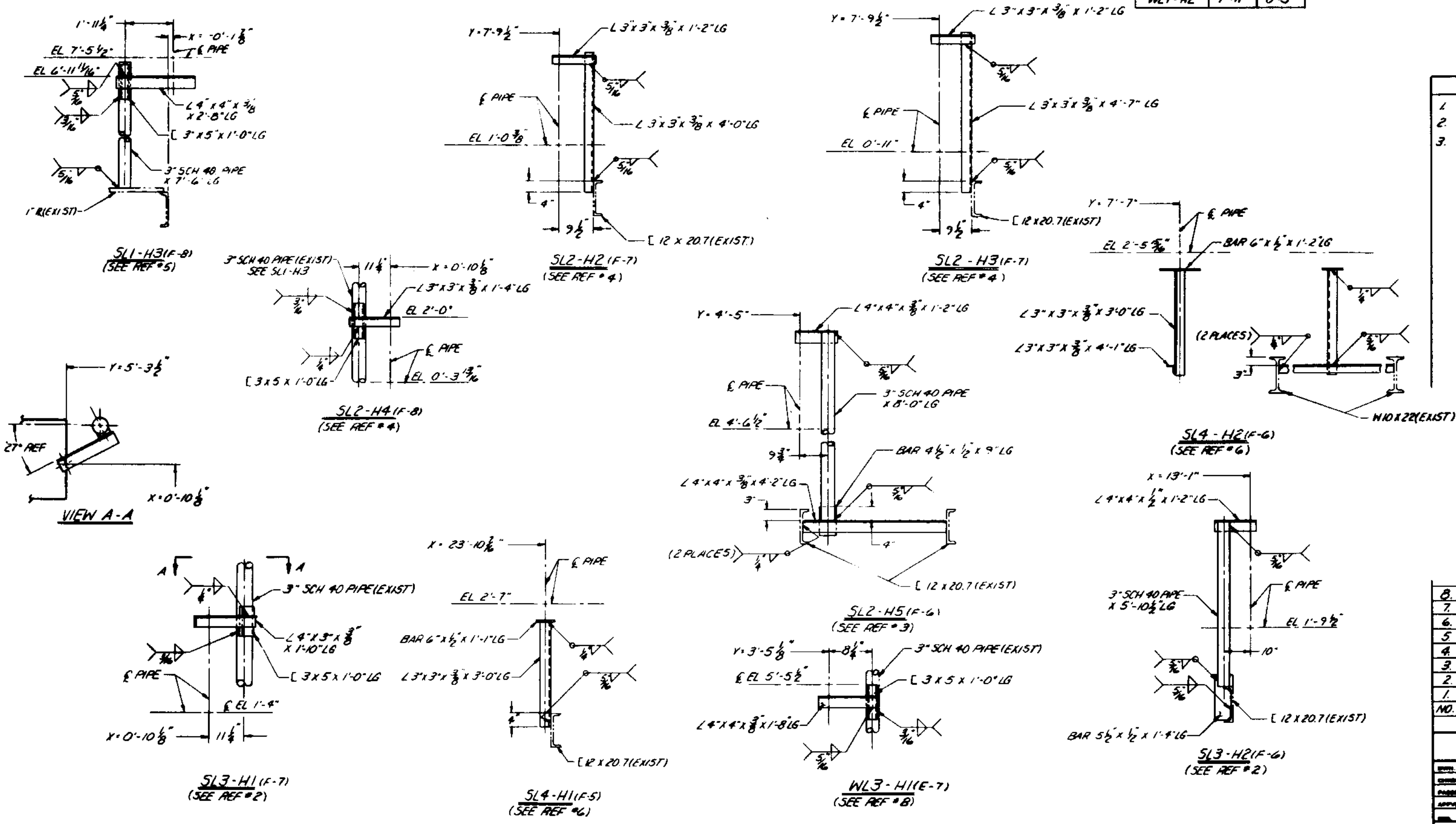
405332 E

REV. 0



HANGER COORDINATES		
MK NO.	X	Y
SL1-H3	-0'-1 3/8"	4'-5"
SL2-H2	9'-1 3/4"	7'-9 1/2"
SL2-H3	1'-6 1/4"	7'-9 1/2"
SL2-H4	0'-10 1/8"	4'-5"
SL2-H5	14'-2 1/2"	4'-5"
SL3-H1	0'-10 1/8"	5'-3 1/2"
SL3-H2	13'-1"	4'-10"
SL4-H1	23'-10 7/8"	7'-7"
SL4-H2	17'-6 3/8"	7'-7"
WL1-H2	28'-1 3/4"	6'-7"
WL3-H2	5'-8"	1'-5"
WL5-H3	9'-6 1/4"	4'-0"
WL5-H4	9'-1 9/16"	6'-7"
WL5-H6	29'-0"	5'-7"
WL5-H7	30'-6"	1'-7"
WL3-H1	2'-1"	3'-5 1/8"
WL6-H2	16'-2 1/2"	2'-3"
WL6-H3	9'-1 9/16"	2'-3"
WL7-H1	7'-2"	4'-11 1/2"
WL7-H2	7'-11"	0'-5"

REVISIONS



NOTES

1. STEEL FABRICATION TO CONFORM WITH AISC STANDARDS.
2. ALL MATERIAL TO BE A-36.
3. ALL WELDS TO BE E70XX ELECTRODES WITH VISUAL INSPECTION.

NO.	TITLE	DWG NO.
8.	STEAM PIPING ASSEMBLY 4300	179933C
7.	SKID ASSEMBLY SHT 2 OF 5	405332E
6.	SALT PIPING ASSEMBLY 3500	179941C
5.	SALT PIPING ASSEMBLY 3400	179940C
4.	SALT PIPING ASSEMBLY 3300	179938C
3.	SALT PIPING ASSEMBLY 3200	179937C
2.	SALT PIPING ASSEMBLY 3100	179936C
1.	SKID ASSEMBLY SHT 4 OF 5	405338E

REFERENCES

SANDIA NATIONAL LABORTORIES
PURCHASE ORDER NO. 81-500

MOLTEN SALT
ELECTRIC EXPERIMENT
STEAM GENERATOR
SUBSYSTEM

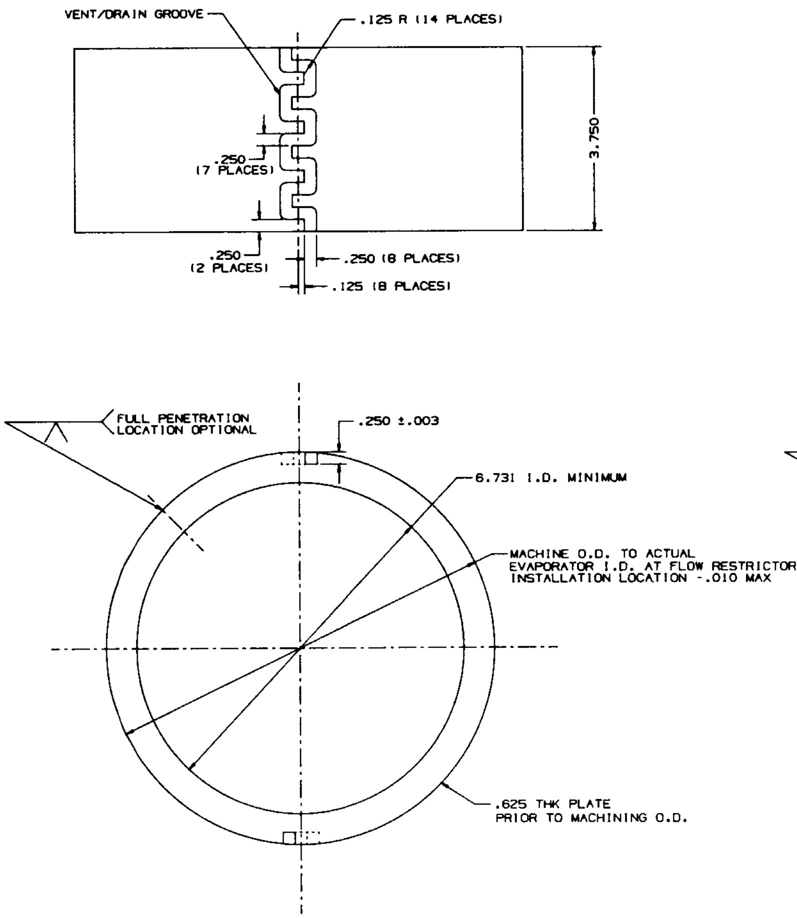
SKID ASSEMBLY
SHT 3 OF 5

700-0027-45

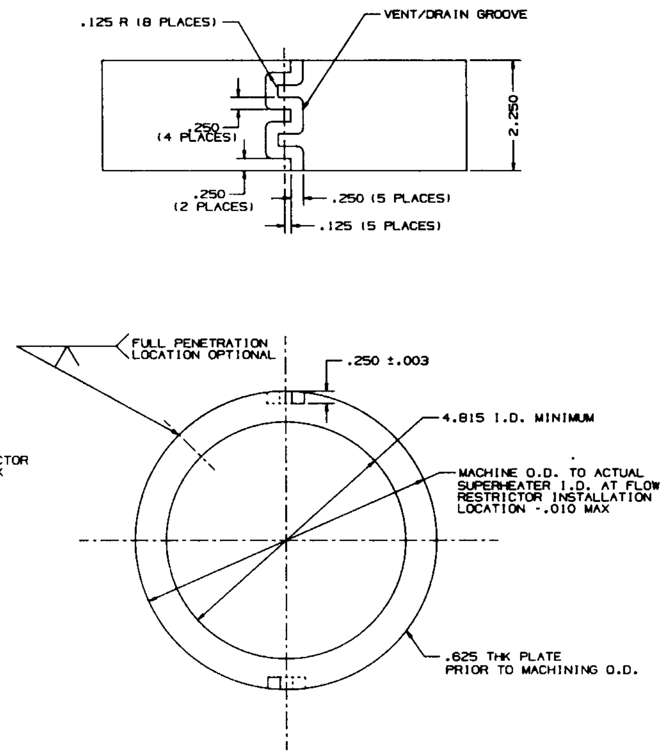
SCALE 1/2"=1'-0"

405333 E 0

REVISIONS				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	(H-3[illegible]) ADDED NOTE. MAS/[illegible]	[illegible]	[illegible]	



FLOW RESTRICTOR
EVAPORATOR
(2 REQ'D)
ONE WITH VENT ON TOP
ONE WITH VENT ON TOP AND BOTTOM



FLOW RESTRICTOR
SUPERHEATER
(2 REQ'D)
ONE WITH VENT ON TOP
ONE WITH VENT ON TOP AND BOTTOM

NOTES

1. FOR GENERAL NOTES SEE APPLICABLE REF DWGS.
2. MATERIAL:
   PLATE - A387 GR22,CL1 FOR EVAPORATOR
   - A240 TP 304 FOR SUPERHEATER
3. ALL DIMENSIONS ARE IN INCHES AND:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE NOTED
   B. IN ACCORDANCE WITH ANSI Y14.5-1973
   C. FOR PART TEMPERATURE OF 68°F

NO.	TITLE	DWG. NO.
2	EVAPORATOR	405328E
1	SUPERHEATER	405325E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500, PROJECT NO.

DRN BY M.A. REBISH
CHKD BY W.J.KULA
PASSED BY RB PIRMAN
APPVD BY DR CASSIDY

MOLTEN SALT
ELECTRIC EXPERIMENT
STEAM GENERATOR
SUBSYSTEM

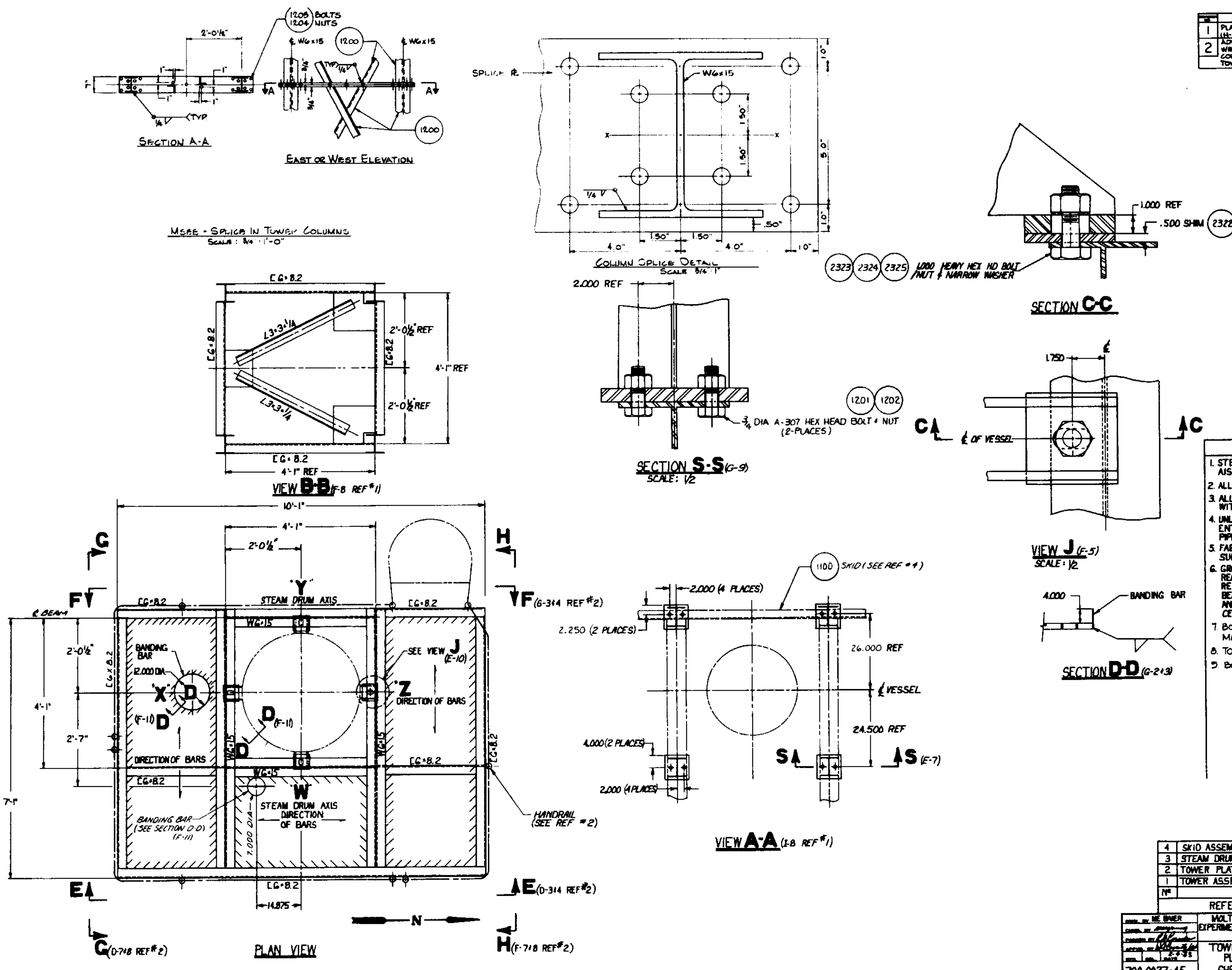
700-0027-45

FLOW
RESTRICTOR

SCALE 1/1

DWG NO 405334 E | REV 1

A-29



REVISIONS

	DESCRIPTION	DATE	APPROVAL
1	PLAN VIEW CHANGED AXES. (H-D) 2 OF 5 WAS 2 OF 2		
2	ADDED SECTION A-A, EAST OR WEST ELEVATION AND COLUMN SPLICE VIEW FOR TOWER		

NOTES

1. STEEL & FABRICATION TO CONFORM WITH AISC STANDARDS
2. ALL MATERIAL TO BE A36
3. ALL WELDS TO BE E70XX ELECTRODES WITH VISUAL INSPECTION.
4. UNLESS SPECIFIED GRATING IS TO COVER ENTIRE PLATFORM WITH EXCEPTIONS AT PIPE, VESSEL & SUPPORT LOCATIONS.
5. FABRICATOR TO ADD GRATING SAG SUPPORTS WHERE DEEMED APPLICABLE.
6. GRATING FOR PLATFORM SHALL BE OF RECTANGULAR WELDED STEEL NON-REVERSIBLE TYPE WITH 1 1/4 x 3/16 THICK BEARING BARS SPACED ON 1 3/16 CENTERS AND WITH CROSS BARS SPACED ON 4" CENTERS
7. BOLTS ARE 3/4-10 UNC 2A, A307 MATERIAL OR BETTER.
8. TORQUE BOLTS TO 70 ± 5 FT/LB.
9. BOLT HOLES: 13/16" DIAMETER.

REFERENCES

Nº	TITLE	DWG Nº
4	SKID ASSEMBLY SHEET 2 OF 5	405332E
3	STEAM DRUM SHEET 1 OF 2	405326E
2	TOWER PLATFORM HANDRAILS SHT 3 OF 3	405337E
1	TOWER ASSEMBLY ELEVATION SHT 2 OF 3	405336E

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

TOWER ASSEMBLY PLAN VIEW SHEET 1 OF 3

THE BABCOCK & WILCOX CO.

700-0027-45

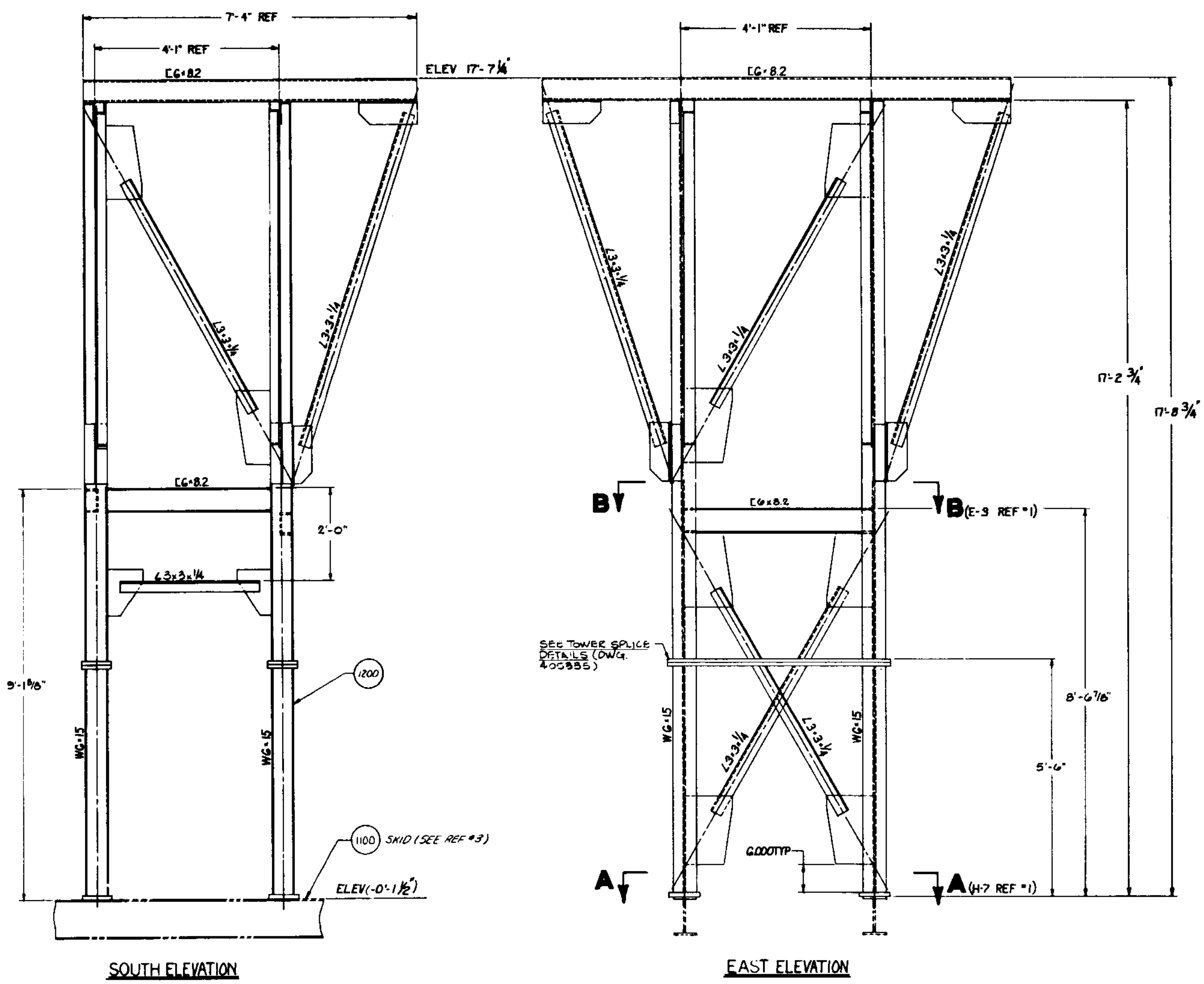
SCALE 1"=1'-0"

405335 E 2

A-30

REVISIONS

NO.	DESCRIPTION	DATE	APPROVAL
1	LOWERED C6x8.2 6½" IN EAST ELEVATION, SHOWED TOWER SPLICE & REMOVED BRACE (∠3x3x¼).1 IN SOUTH ELEVATION REMOVED (2) BRACE (∠3x3x¼) AND ADDED ONE (∠3x3x¼) BELOW THESE.		

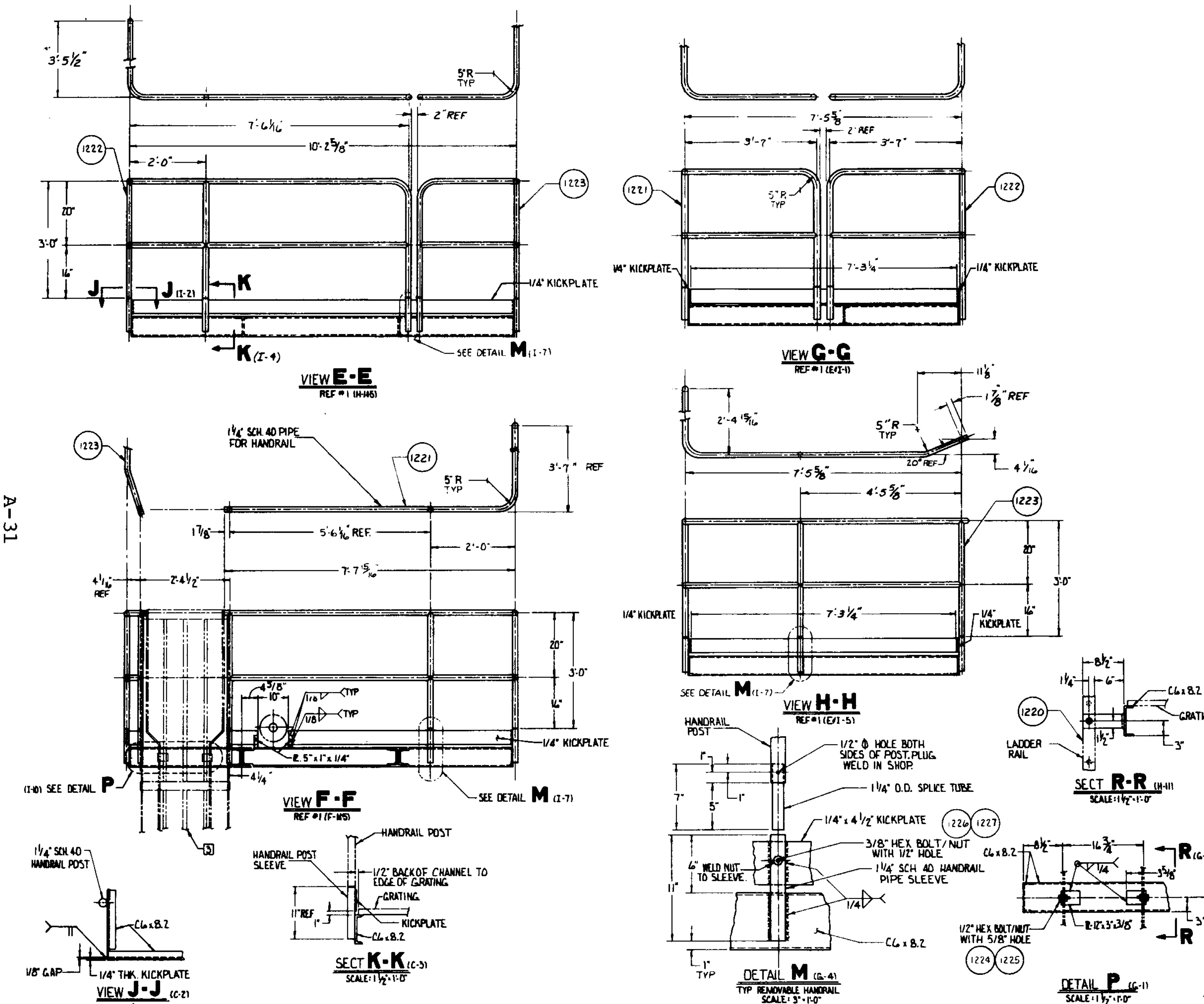


NOTES
1. STEEL AND FABRICATION TO CONFORM WITH AISC STANDARDS.
2. ALL MATERIAL TO BE A36.
3. ALL WELDS TO BE E70XX ELECTRODES WITH VISUAL INSPECTION.

Nº	TITLE	DWG Nº
3	SKID ASSEMBLY SHEET 2 OF 2	405332E
2	TOWER PLATFORM HANDRAILS	405337E
1	TOWER ASSEMBLY PLAN VIEW	405335E

REFERENCES

M E BAKER	MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM	THE BABCOCK & WILCOX CO.
700-0027-45	TOWER ASSEMBLY ELEVATION SHEET 2 OF 3	405336 E — REV. 1
	SCALE 1"=1'-0"	



A-31

NOTES

1. STEEL AND FABRICATION TO CONFORM WITH AISC STANDARDS.
2. ALL WELDS TO BE E70XX ELECTRODES WITH VISUAL INSPECTION.
3. [3] FOR LADDER INFORMATION REF. B&W STANDARD DWG. 196304 C REV. 1.
4. ALL WELDS ON HORIZONTAL RAILS SHALL BE GROUND SMOOTH.
5. FOR 1 1/4" Ø SCH 40 HANDRAIL PIPE USE 1 1/4" O.D. SPLICE TUBE.
6. MATERIALS:
   - STRUCTURAL STEEL - A-36
   - BOLTS AND NUTS - A-307
   - HANDRAIL - 1 1/4" SCH. 40
   - SPLICE TUBE - 1 1/4" O.D.
7. ALL EXTERNAL SURFACES OF HANDRAIL PIPING IS TO BE PAINTED.

NO.	TITLE	DWG. NO.
2	TOWER ASSEMBLY - ELEVATION SHT 2 OF 3	405336 E
1	TOWER ASSEMBLY - PLAN VIEW SHT 1 OF 3	405335 E

REFERENCES

DRWN. BY M.A.A.

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

TOWER PLATFORM HANDRAILS

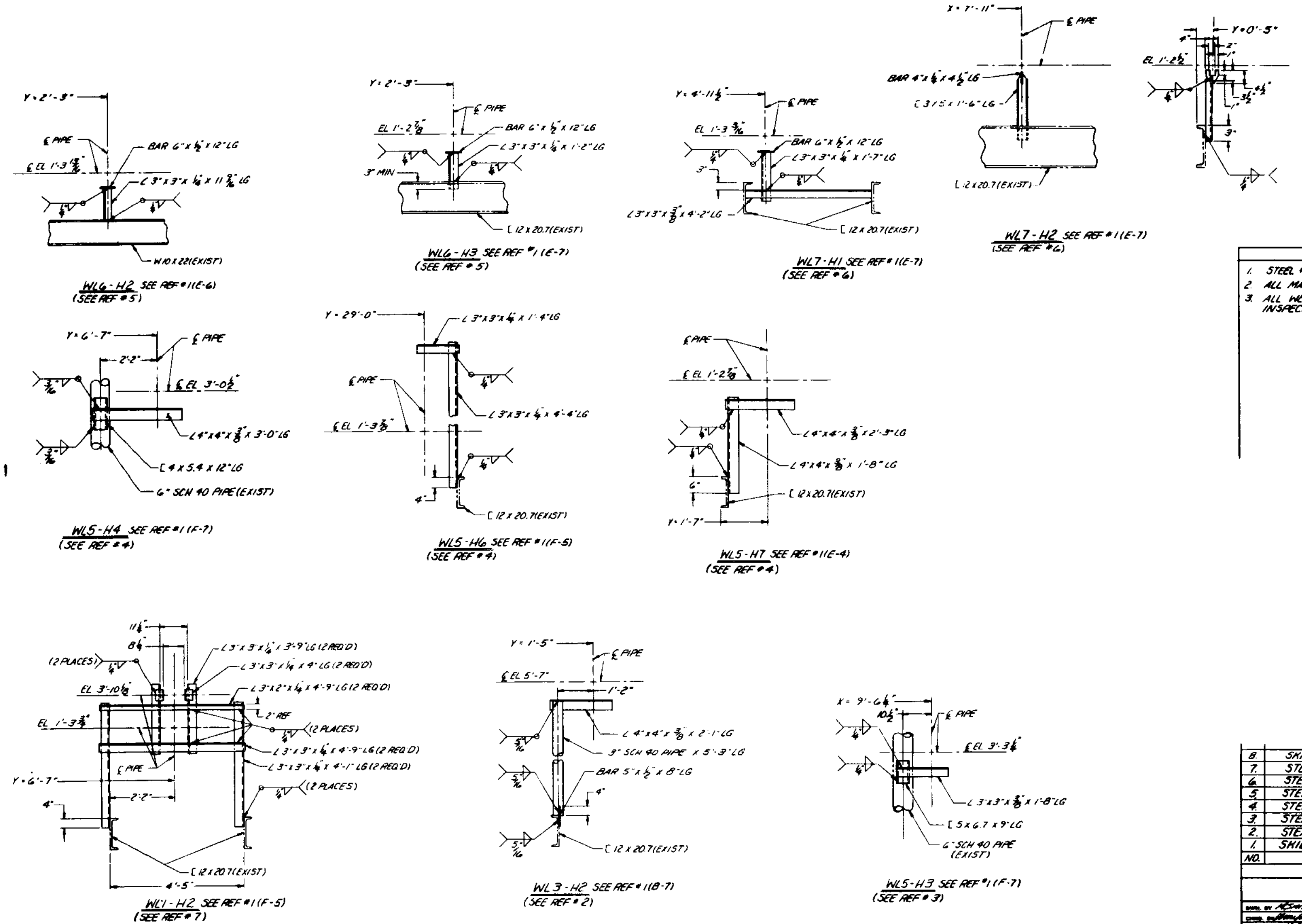
SHEET 3 OF 3

700-0027-45

SCALE: 1" = 1'-0"

405337 E

REV. 0



REVISIONS

NOTES

1. STEEL & FABRICATION TO CONFORM WITH AISC STANDARDS.
2. ALL MATERIAL TO BE A-36.
3. ALL WELDS TO BE E70XX ELECTRODES WITH VISUAL INSPECTION.

NO.	TITLE	DWG NO.
8.	SKID ASSEMBLY SHT 2 OF 5	405332E
7.	STEAM PIPING ASSEMBLY 4100	179944C
6.	STEAM PIPING ASSEMBLY 4800	179943C
5.	STEAM PIPING ASSEMBLY 4700	179942C
4.	STEAM PIPING ASSEMBLY 4600	179939C
3.	STEAM PIPING ASSEMBLY 4500/4900	179935C
2.	STEAM PIPING ASSEMBLY 4300	179933C
1.	SKID ASSEMBLY SHT 3 OF 5	405333E

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500.

MOLTEN SALT
ELECTRIC EXPERIMENT
STEAM GENERATOR
SUBSYSTEM

Babcock & Wilcox
a McDermott company

SKID ASSEMBLY
SHT 4 OF 5

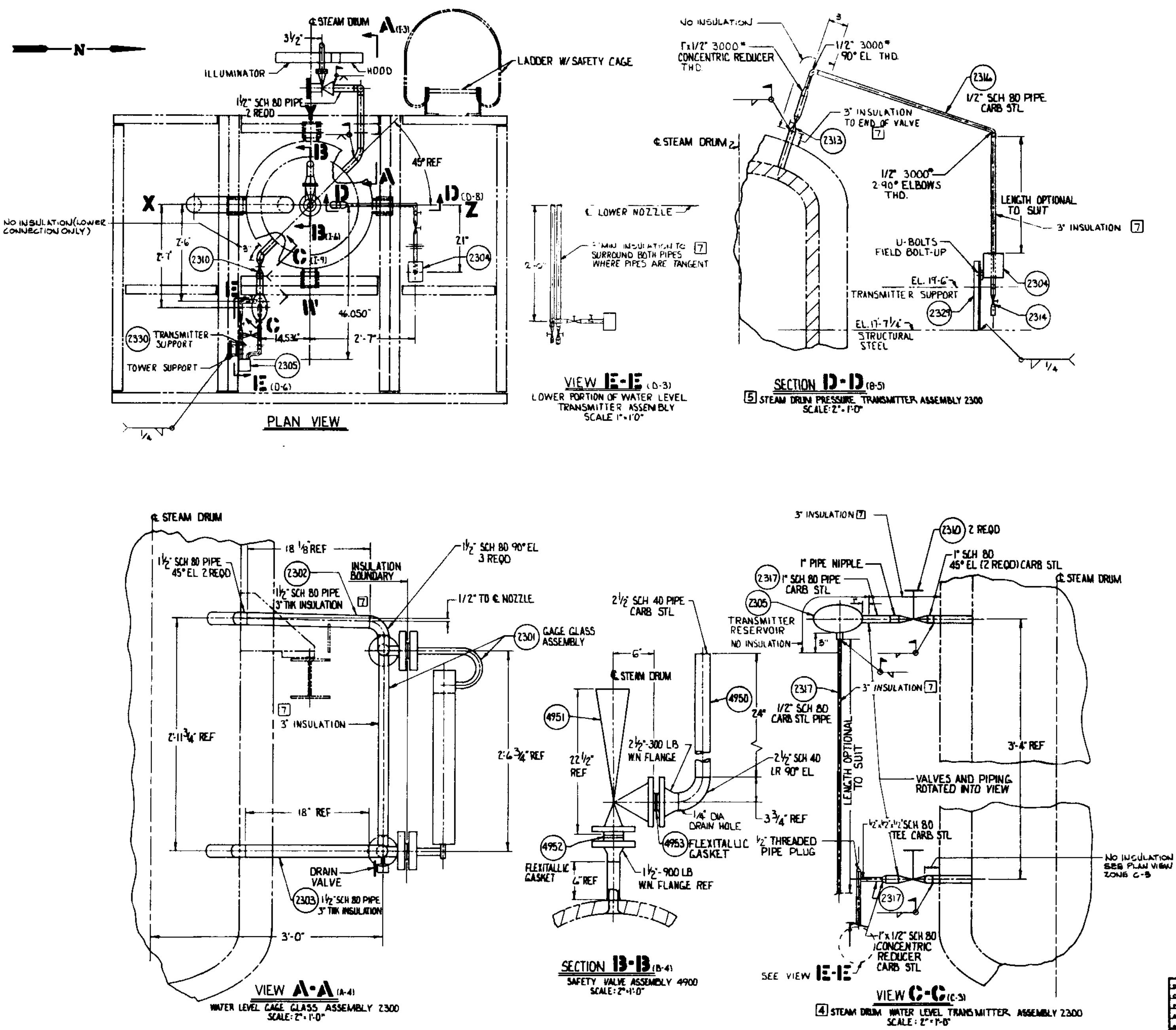
700-0027-45

SCALE 3/4"=1'-0"

405338 E

REV. 0

REVISIONS			
NO.	DESCRIPTION	DATE	APPROVAL
1	CHANGED INSULATION DESIGNATED AREA'S PLAN, A-A, D-D, C-C.		



NOTES

1. FOR GENERAL NOTES SEE REFERENCE # 1.
2. DESIGN CONDITIONS:
   PIPING DESIGN PRESSURE = 1325 PSIA
   PIPING DESIGN TEMPERATURE = 600°F
3. ALL DIMENSIONS ARE:
   A. CONSIDERED NOMINAL UNLESS OTHERWISE SPECIFIED.
   B. IN ACCORDANCE WITH ANSI Y14.5-1973.
   C. FOR PART TEMPERATURE.
4. STEAM DRUM WATER LEVEL TRANSMITTER PIPING SHALL BE FABRICATED IN ACCORDANCE WITH B&W DOCUMENT RLD-700-0027-45-6.
5. STEAM DRUM PRESSURE TRANSMITTER PIPING SHALL BE FABRICATED IN ACCORDANCE WITH B&W DOCUMENT RLD-700-0027-45-2.
6. HEAT TRACING SPECIFICATION - REFERENCE FOR LEVEL AND PRESSURE LINES - B&W SPECIFICATION RLD-700-0027-45-9.
7. INSULATION SPECIFICATION FOR INSTRUMENT LINES - B&W SPECIFICATION DAE-700-0027-45-1.

NO.	TITLE	DWG. NO.
2	STEAM DRUM	405326 E
1	PIPING ARRANGEMENT	405340 E

REFERENCES

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

STEAM DRUM ACCESSORIES

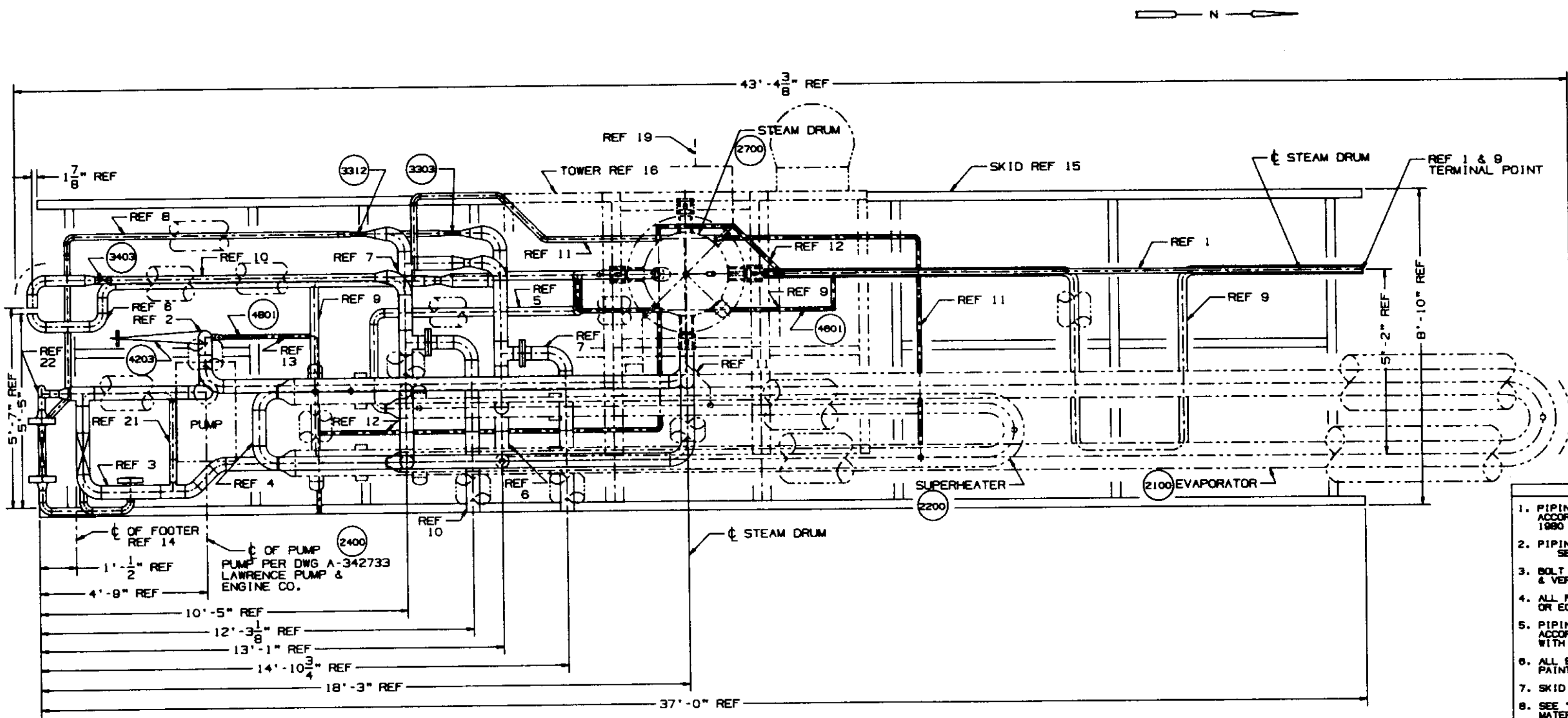
DRAWN BY M.A.A.

700-0027-45

SCALE 1"=1'-0"

405339 E REV 1

REVISIONS				
REV	DESCRIPTION	DATE	APPROVAL	



NOTES

1. PIPING DESIGN AND FABRICATION TO BE IN ACCORDANCE WITH ANSI B31.1 - POWER PIPING, 1980 EDITION WITH WINTER 1981 ADDENDA.
2. PIPING DESIGN CONDITIONS: SEE REFERENCE DWGS 1 THRU 13
3. BOLT HOLES IN FLANGES TO STRADDLE HORIZONTAL & VERTICAL AXIS OF THE PIPES.
4. ALL FLANGE BOLTS TO BE LUBRICATED WITH NEOLUBE OR EQUIVALENT.
5. PIPING SHALL BE PREPARED FOR SHIPMENT IN ACCORDANCE WITH GOOD COMMERCIAL PRACTICES AND WITH ALL OPENINGS SEALED.
6. ALL EXTERNAL SURFACES OF THE PIPING ARE TO BE PAINTED WHERE APPLICABLE.
7. SKID ASSEMBLY SHIPPING WEIGHT - 25,000 LBS.
8. SEE "HARDWARE LIST" FOR A COMPLETE LIST OF MATERIALS.
9. ELECTRICAL IS PER B&W SPECIFICATION NO. RLD-700-0027-45-11, "SGS SKID ELECTRICAL WORKSCOPE"
10. CONTROLS AND SIGNAL WIRING IS PER B&W SPECIFICATION RLD-700-0027-45-10, "SGS CONTROL AND SIGNAL JUNCTURE BOXES".
11. PIPING SUPPORTS ARE PER B&W SPECIFICATION VTL-700-0027-45-1, "PIPING SUPPORTS".
12. SHOP INSULATION IS PER B&W SPECIFICATION DAE-700-0027-45-1, "SGS SKID INSULATION".
13. FIELD ERECTION INCLUDING ELECTRICAL, INSULATION AND HEAT TRACING IS PER B&W SPECIFICATION DAE-700-0027-45-3. "ERECTION SPECIFICATIONS".
14. SHOP HEAT TRACING IS PER B&W SPECIFICATION RLD-700-0027-45-9, "SGS HEAT TRACING".

NO.	ASS'Y	TITLE	DWG. NO.
22	4350	CIRCULATION HEATER PIPING INLET	179945C
21	4350	CIRCULATION HEATER PIPING OUTLET	179946C
20		LIST OF DRAWINGS	179949C
19	2301	STEAM DRUM ACCESSORIES	405339E
18		PIPNG ARRANGEMENT SIDE ELEVATION	405342E
17		PIPING ARRANGEMENT FRONT ELEVATION	405341E
16	1200	TOWER ASSEMBLY PLAN VIEW	405335E
15	1100	SKID ASSEMBLY	405331E
14		PEDESTAL SUPP'T & FOUNDATION PLAN	405330E
13	4800	STEAM PIPING WATER DRAIN	179943C
12	4700	STEAM PIPING BLOWDOWN	179942C
11	3500	SALT PIPING SALT DRAIN	179941C
10	3400	SALT PIPING EV SALT OUT & OVERPRES	179940C
9	4600	STEAM PIPING SH STEAM OUT & ATTEMP	179939C
8	3300	SALT PIPING COLD SALT CONTROL	179938C
7	3200	SALT PIPING EVAPORATOR SALT INLET	179937C
6	3100	SALT PIPING HOT SALT INLET	179936C
5	4500	STEAM PIPING SUPERHEATER INLET	179935C
4	4400	STEAM PIPING RISER	179934C
3	4300	STEAM PIPING EVAPORATOR WTR INLET	179933C
2	4200	STEAM PIPING DOWNCOMER	179932C
1	4100	STEAM PIPING FEEDWATER	179944C

REFERENCES

SANDIA NATIONAL LABORATORIES
PURHASE ORDER NO. 81-500

DWN BY M.A. REBISH
CHKD BY
PASSED BY
APPVD BY

MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

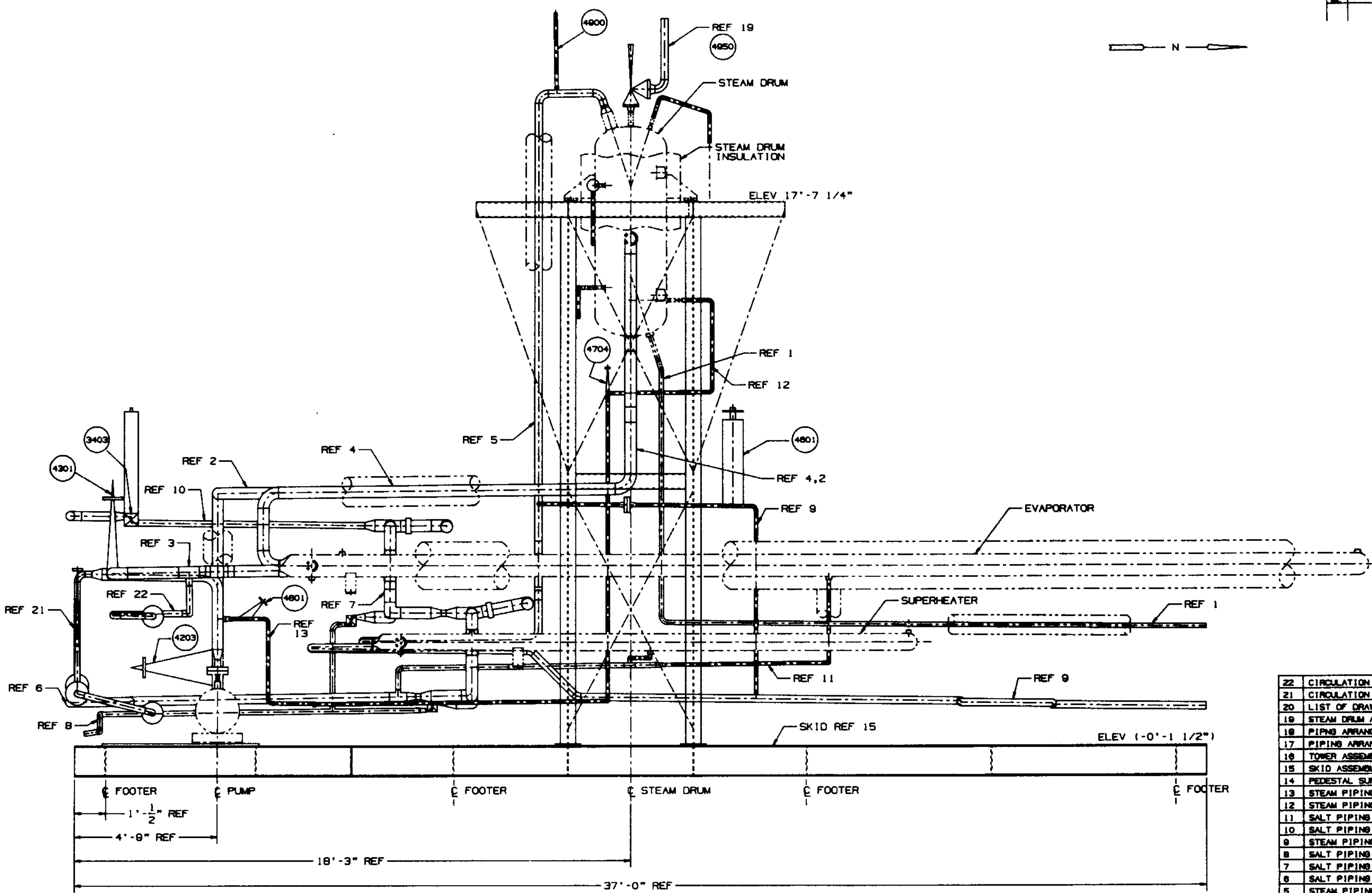
PIPING ARRANGEMENT PLAN VIEW SHEET 1 OF 3

700-0027-45

SCALE 1/16

DWG NO 405340E

REV 0



REVISIONS			
REV.	DESCRIPTION	DATE	APPROVAL

NO.	TITLE	DWG. NO.
22	CIRCULATION HEATER PIPING OUTLET	179946C
21	CIRCULATION HEATER PIPING INLET	179945C
20	LIST OF DRAWINGS	179949C
19	STEAM DRUM ACCESSORIES	405339E
18	PIPNG ARRANGEMENT SIDE ELEVATION	405342E
17	PIPING ARRANGEMENT FRONT ELEVATION	405341E
16	TOWER ASSEMBLY PLAN VIEW	405338E
15	SKID ASSEMBLY	405331E
14	PEDESTAL SUPP'T & FOUNDATION PLAN	405330E
13	STEAM PIPING WATER DRAIN	179943C
12	STEAM PIPING BLOWDOWN	179942C
11	SALT PIPING SALT DRAIN	179941C
10	SALT PIPING EV SALT OUT & OVERPRES	179940C
9	STEAM PIPING SH STEAM OUT & ATTEMP	179939C
8	SALT PIPING COLD SALT CONTROL	179938C
7	SALT PIPING EVAPORATOR SALT INLET	179937C
6	SALT PIPING HOT SALT INLET	179936C
5	STEAM PIPING SUPERHEATER INLET	179935C
4	STEAM PIPING RISER	179934C
3	STEAM PIPING EVAPORATOR WTR INLET	179933C
2	STEAM PIPING DOWNCOMER	179932C
1	STEAM PIPING FEEDWATER	179944C

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DWN BY M.A. REBISH
CHKD BY
PASSED BY
APPVD BY
4-8-79

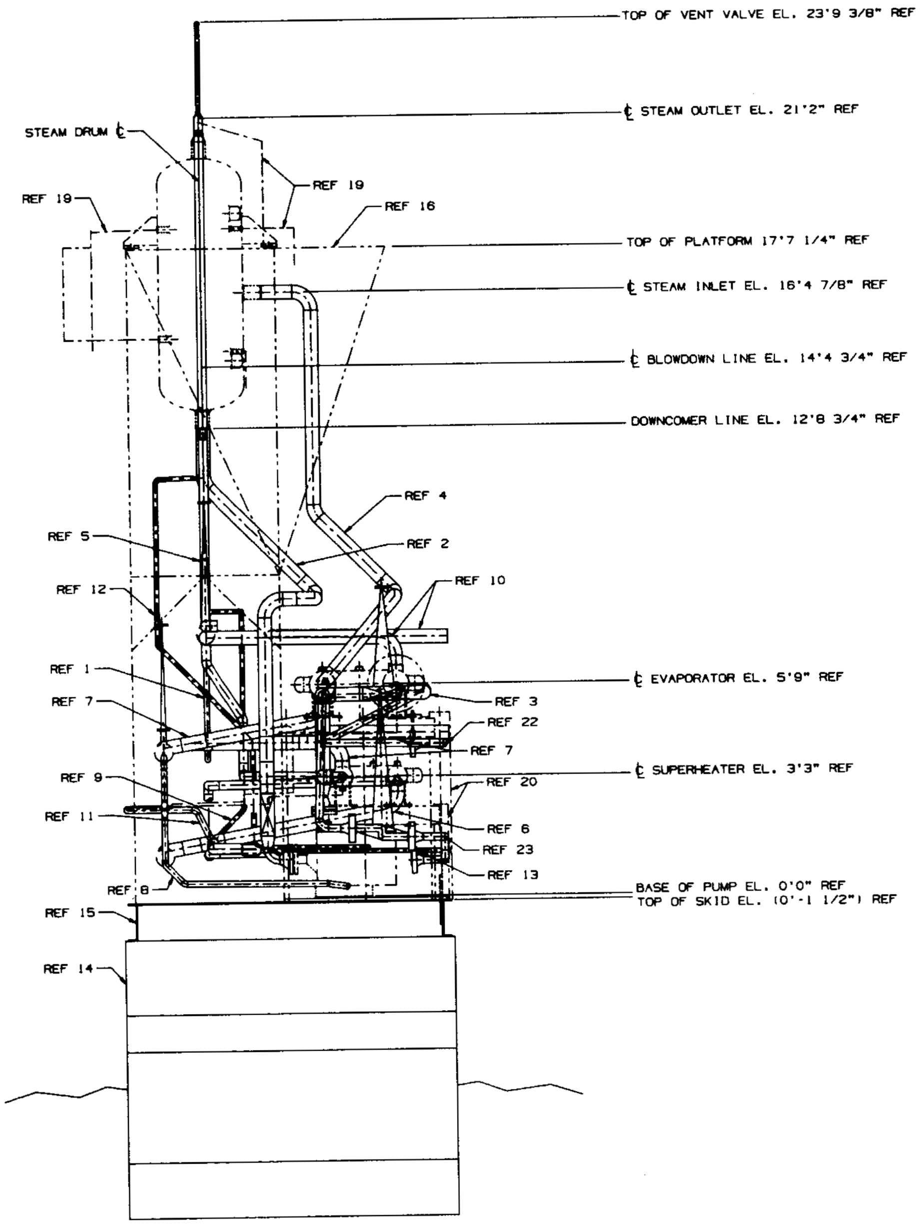
MOLTEN SALT
ELECTRIC EXPERIMENT
STEAM GENERATOR
SUBSYSTEM

700-0027-45

PIPING ARRANGEMENT
FRONT ELEVATION
SHEET 2 OF 3

SCALE 1/10

DWG NO 405341 E
REV 0



SOUTH ELEVATION

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVAL

NO.	TITLE	DWG. NO.
23	CIRCULATION HEATER PIPING INLET	179945C
22	CIRCULATION HEATER PIPING OUTLET	179946C
21	LIST OF DRAWINGS	179949C
20	SKID ASSEMBLY SHEET 1	405331E
19	STEAM DRUM ACCESSORIES	405339E
18	PIPNG ARRANGEMENT SIDE ELEVATION	405342E
17	PIPING ARRANGEMENT FRONT ELEVATION	405341E
16	TOWER ASSEMBLY PLAN VIEW	405335E
15	SKID ASSEMBLY	405331E
14	PEDESTAL SUPP'T & FOUNDATION PLAN	405330E
13	STEAM PIPING WATER DRAIN	179943C
12	STEAM PIPING BLOWDOWN	179942C
11	SALT PIPING SALT DRAIN	179941C
10	SALT PIPING EV SALT OUT & OVERPRES	179940C
9	STEAM PIPING SH STEAM OUT & ATTEMP	179939C
8	SALT PIPING COLD SALT CONTROL	179938C
7	SALT PIPING EVAPORATOR SALT INLET	179937C
6	SALT PIPING HOT SALT INLET	179936C
5	STEAM PIPING SUPERHEATER INLET	179935C
4	STEAM PIPING RISER	179934C
3	STEAM PIPING EVAPORATOR WTR INLET	179933C
2	STEAM PIPING DOWNCOMER	179932C
1	STEAM PIPING FEEDWATER	179944C

REFERENCES

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

DRN BY M.A. REBISH
CHKD BY
PASSED BY
APPVD BY

MOLTEN SALT
ELECTRIC EXPERIMENT
STEAM GENERATOR
SUBSYSTEM

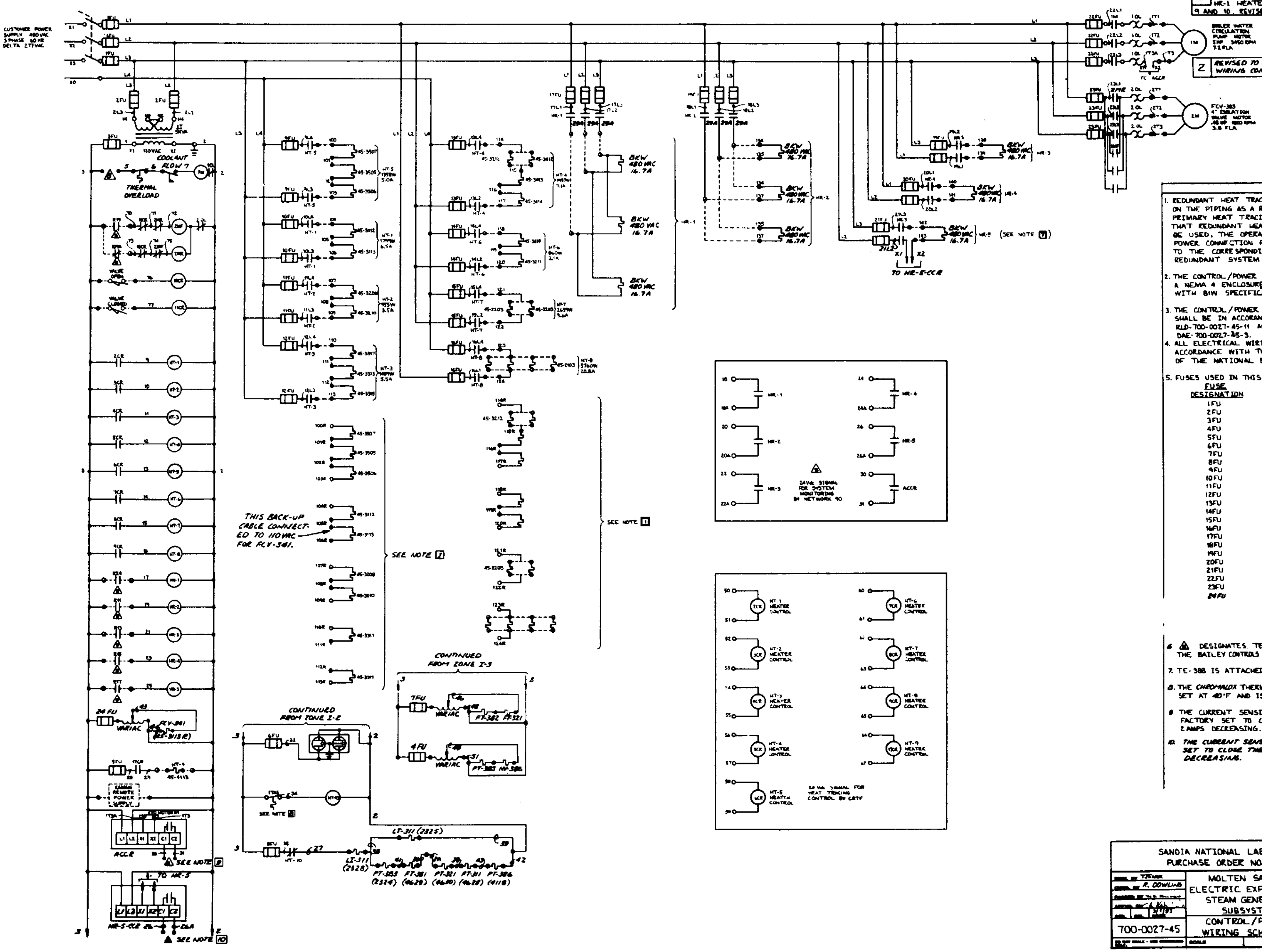
PIPING ARRANGEMENT
SOUTH ELEVATION
SHEET 3 OF 3

700-0027-45

SCALE 1/16

DWG NO 405342 E

REV 0



REVISIONS

REV	DESCRIPTION	DATE	APPROVAL
1	REVISED M2 STARTER AND HR-1 HEATER. ADDED NOTES 9 AND 10. REVISED DESIGNATION OF HEAT TRACING CABLES IN HT-3 AND HT-5. TJF	3/28/83	RLO
2	REVISED TO REFLECT AS BUILT WIRING CONFIGURATION. RD	4/4/84	

NOTES

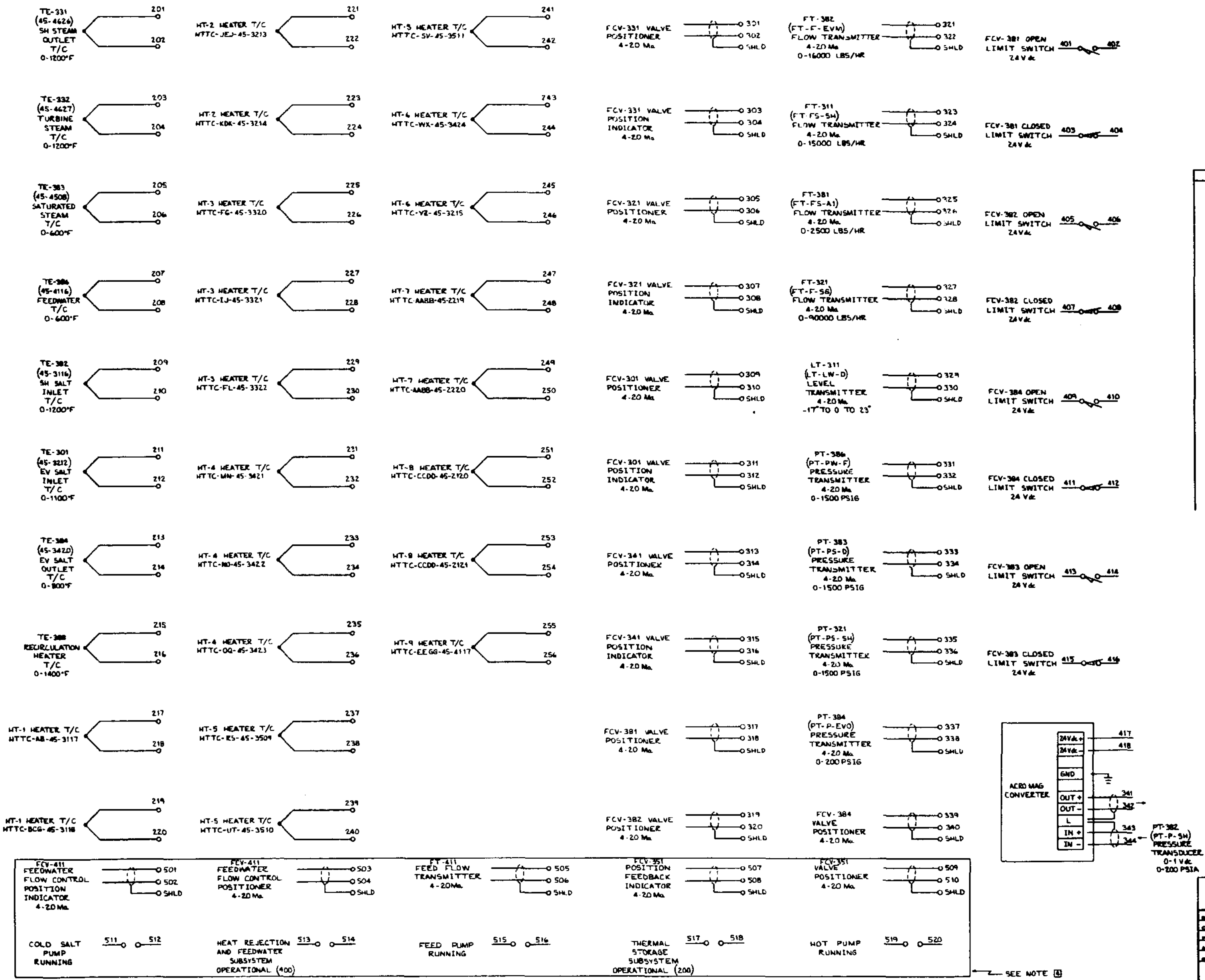
1. REDUNDANT HEAT TRACING CABLES ARE PROVIDED ON THE PIPING AS A REPLACEMENT FOR THE PRIMARY HEAT TRACING CABLES. IN THE EVENT THAT REDUNDANT HEAT TRACING CABLES MUST BE USED, THE OPERATOR NEED ONLY MOVE THE POWER CONNECTION FROM THE PRIMARY SYSTEM TO THE CORRESPONDING CONNECTION ON THE REDUNDANT SYSTEM DESIGNATED BY AN "R".
2. THE CONTROL/POWER JUNCTION BOX SHALL BE A NEMA 4 ENCLOSURE FABRICATED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-10.
3. THE CONTROL/POWER INTERCONNECTING WIRING SHALL BE IN ACCORANCE WITH B&W SPECIFICATION RLD-700-0027-45-11 AND ERECTION SPECIFICATION DAE-700-0027-45-3.
4. ALL ELECTRICAL WIRING SHALL BE IN ACCORDANCE WITH THE LATEST EDITION OF THE NATIONAL ELECTRIC CODE.
5. FUSES USED IN THIS JUNCTION BOX ARE

FUSE DESIGNATION	FUSE SIZE
1FU	NOS-150
2FU	NOS-10
3FU	NON-45
4FU	FRN-4
5FU	NON-3
6FU	KAB-10
7FU	FRN-4
8FU	NON-6
9FU	NOS-6
10FU	NOS-10
11FU	NOS-6
12FU	NOS-6
13FU	NOS-10
14FU	NOS-6
15FU	NOS-10
16FU	NOS-25
17FU	NOS-30
18FU	NOS-30
19FU	NOS-20
20FU	NOS-20
21FU	NOS-20
22FU	FRSR-8
23FU	FRSR-1.8
24FU	FRN-4

6. △ DESIGNATES TERMINAL CONNECTION FOR THE BAILEY CONTROLS NETWORK 90.
7. TE-388 IS ATTACHED TO HEATING ELEMENT HR-5.
8. THE CHROMALOX THERMAL SWITCH IS FACTORY SET AT 40°F AND IS ADJUSTABLE.
9. THE CURRENT SENSING DEVICE (ACCR) IS FACTORY SET TO CLOSE THE CONTACT AT 2 AMPS DECREASING.
10. THE CURRENT SENSING DEVICE ON HR-5-CCR IS SET TO CLOSE THE CONTACT AT 10 AMPS DECREASING.

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

TJF	MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM	
R. DOWLING		
700-0027-45	CONTROL/POWER WIRING SCHEMATIC	405343 E — REV. 2



REVISIONS

1	REVISED NOTE 4. ADDED NOTES 5 AND 6. TJF		

NOTES

1. THE SIGNAL WIRING JUNCTION BOX SHALL BE A NEMA 4 ENCLOSURE FABRICATED IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-10.
2. THE SIGNAL INTERCONNECTING WIRING SHALL BE IN ACCORDANCE WITH B&W SPECIFICATION RLD-700-0027-45-11 AND ERECTION SPECIFICATION DAE-700-0027-45-3.
3. ALL ELECTRICAL WIRING SHALL BE IN ACCORDANCE WITH THE LATEST EDITION OF THE NATIONAL ELECTRIC CODE.
4. TERMINATIONS AVAILABLE FOR SIGNAL WIRING BY CRTF FOR INPUT TO THE BAILEY CONTROLS NETWORK 90. AS AN ALTERNATE, THESE SIGNALS MAY BE WIRED DIRECTLY TO NETWORK 90 TERMINATIONS.
5. TERMINATIONS BETWEEN THE SIGNAL WIRING JUNCTION BOX AND NETWORK 90 ARE SHOWN ON BAILEY CONTROLS DRAWINGS 8083958A THROUGH 8083969A AND 8084086A.
6. THE SIGNAL FOR THE 20 THERMOCOUPLES DENOTED "HEATER T/C" ARE SENT TO THE CRTF DATA LOGGER; WIRING BY CRTF.

SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500

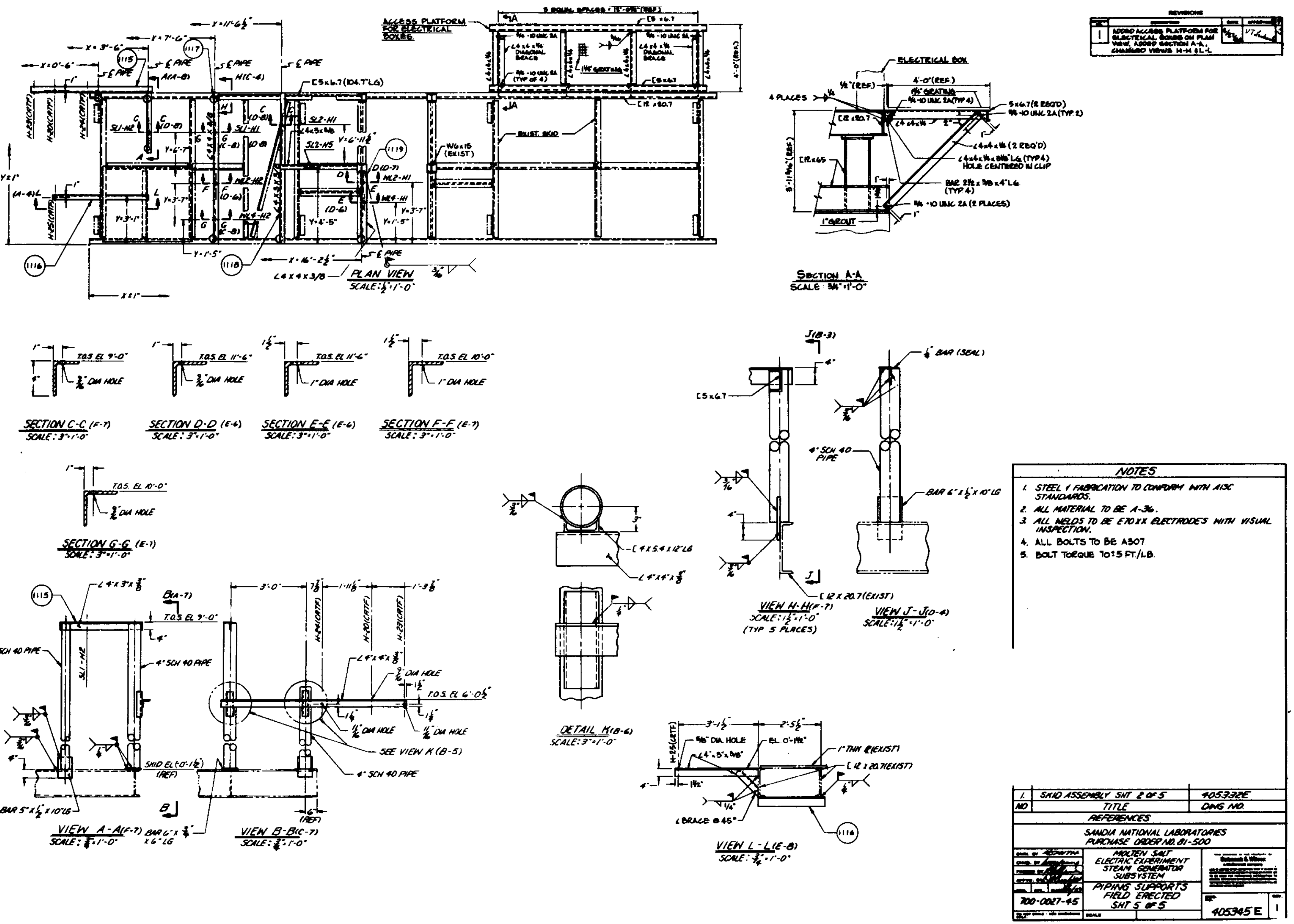
MOLTEN SALT ELECTRIC EXPERIMENT STEAM GENERATOR SUBSYSTEM

SIGNAL WIRING SCHEMATIC

DRAWN BY T.J.FARR
CHKD. BY P. DOWLING

700-0027-45

405344 E 1


ACCESS PLATFORM FOR ELECTRICAL BOXES
ELECTRICAL BOX
PLAN VIEW
SCALE: 1/2"=1'-0"
SECTION A-A
SCALE 3/4"=1'-0"
SECTION C-C (F-7)
SCALE: 3"=1'-0"
SECTION D-D (E-6)
SCALE: 3"=1'-0"
SECTION E-E (E-6)
SCALE: 3"=1'-0"
SECTION F-F (E-7)
SCALE: 3"=1'-0"
SECTION G-G (E-7)
SCALE: 3"=1'-0"
VIEW H-H (F-7)
SCALE: 1 1/2"=1'-0"
(TYP 5 PLACES)
VIEW J-J (D-4)
SCALE: 1 1/2"=1'-0"
DETAIL K (B-6)
SCALE: 3"=1'-0"
VIEW A-A (F-7)
SCALE: 3/4"=1'-0"
VIEW B-B (C-7)
SCALE: 3/4"=1'-0"
VIEW L-L (E-8)
SCALE: 3/4"=1'-0"
NOTES
1. STEEL & FABRICATION TO CONFORM WITH AISC STANDARDS.
2. ALL MATERIAL TO BE A-36.
3. ALL WELDS TO BE E70XX ELECTRODES WITH VISUAL INSPECTION.
4. ALL BOLTS TO BE A307.
5. BOLT TORQUE 70±5 FT./LB.
1. SKID ASSEMBLY SHT 2 OF 5 405332E
NO TITLE DWG NO.
REFERENCES
SANDIA NATIONAL LABORATORIES
PURCHASE ORDER NO. 81-500
MOLTEN SALT
ELECTRIC EXPERIMENT
STEAM GENERATOR
SUBSYSTEM
PIPING SUPPORTS
FIELD ERECTED
SHT 5 OF 5
700-0027-45
405345 E

APPENDIX B

B&W Letter Report 700-0027-45-LR-1

"B&W Action Items Relative to Circulation Heater Failure"

LETTER REPORT
B&W ACTION ITEMS RELATIVE TO CIRCULATION HEATER FAILURE

Report No. 700-0027-45-LR-1

MOLTEN SALT ELECTRIC EXPERIMENT
STEAM GENERATING SUBSYSTEM

for

Sandia National Laboratories
Central Receiver Test Facility
Albuquerque, New Mexico

B&W Contract No. 700-0027-45
Sandia Purchase Order 81-5100

Revision	Date	Prepared By	Checked By	Reviewed By	Approved By (Engr. Mgr.)
0	2-22-84	[illegible]	R. Dowling	[illegible]	C R Kakarala

BABCOCK & WILCOX
A McDermott Company
Nuclear Equipment Division
Barberton, Ohio

2055i

Table of Contents

1.0 Introduction

A catastrophic failure of the pressure boundary of the Chromalox circulation heater in the Steam Generator Subsystem (SGS) of the Molten Salt Electric Experiment (MSEE) occurred on January 19, 1984. Representatives of SNLL, CRTF, B&W, M-M, and Chromalox met at CRTF on January 24, 1984 to try to establish what led to the heater pressure boundary failure, to determine actions required to prevent reoccurrence of such an incident, and to determine actions necessary to get the SGS back on line. B&W action items as a result of the meeting were:

1) Assess the SGS for any possible damage as a result of this occurrence.
2) Review water/steam system freeze protection and refurbish as required to improve freeze protection.
3) Review SGS controls and interlocks and revise as necessary.
4) Review SGS operating procedures and revise as necessary.

The purpose of this letter report is to address these action items. As background to these action items this report includes summary discussion of (1) subsystem conditions prior to the incident, (2) the scenario of subsystem conditions during the incident which led to the pressure boundary failure, and (3) the evaluation of temperature transients during the incident. As a matter of definition, the "incident" covers the time period from roughly 1500 hr. on January 18 to 0730 hr. on January 19.

2.0 SGS Conditions Prior to the Incident

On the night of January 17-18 the SGS was placed in diurnal shutdown. During the night the circulation heater was de-energized on a false low-low steam drum water level signal (LT-311) caused by freezing in the water level transmitter piping. Subsequent to this heater trip SGS steam pressure gradually reduced. Original plans had been to perform SGITP No. 9 on January 18; however, on the morning of January 18 the CRTF H-P data acquisition was down for maintenance so it was decided to postpone SGITP No. 9.

B&W site engineer R. L. Dowling used this down time to implement a planned circuit change on the water/steam transmitters' piping freeze protection circuit HT-10. The circuit change was designed to increase heat trace power on the transmitter piping due to previous instances of freezing in transmitter lines during overnight diurnal shutdown conditions. Throughout the day on January 18 the circulation heater remained de-energized, and the saturated steam temperature/pressure continued to reduce gradually. After the circuit changes on HT-10 were completed and HT-10 was activated, level transmitter LT-311 thawed out and was providing a correct level indication. Steam drum pressure transmitter (PT-383) piping, which had also frozen on the night of January 17-18, was thawed using a propane torch and was providing a correct reading when compared to saturation temperature. The superheater and all steam piping downstream of the steam drum remained filled with condensate generated the night of January 17-18, therefore it was judged that water inventory in the steam drum was sufficient for the diurnal shutdown operation for the night of January 18-19; no feedwater was added. The diurnal shutdown automatic pressure controller (EHAC) for the circulation heater was activated; this energized the circulation heater to increase the steam pressure and then to maintain the pressure overnight at a nominal value of 1100 psig. Subsequent to activating the automatic pressure controller the SGS was left unattended.

3.0 Steam Pressure Control During Diurnal Shutdown

As a preface to the discussion of the circulation heater pressure boundary failure, a review of the use of the heater for maintenance of steam pressure during diurnal shutdown is in order. The SGS specification indicates that steam pressure during diurnal shutdown would be maintained by circulation of cold salt through the SGS. During the SGS design phase, SNL indicated that neither circulating salt by an automatic, unmanned system nor maintaining personnel on site around the clock to control salt circulation was an acceptable operating alternative. During this same time period the addition of the circulation heater to the SGS was being considered for heat-up of the water/steam system from ambient conditions, rather than using the HRFS to provide heat input for this cold start-up operation. The circulation heater could therefore serve the dual purpose of cold system start-up and overnight pressure maintenance without the need for salt recirculation or manned operation at all times.

The original concept of steam pressure maintenance during diurnal shutdown was to activate one or more of the five heater circuits at the end of the operating day to maintain approximately 1100 psig steam pressure overnight. The number of heater elements required to be activated was to be based on operating experience. There was no active control on heater element operation during diurnal shutdown. Interlocks in the control system de-energized the heaters for several conditions: (a) low-low steam drum water level (LT-311), (b) boiler water circulation pump (BWCP) not running, (c) heater inlet valve FCV-384 closed, or (d) high heater element temperature (TE-388). Each of these heater trip signals required a manual re-start of the heater subsequent to clearing the cause of the trip.

Operating experience indicated that the heat input required to have steam pressure reasonably close to 1100 psig at the end of the diurnal shutdown period tended to vary somewhat with such things as ambient conditions and length of the diurnal shutdown period. An automatic pressure controller for diurnal shutdown (EHAC) was incorporated into the control system to maintain a nominal steam pressure of 1100 psi. Using the steam drum pressure signal (PT-383) as the controller set point signal, each of five circulation heater circuits was energized and de-energized at specified steam pressures as indicated on Figure 3.1.

The same interlocks as noted previously for the manual operation of the heaters de-energized the heaters with EHAC "on"; however, when any of those trips was cleared, heaters would re-energize automatically. With EHAC "off", heater operaton was the same as described in the original control system, including the manual heater re-start requirement following a clear of any trip.

4.0 Circulation Heater Pressure Boundary Failure Incident

The scenario for the cause of the circulation heater pressure boundary failure was developed based on a review of data available subsequent to the incident. As noted previously, the CRTF H-P data acquisition system was down for maintenance on January 18; the system was not placed back in service for the night of January 18-19. SGS data signals which are fed to the Network 90 were stored at three minute intervals during the incident; this allowed trending plots of this data to be made. SGS temperature signals which are fed to the Acurex data logger were recorded at one hour intervals during the incident. The Network 90 trend plots and plots of the recorded Acurex temperature data as a function of time were provided to the attendees at the January 24 meeting at CRTF. At this meeting D. C. Smith, CRTF SGS Test Engineer, presented a review of the available data and a scenario for the cause of the pressure boundary failure based on that data. There was general agreement among the meeting attendees that the scenario presented was consistent with the data available. Following is a summary of the events which occurred during the incident. Figure 4.1 is a composite plot of the temperatures of interest as a function of time of day.

When the diurnal shutdown pressure controller (EHAC) was activated about 1500 hours on January 18, all circulation heater circuits (70 kw) were energized because of the low steam pressure in the SGS. During the period from 1500 to 2000 hours the saturated steam temperature (TE-383) rose at about a constant rate. During this period freezing occurred in both the steam drum pressure transmitter (PT-383) piping and steam drum water level transmitter (LT-311) piping. PT-383 froze with a relatively low signal of about 300 psi, while LT-311 froze with a signal out of range on the high water level end of the scale. The false low PT-383 signal continued to demand the full 70 KW heater power from the EHAC throughout the incident.

During the period from 2000 to 2330 hours saturated steam temperature (and pressure) remained about constant. Circulation heater element temperature TE-388 can be used as an indicator of whether or not the heaters were energized. The TE-388 interlock on the heater de-energizes the heaters above 565F; when TE-383 reduces below 565F the heaters are re-energized (with EHAC "on"). During this time period TE-388 reads about a constant 565F, indicating the heater was either on or cycling on/off during the period. Operating experience has indicated that on the order of 15 KW input from the heater is required to balance subsystem heat losses to maintain steam pressure. With 70 KW heater input when the heater is on, the steam produced by excess heater input was trying to raise subsystem steam pressure. At some pressure below the set pressure (1310 psig) of the pressure relief valve (PSV-381), this valve will start to "simmer", allowing steam to exit the SGS. With loss of steam through PSV-381, the SGS water inventory was being depleted throughout this period of time. When drum water level reached the low-low alarm point of -15 inches, the alarm interlock on heater operation would have de-energized the heaters; however, with the LT-311 signal frozen at the high end of the water level range this interlock was not activated, and water inventory continued to be depleted.

During the period from 2330 hours on January 18 to 0130 hours on January 19, the saturation temperature (and pressure) remained approximately constant. Based on TE-388 the heater was energized during the first half of this time period. A spike in the temperature of the evaporator inlet pipe (T/C 6006; Acurex Channel 231) up to 829F occurred at 0030 hours. T/C 6006 is located near the evaporator water inlet nozzle, about 13 feet downstream from the circulation heater outlet. On the basis of this high temperature it is hypothesized that steam temperatures in excess of this value were generated in the circulation heater for some time during the initial part of the 2330 to 0130 hour time period. As SGS water inventory continued to be depleted, the water level reduced to the top of the heated portion of the heater elements. As water level dropped below this elevation, steam production by boiling below the water level decreased, and the steam produced was superheated by the elements' surface above the water level. The exposed elements and the superheated steam increased the heater pressure boundary temperature to well in excess of the heater vessel design temperature of 566F. Heater element temperature thermocouple TE-388 was improperly located by the circulation heater vendor at the bottom of the element heated length rather than at the top. Had TE-388 been located at the top, when the heated portion of the elements became uncovered the resulting immediate rise in sheath temperature would have de-energized the heaters. (Had TE-388 been located at the top and caused the heaters to be de-energized when TE-388 exceeded 565F, the heaters, with EHAC on, would have re-energized when TE-388 dropped below 565F. The heater would have operated in an on/off cycling mode; however, further water inventory depletion would likely have been small, and the on cycle of the heater would likely have been short enough to prevent excessive pressure boundary temperature increases.) With TE-388 located at the bottom, the thermocouple remained in a water environment and below the trip temperature for some period of time while the upper portion of the heaters were uncovered. Eventually the combination of reducing water level in the heater and conduction axially in the heater sheaths was sufficient to raise TE-388 above the trip temperature and de-energize the heaters. During the latter portion of the 2330 to 0130 hr. period the heater remained de-energized, and the pipe temperature at the evaporator water inlet reduced to near the value at the beginning of the period.

Around 0130 hours the saturated steam temperature (and pressure) started to reduce. Based on TE-388, the circulation heater appears to remain de-energized until about 0330 hr. TE-388 may have remained above 565F due to heat input from the cooling of the heater pressure boundary and elements. After 0330 hr. the TE-388 data indicated that the heater was cycling on/off. The saturation temperature (and pressure) continued to decrease. This seems to indicate that water level in the heater was quite low. With low water level, insufficient steam was generated to maintain pressure, during heater on cycles. Also TE-388 heated up fairly rapidly causing heater cycling. During this on/off cycling, steam in the heater and the heater pressure boundary itself could again have been heated to temperatures in excess of the vessel design temperature. However, because of the low rate of steam production such temperatures were not in evidence in the evaporator inlet piping as indicated by T/C 6006.

At about 0456 hr., there was a rapid decrease in the saturation temperature which reflected the depressurization of the SGS due to the failure of the circulation heater pressure boundary. It is hypothesized that the failure was the result of the pressure boundary being at temperatures in excess of the heater design temperatures during all or part of the period from about midnight to 0500 hr. When R. L. Dowling arrived at the site at about 0700 hr. and discovered the failure, the boiler water circulation pump (BWCP) was still running, and the heater elements were continuing to cycle on/off. The BWCP was still running because the false drum water level signal prevented pump trip on low-low water level alarm. At about 0715 hr., the BWCP was stopped, and the heaters were de-energized.

5.0 Temperature Transients During the Incident

There are two temperature transients during the incident which are of interest in evaluating the effect of the incident on the Steam Generator Subsystem. The first is the temperature excursion which occurred sometime during the period between 2330 and 0130 hours as indicated by the change in the temperature of the evaporator inlet pipe. The second is the rapid decrease in saturation temperature which occurred at about 0500 hours as the result of the rapid depressurization of the subsystem.

Making an accurate assessment of the steam temperatures and component metal temperatures downstream of the circulation heater for the first temperature excursion is limited by the scarcity of data. Development of temperature profiles must be based on three T/C 6006 data points (580F, 829F, 640F) spaced at one hour intervals. Because of this large interval the 829F temperature does not necessarily represent the maximum temperature at T/C 6006. Also, T/C 6006 is not necessarily representative of the pipe temperature at the circulation heater outlet end of the piping. A steam temperature vs. time profile is estimated both at the circulation heater outlet end of the pipe and at the evaporator water inlet end of the pipe. The up ramp portion of these temperature ramps is affected by such things as the relationship between steam production rate and degrees superheat generated in the heater, the heat transfer coefficient on the pipe I.D. and its relation to steam flow rate and degrees superheat, the heat capacity of the piping, the temperature difference between the sheath surface and the superheated steam temperature in the heater, the heat loss from the heater through the insulation and the uninsulated heater element flanges, and potential churning and carryover of water droplets into the steam space above the water level in the heater. The down ramp portion of these temperature ramps is essentially controlled by heat losses to the ambient, as the heaters are de-energized during the down temperature ramp. At the end of the down temperaure ramp the steam temperature and pipe temperature will be essentially equal because the pipe insulation is the controlling resistance to heat transfer. Various quantitative and qualitative evaluations and judgments were made considering the above noted effects to develop the estimated steam temperature vs. time profiles at the heater outlet and at the evaporator inlet as shown on Figure 5.1. The maximum steam temperature at the heater outlet end is 950F and at the evaporator inlet end is 900F.

The data for the temperature excursion at the time of heater pressure boundary failure (0500 hr) indicate a decrease in saturation temperature from 472F to 240F in about 7 minutes. To conservatively bound this temperature decrease, the steam temperature is assumed to decrease instantaneously from 472F to 212F.

6.0 Assessment of the SGS for Damage as a Result of the Incident

6.1 Structural Assessment

Those portions of the SGS which might have been subjected to the effects of one or both of the temperature excursions discussed in Section 5.0 were evaluated for possible structural damage.

Effect on Piping

The list of pipe sizes in Table 6.1 includes those sizes which were affected by the high steam temperature increase/decrease transient (see Figure 6.1). For conservatism the pipe temperature was assumed equal to the steam temperature. All of the piping in the list is A106 Grade B piping material. ANSI B31.1 does not permit the use of this material above 800F. Also, the allowance for variation of pressure and/or temperature above design conditions in Par. 102.2.4 is related to the maximum allowable stress values in appendix A for the coincident temperature. The highest temperature in Appendix A for which an allowable stress value is given is 800F. This is significantly lower than the peak of 950F to which some of the piping was exposed.

Table 6.3 contains the stresses calculated for the various pipe sizes listed in Table 6.1 due to an internal pressure of 1180 psig. The stresses are calculated using the minimum pipe wall thickness (.875 x nominal thickness); however, no reduction is made for corrosion since the piping is at the beginning of its life cycle. The highest hoop stress occurs in the 4" schedule 80 piping with a value of 8.5 ksi. This is significantly higher than the allowable stress values at 950F listed in Table 6.2 for either ASME Section I (3.0 ksi) or for petroleum refinery piping (4.5 ksi). However, the yield stress at 950F for the piping material is 16.7 ksi and 8.5/16.7 = .509. Therefore, it is judged that no significant damage occurred to the A106 Grade B piping during the short term thermal transient to 950F as concerns the basic hoop stress.

Piping expansion stresses are adjusted in Table 6.4. The worst condition occurs in the evaporator inlet pipe at the 4" x 4" x 2" tee fitting because of the stress intensification factor. The values of 2Sy = 42800 psi and Su = 39600 psi are not exceeded at 950F. The stress range of 35159 psi consists of the stresses due to dead load, pressure and thermal expansion, none of which is reversible. Therefore the adjusted alternating stress is:

$$S_a' = \frac{1}{2}(35159)\left(\frac{30.0 \times 10^6}{18.5 \times 10^6}\right) = \underline{\underline{28500 \text{ psi}}}$$

The value of S_a' exceeds Sy, therefore the mean stress = 0. From the fatigue curve in Fig. I-9.1 of ASME Section III, the allowable number of cycles N 2.5 x 10^4. The contribution to fatigue damage for one cycle is not significant.

The increased piping forces and moments due to the temperature spike appear to be acceptable on the evaporator and steam drum nozzles.

Table 6.5 shows the maximum service pressure ratings for the flanged joints at temperatures over the range of the thermal transient. This table indicates that the 2" 900 lb flange at the circulation heater outlet connection should be examined for damage. The gasket seating surface should be checked for flatness to assure proper gasket sealing. The bolt circle should be checked for any out-of-flatness which could induce bending in the bolts. R. L. Dowling requested CRTF to inspect the flange. The results of the inspection indicate no distortion to the gasket seating surface or bolt circle region. As a matter of interest, inspection of the circulation heater outlet flange also showed no distortion.

The instantaneous drop in steam temperature and pressure at the time of heater pressure boundary failure should not have had a significant effect on the structural integrity of the piping.

Effect on Evaporator

The evaporator was analyzed for the steam temperature transient shown on Figure 6.1. The method of analysis of this transient as it applies to the evaporator envelopes the instantaneous down temperature ramp which occurs when the circulation heater pressure boundary failed.

A. Tubesheets

The effect of the temperature transient shown in Figure 6.1 was evaluated for the evaporator water inlet tubesheet. The evaluation was made using assumptions of a step change from 580F to 900F followed by a steady state condition and then a step change from 900F to 640F. A film coefficient of 1000 Btu/hr-ft^2-^{o}F was conservatively assumed. The tubesheet was assumed to be a flat unperforated plate in the evaluation. The fatigue usage factor for one cycle of this transient is negligible.

B. Water Side Shell

The evaporator shell on the water side is 0.875 inch thick compared with 2.0 inches thick for the tubesheet. Therefore, the thinner shell responds more quickly to a temperature change with a consequent reduction in stresses due to a through thickness thermal gradient. One cycle of the above described transient has no significant effect on the structural integrity of the evaporator shell.

C. Water Side Shell to Tubesheet Juncture

The effect of the transient on the discontinuity stresses at the juncture of the shell and tubesheet on the water side was investigated. The contribution to fatigue damage was found to be small, i.e., on the order of .0025 for a single cycle.

D. Salt Side Shell

The evaporator shell on the salt side is 0.322 inch thick compared with 0.875 inch thick on the water side. The effect of the water side transient on the salt side shell is buffered by the tubes and shroud. Any thermal motion at the shell to tubesheet juncture caused by the water side transient will be caused by temperature changes in the rim of the tubesheet (2.0 inches thick). The shell is much thinner and will closely follow the tubesheet temperature so that no significant discontinuity stresses will develop.

E. Tube-to-Tubesheet Welds

Fabrication data on tube expanding into the tubesheets were examined in conjunction with the tube contraction during the "down" thermal transient. It was found that the tube-to-tubesheet welds were not significantly affected even in the condition of the worst tolerance stack-up.

F. Water Side Heads, Handholes, and Drain Connections

The water side heads, handhole and drain connections have not been significantly affected by the single cycle of the transient which was described above.

G. Tubes

The tube design temperature is 900F, therefore the steam temperature transient on Figure 6.1 is not a concern for the evaporator tubes. The possibility of a tube to shell interference at the looped end of the evaporator was checked for the conditions of the tube being hotter than the shell such as might occur for the transient shown on Figure 6.1. With an average shell temperature of 580F, an average tube temperature of 844F would be required for the outer-most tube in the bundle to just contact the shell I.D. at the U-bend. Using a conservative approach to estimate the maximum average tube temperature during the transient on Figure 6.1 results in a tube temperature less than 844F; therefore, no interference occurs.

Effect on Steam Drum

The steam drum is subjected to the instantaneous down ramp of steam temperature and pressure which occurs at the point of circulation heater pressure boundary failure. There is no significant structural effect to any of the steam drum shells, heads, nozzles, or internals attachments as a result of one cycle of this transient.

6.2 Boiler Water Circulation Pump

As noted previously, the boiler water circulation pump (BWCP) operated throughout the incident, raising concerns about potential damage to pump internals. The fact that the pump continued to operate was viewed as an indication that sufficient water remained in the bearing cavity to maintain cooling and lubrication on the bearings. The pump was inspected on January 30. Visual inspection of the shaft and bearing surfaces indicated no damage. The shaft and bearings were measured and found to be within the allowable tolerance range as noted below.

	Actual Diameter	Allowable Diameter Range
Front bearing I.D.	.996"	.9955" - 1.000"
Rear bearing I.D.	.9985"	.9955" - 1.000"
Shaft O.D. @ front bearing	.993"	.990" - .993"
Shaft O.D. @ rear bearing	.993"	.990" - .993"

A few very minor pits were noted on the pump impeller. These pits were judged to be acceptable.

6.3 Water/Steam System Hydrotest

A hydrotest of the SGS water/steam system at 2100 psi was performed on February 1. No external pressure boundary leaks were noted, except at several locations with mechanical connections such as gaskets and valve packing. One of the flange gaskets on circulation heater inlet valve FCV-384 leaked; the gasket will be replaced. There was a slow leak through the valve seat on the chemical feed isolation valve HV-388; the valve will be disassembled and the seat area cleaned up. Several minor leaks through valve packing were corrected by tightening the packing nuts.

7.0 Review of the Water/Steam System Freeze Protection

7.1 Transmitters and Associated Piping

Each of the water/steam system transmitters and associated piping has been provided with an arrangement of heat tracing and insulation to maintain water in the transmitter lines above freezing. As described previously, on the night of the circulation heater pressure boundary failure, freezing in the drum water level (LT-311) and steam drum pressure (PT-383) transmitter lines resulted in false signals to the control system.

The following transmitters are located in the water/steam system:

Steam Drum Water Level	LT-311
Steam Drum Pressure	PT-383
Main Steam Flow	FT-311
Steam Delivery Pressure	PT-321
Feedwater Pressure	PT-386
Attemperation Steam Flow	FT-381

Sketches of the as-built conditions for the transmitters, piping, insulation, and heat tracing were prepared by the B&W site engineer for use in evaluating the freeze protection. These sketches are shown on Figures 7.1 through 7.5.

The following criteria were used to review the transmitter/piping freeze protection and to establish any refurbishment requirements:

1) For a minimum ambient temperature of $0^{o}F$ combined with the minimum SGS operating temperature at the transmitter piping connection location, no freezing in the transmitters/piping
2) For the maximum ambient temperaure at which the freeze protection heat tracing operates (40F) combined with the

maximum SGS operating temperature at the transmitter piping connection location, transmitter temperature to be less than 200F (to avoid transitter damage).

3) For a maximum ambient temperature of 115F combined with the maximum SGS operating temperature at the transmitter piping connection locations, transmitter temperature to be less than 200F.

4) Use of a range of insulation conductivity of .03 - .06 Btu/hr-ft-F.

5) To account for a range of calm to high wind conditions, use a convection coefficient range of 0.5 - 22 Btu/hr-ft^2-F.

6) Make any required refurbishment consistent with getting the SGS back on-line at the time the new circulation heater is delivered.

A review of the transmitter, piping, insulation, and heat tracing arrangements indicates that the general thrust of improving freeze protection while keeping transmitter temperatures below 200F should be to reduce heat losses as opposed to simply increasing power input to the heat tracing. One source of potential large variations in heat loss depending on ambient temperature and wind conditions is the uninsulated valve yokes and handwheels on the various shutoff valves on the instrument piping. By placing a wind shield over the portion of the valves which extends beyond the insulation, the heat loss and variability of the heat loss can be reduced. These wind shields will be simple metal "cans" placed over the valves which can easily be removed when valve opening/closing is required. To further reduce heat loss and improve heat tracing effectiveness, some previously uninsulated portions of instrument piping and valves will be insulated. Some short uninsulated sections of piping may remain on some transmitter piping to assure that the transmitter temperature does not exceed 200F at maximum ambient temperature conditions. The present wiring circuit for heat trace protection (HT-10) will remain as is. Thermocouples which can be read with a hand-held meter will be added at various locations to aid in evaluation of the freeze protection arrangements. Following is a summary of the planned refurbishment for each of the transmitter/piping arrangements.

Steam Drum Pressure Transmitter PT-383

Refer to Figure 7.1.

Add a 30" long, 7 ohm heat trace cable on the upper portion of the piping, starting at the upper termination point of the existing heat trace cable.

Add 3" insulation to presently uninsulated upper portion of the piping.

Add 3" insulation to the drain leg and valve.

Add valve wind shields as noted.

Add local T/C's as noted (*).

Note: The new heat trace cable will be wired on a new circuit; see discussion in Section 7.2.

Steam Drum Level Transmitter LT-311

Refer to Figure 7.2

Add 3" insulation to presently uninsulated section of upper horizontal piping.

Add 3" insulation to within 3" of the reservoir on the vertical piping.

On the lower horizontal piping connection to the steam drum, remove a 3" length of insulation as measured from the OD of steam drum insulation.

Add 3" insulation to drain legs and valves.

Add valve wind shields.

Add local T/C's as noted (*)

<u>Steam Delivery Pressure Transmitter PT-321</u>

Refer to Figure 7.3

Add 3" insulation to presently uninsulated piping on the lower horizontal run at the transmitter.

Add valve wind shields as noted.

Note: To prevent overheating the transmitter with the maximum SGS operating temperature of 950F in the steam delivery pipe, the vertical section of instrument piping must remain uninsulated. With a minimum SGS operating temperature of about 200F in the steam delivery pipe during diurnal shutdown combined with extreme ambient temperature and wind conditions, freezing may occur in this uninsulated pipe run. However, PT-321 serves no control or monitoring functon during diurnal shutdown. When the steam delivery temperature increases at the time the SGS is brought on-line for normal operation, any freezing incurred during diurnal shutdown will likely clear itself. Operating experience to date has never indicated a problem with the availability of the PT-321 signal for control/monitoring during normal operation.

<u>Main Steam Flow Transmitter FT-311</u>

Refer to Figure 7.4.

Add valve wind shields as noted.

Add local T/C's as noted (*)

Same note as for PT-321 above applies to FT-311.

<u>Feedwater Pressure Transmitter PT-386</u>

Refer to Figure 7.5.

Add 3" insulation to all uninsulated piping.

Add valve wind shields.

Add local T/C's as noted (*)

Note: With minimum operating temperature in the feedwater pipe during diurnal shutdown combined with extreme ambient temperature and wind conditions, freezing may occur in the upper horizontal run of the instrument piping. However, PT-386 serves no control function at any time. When the feedwater line temperature increases for normal operation, any freezing incurred during diurnal shutdown will likely clear itself.

Attemperator Steam Flow Transmitter FT-381

During preparations for changing the HT-10 circuit wiring in January it was discovered that the heat trace cable for the transmitter FT-381 transmitter piping had actually been installed on the steam attemperator piping. As FT-381 serves no control function (monitoring only), it has been decided to take the following course of action:

1) Evaluate the effectiveness of the refurbishment of the freeze protection on the other transmitters.

2) Using the lessons learned from the other transmitters, evaluate the freeze protection requirements for FT-381 including the requirement for heat trace cable.

3) Install a new heat trace cable for FT-381 freeze protection; this is the preferable course of action to removing the existing cable which would require removing and re-installing the attemperator pipe insulation.

4) Install the heat trace cable and re-insulate the transmitter piping.

7.2 Chemical Feed Piping

The chemical feed piping from the chemical feed pump to the feedwater pipe requires freeze protection. CRTF is providing freeze protecton from the pump to isolation valve HV-388; B&W will provide freeze protection from the isolation valve to the feedwater pipe. The original concept had been to locate HV-388 very close to the feedwater pipe connection point so that heat tracing between the valve and the feedwater pipe would not be required. Because of interference problems with other piping, the valve had to be located further away from the feedwater pipe, as shown on Figure 7.6.

A 30 inch long, 7 ohm heat trace cable will be added to the chemical feed pipe between HV-388 and the feedwater pipe and the 3 inch insulation will be re-installed. This cable will be wired in series with the 7 ohm cable being added to the PT-383 transmitter piping. A Variac will be used to control the power output of these cables. Power to these cables will run continuously. A wind shield will be added to the exposed portion of valve HV-388.

As noted on Figure 7.6, check valve CV-381 will be deleted from the piping. The chemical feed pump has an integral check valve, eliminating the need for CV-381. A vent valve has also been added to the line to facilitate drainage.

8.0 Review of SGS Controls and Interlocks

The SGS controls and interlocks have been reviewed. The following modifications will be made to the control system.

1. SNL will assure that the heater vendor locates heater element thermocouple TE-388 near the top of the heated portion of heater element HR-5. As discussed in Secton 4.0, this is a key element in preventing depletion of water inventory in the heater.
2. A quality check on the TE-388 signal will be added. Should the temperature signal go bad (e.g. T/C failure, loose wire), all power to the circulation heater will go off.
3. A current sensing relay will be added to the 480v. line on HR-5. Should current flow to HR-5 be disrupted (e.g. blown fuse, heater failure), the current sensing relay will cause all power to the heaters to go off. Because HR-5 has TE-388 on it, should HR-5 be de-energized while other heaters are operating, TE-388 would not be representative of the sheath temperature of an operating heater element, and therefore the ability of TE-388 to protect against element failure would be reduced.
4. A quality check on the LT-311 signal will be added. Should the water level signal go bad when EHAC is on (e.g. freezing in transmitter lines, loose wire), EHAC will go off and all power to the circulation heater will go off. Because the pressure differential across LT-311 is very small compared to the absolute system pressure, freezing in a transmitter line will cause a bad signal in virtually all cases. (Note: Heater elements can be energized manually with EHAC off and an LT-311 bad quality signal. This is necessary for heat-up from empty, prior to placing LT-311 in service.)

5. The controller set point signal for the automatic pressure controller (EHAC) will be changed from the saturation pressure signal PT-383 to the saturation temperature signal TE-383. This eliminates the concern of an erroneous PT-383 signal caused by freezing in the transmitter lines affecting the heater operation. The heater circuits will be energized and de-energized at the TE-383 temperatures indicated on Figure 8.1.

6. A quality check on the TE-383 signal will be added. Should the temperature signal go bad (e.g. T/C failure, loose wire), all power to the circulation heater will go off.

7. A pulse signal has been added to the Network 90 to prevent the BWCP from restarting automatically when a BWCP trip signal is cleared and the BWCP "on" signal is coming from EMCON. This change makes the pump starting requirements following a trip the same from both EMCON and Network 90.

8. Circulation heater element circuit HR-1 will be deleted from the diurnal shutdown automatic pressure control (EHAC). Based on operating experience, having HR-2 through HR-5 in EHAC is sufficient to maintain steam pressure in diurnal shutdown.

9. Interlocks in the control system will now de-energize the circulation heater for the following conditions:

   a) Low-low drum water alarm (LT-311)

   b) BWCP not running

   c) Heater inlet valve FCV-384 closed

   d) High heater element temperature (TE-388)

   e) Bad quality signal on TE-388

f) Loss of current flow to heater circuit HR-5

g) Bad quality signal on LT-311 with EHAC on

h) Bad quality signal on TE-383

The control system will be configured such that the heaters must be energized by a manual signal subsequent to clearing any of the heater trip conditions; no automatic re-energizing of heaters will occur.

9.0 Review of SGS Operating Procedures

The original SGS operating procedures were delineated in Revision 0 of the SGS Operating and Maintenance Manual. These procedures were incorporated into the General Steam Generation Procedures (GSGP) in Martin-Marietta document MCR-83-548, "Integrated Test Procedures for the Steam Generation Acceptance Testing". These are the procedures used to operate the SGS, together with the other subsystems, during testing. Throughout the period of SGS operation, revisions to the GSGP have been made to improve the procedures based on operating experience.

B&W is currently completing a review of the latest version of the GSGP. In general these procedures are acceptable. A marked copy of these procedures with B&W comments will be submitted under separate cover. With regard to potential operation of the SGS with frozen transmitters, cautionary statement(s) will be added at appropriate places in the procedures to indicate necessary operator action.

Figures and Tables

EHAC Set Points

for Heater Circuits On/Off

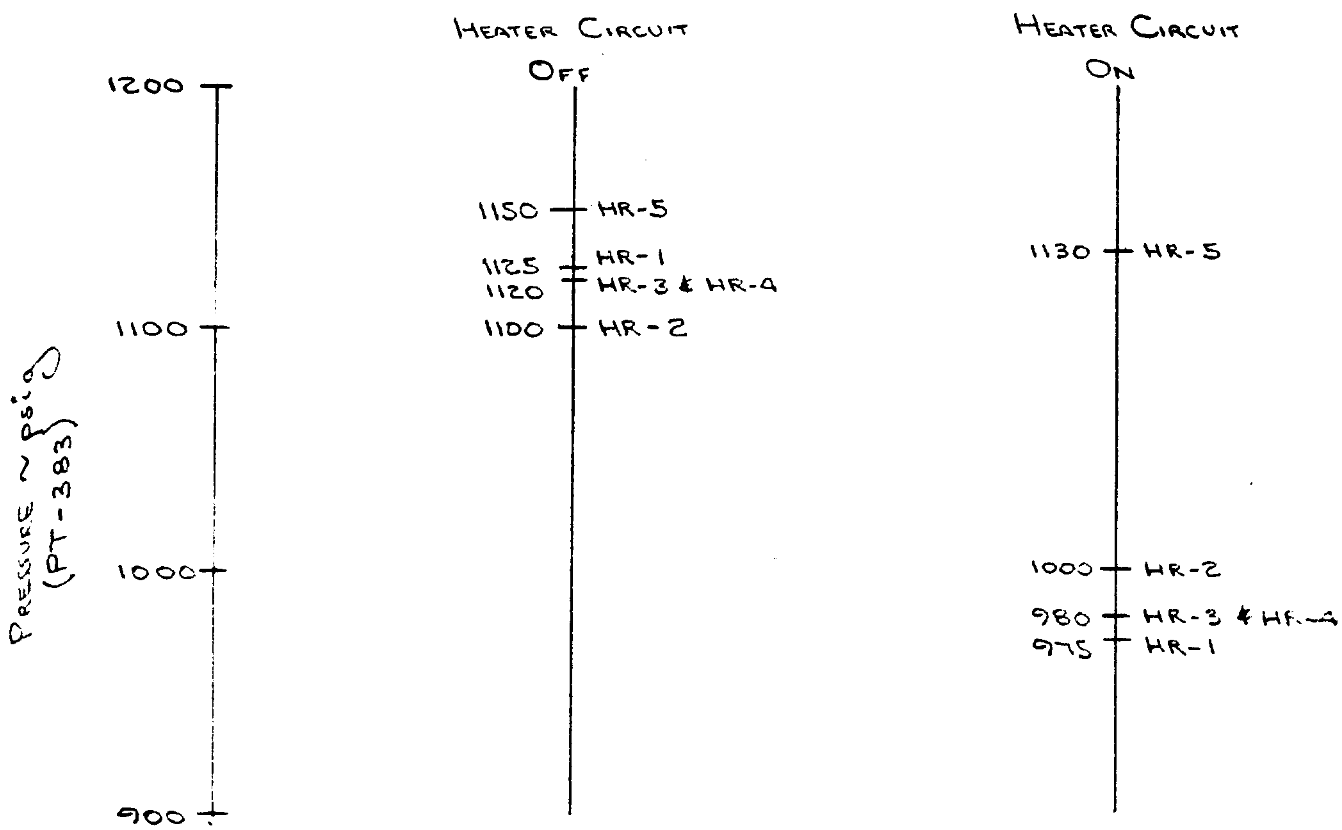


Figure 3.1

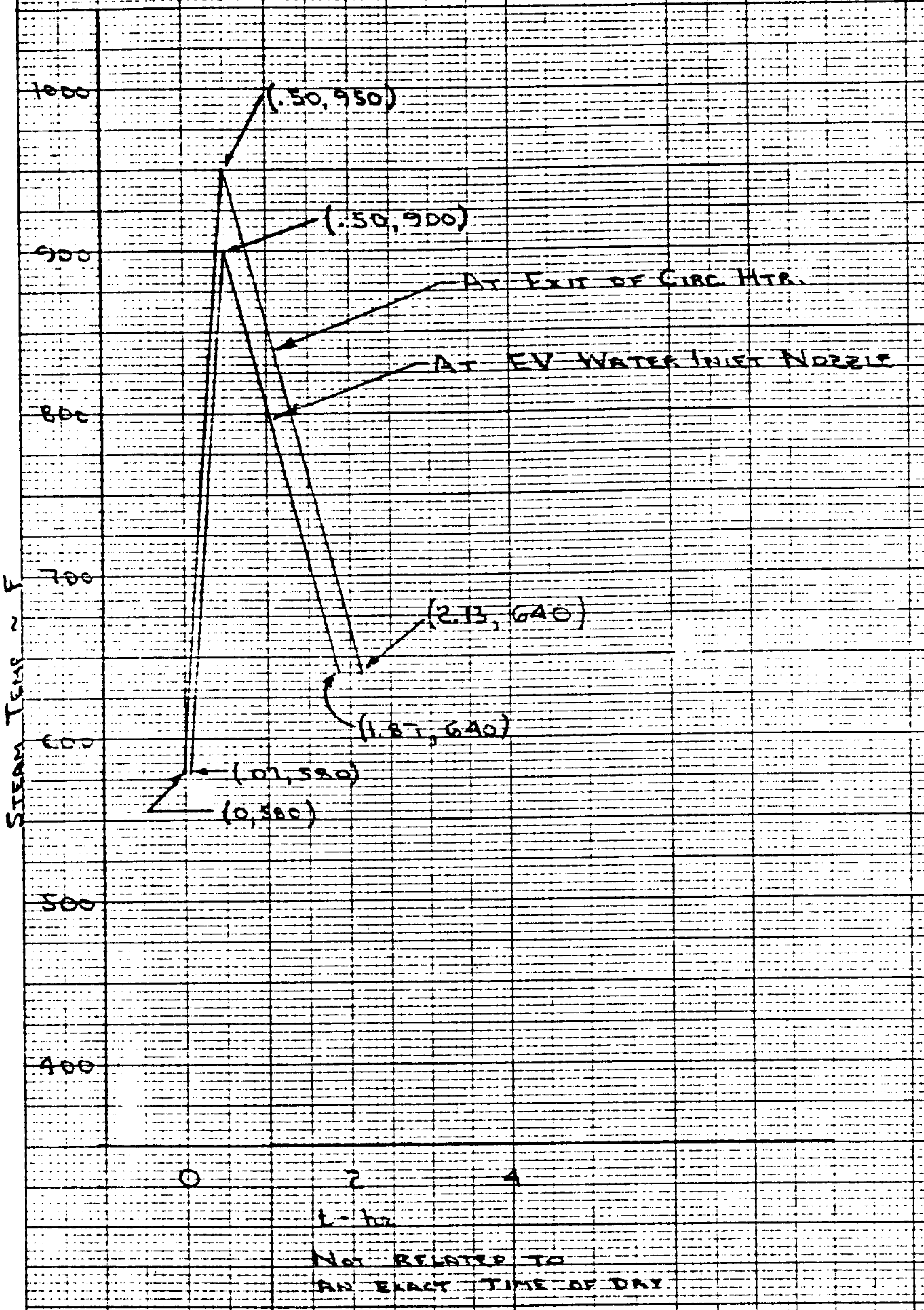

1000
900
800
700
600
500
400
STEAM TEMP ~ F
(.50, 950)
(.50, 900)
AT EXIT OF CIRC HTR.
AT EV WATER INLET NOZZLE
(2.13, 640)
(1.87, 640)
(.07, 580)
(0, 580)
0
2
4
t - hr
NOT RELATED TO
AN EXACT TIME OF DAY

FIGURE 5.1

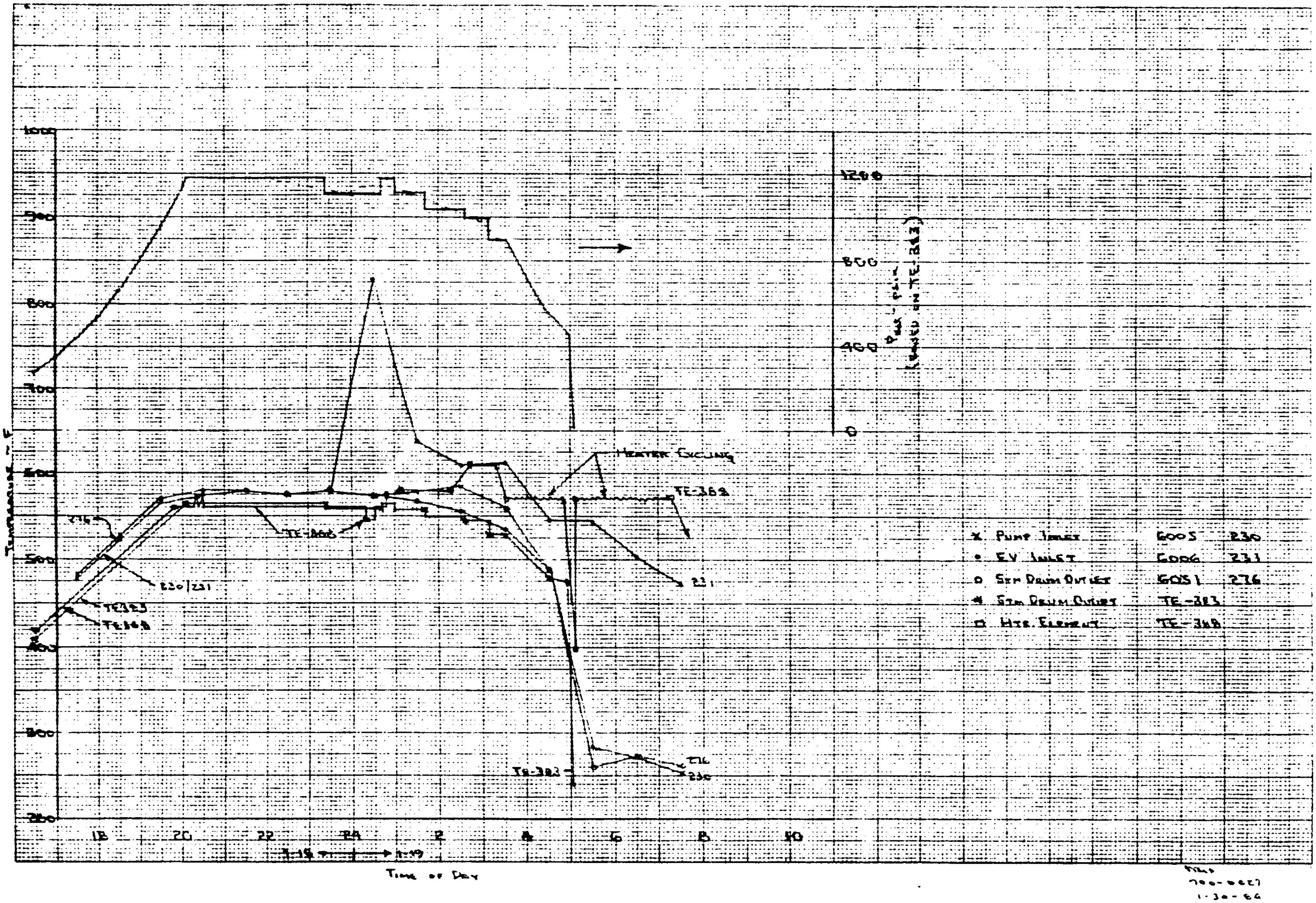

1000
900
800
700
600
500
400
300
1200
800
400
0
HEATER CYCLING
TE-368
TE-383
276
230/231
231
230
18
20
22
24
2
4
6
8
10
TIME OF DAY
× PUMP INLET 6005 230
• EV INLET 6006 231
o STM DRUM OUTLET 6051 276
STM DRUM OUTLET TE-383
□ HTR. ELEMENT TE-368

FIGURE 4.1

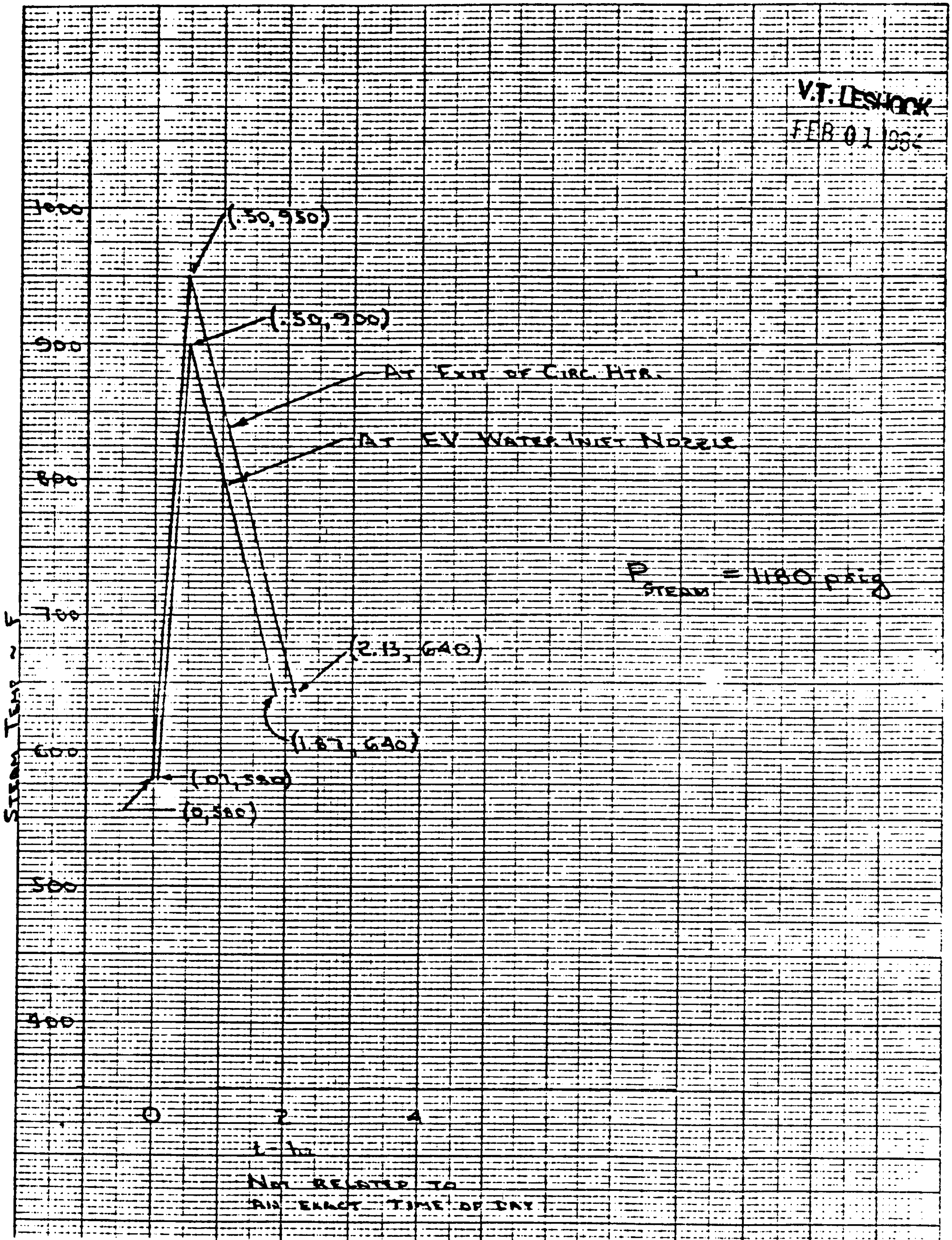


FIGURE 6.1 TEMPERATURE TRANSIENT PRIOR TO RUPTURE

MSEE: TABLE 6.1 PIPING EXPOSED TO THE ELEVATED TEMPERATURE TRANSIENT

DWG Nº	ITEM	NOTES	PIPE SIZE	MAT'L
179933C	EVAP WATER INLET PIPING	1	4" SCH 80	A106 Gr.B
179934C	" " OUTLET " (RISER)	—	4" SCH 80	"
179935C	SH INLET PIPING	2	1" SCH 80	"
		—	2½" SCH 80	"
179946C	CIRC HTR OUTLET PIPING.	3	2" SCH 80	"

NOTES:

1. INCLUDES 2" 1500# RF WN FLG & 4" VALVE MK 4301.
2. " 1" VALVE MK 4901.
3. " 2" 900# RF WN FLG

MSEE: TABLE 6.2 ALLOWABLE STRESS VALUES FOR A106 Gr B

SE = MAXIMUM ALLOWABLE STRESS VALUE IN TENSION PER TABLE A-1 OF ANSI B31.1 1977 Ed PLUS ADDENDA THROUGH WINTER 1979.

E = 1.0 FOR SEAMLESS PIPE.

TEMP, °F →	-20 → 650	700	750	800	850	900	950
SE, KSI →	15.0	14.3	12.9	10.8	(1)	(1)	(1)
Su, KSI →	60.0	60.0	59.4	55.1	50.2	44.6	39.6
Sy, KSI →	@ 650F 25.4	25.2	24.4	23.3	22.5	22.2	21.4
$E \times 10^{-3}$, KSI →	25.7	24.8	24.2	23.4	22.1	18.5	16.7
SE, KSI (2)	15.0	14.4	13.0	10.8	(7.8) (3)	(5.0)	(3.0)
SE, KSI (4)	15.0	14.4	13.0	10.8	8.6	6.5	4.5

(1) ANSI B31.1 ADVISES THAT A106 GR B MAT'L SHOULD NOT BE USED AT DESIGN TEMP ABOVE THOSE FOR WHICH STRESS VALUES ARE GIVEN

(2) DATA FROM ASME-SECT I, TABLE PG-23.1 FOR SA-106 Gr B.

(3) STRESS VALUES ARE PERMISSIBLE BUT, EXCEPT FOR TUBULAR PRODUCTS 3 IN. O.D. OR LESS ENCLOSED WITHIN THE BOILER SETTING, USE OF THE MATERIAL AT THESE TEMPERATURES IS NOT CURRENT PRACTICE UNDER SECT. I

(4) FOR PETROLEUM REFINERY PIPING.

TABLE 6.3 HOOP STRESS IN PIPES.

PIPE SIZE[1]	D_o, IN	t_{NOM}, IN	t_{MIN},[2] IN	SE,[3] KSI	
1" SCH 80	1.315	.179	.1566	4.5	
2" SCH 80	2.375	.218	.1908	6.9	
2½" SCH 80	2.875	.276	.2415	6.6	
4" SCH 80	4.500	.337	.2949	8.5	

NOTES:

(1) All piping material is ASTM 106 Grade B.

(2) $t_{MIN} = .875\ t_{NOM}$.

(3) Hoop stress in the pipe is calculated using ANSI B31.1, Par 104.1.2, equation 4:

$$SE = P\left(\frac{D_o}{2t_m} - y\right)$$

where, A = 0.0, y = .4,
E = 1.0 for seamless pipe
and P = 1180 psig.

TABLE 6.4 ADJUSTED PIPING STRESSES.

PIPE	REF.	SEQ. Nº	$\sigma_{PRESS + D.L.}$, PSI	$\sigma_{THERMAL}$ PSI	NEW TEMP., °F	K_{TH}	$K_{TH}\sigma_{TH}$, PSI	σ_{TOTAL} (3)
EVAP. INLET	DAPGJOE (WL3)	6 END (TEE)	8215	14845	950	1.815 (1)	26944	35159 ⇐ MAX
		11 END (RED)	5524	12842	↓	↓	23308	28832
		12 END (PUMP DISCH)	5245	7026	↓	↓	12752	17997
		1 BEG (EV INLET)	5305	1658	↓	↓	3009	8314
		50 BEG (HTR OUTL)	5377	2119	↓	↓	3846	9223
		60 BEG (HTR INL)	8621	2831	↓	↓	10313	18934
RISER	DAPGJUQ (WL4)	1 BEG (EV OUTL)	4927	5682	900	1.698 (2)	9648	14575
		5 BEG (ELBOW)	4704	8744	↓	↓	14847	19551
		11 END (STM DRUM)	5420	5568	↓	↓	9454	14874
~~DCMR~~	~~DAPGJ62~~ (WL2)	~~101 BEG~~ (STM DRUM)	~~4807~~	~~3977~~			~~6753~~	~~11560~~
		~~115 END~~ (RED)	~~4997~~	~~24010~~			~~40769~~	~~45766~~
		~~117 END~~ (PUMP SUCT)	~~5826~~	~~13276~~			~~22543~~	~~28369~~
SH INLET	DAPGJWJ (WL5)	1 BEG (STM DRUM)	3807	8844	↓	↓	15017	18824
		17 END (SH INL)	3604	3788	↓	↓	6432	10036

(1) $K_{TH}\big|_{950F} = \dfrac{|\alpha \cdot \Delta T|_{950F}}{|\alpha \cdot \Delta T|_{600F}} = \dfrac{(7.905\times10^{-6})(950-70)}{(7.23\times10^{-6})(600-70)} = \underline{\underline{1.815}}$

(2) $K_{TH}\big|_{900F} = \dfrac{|\alpha \cdot \Delta T|_{900F}}{|\alpha \cdot \Delta T|_{600F}} = \dfrac{(7.84\times10^{-6})(900-70)}{(7.23\times10^{-6})(600-70)} = \underline{\underline{1.698}}$

(3) $2S_y$ = 42800 psi @ 950°F & 44400 psi @ 900°F ; S_u = 39600 psi @ 950°F & 44600 psi @ 900°F

1/27/84

Heat Trace Stm. Drum Pressure Transmitter

Heat Trace Current 2.17A

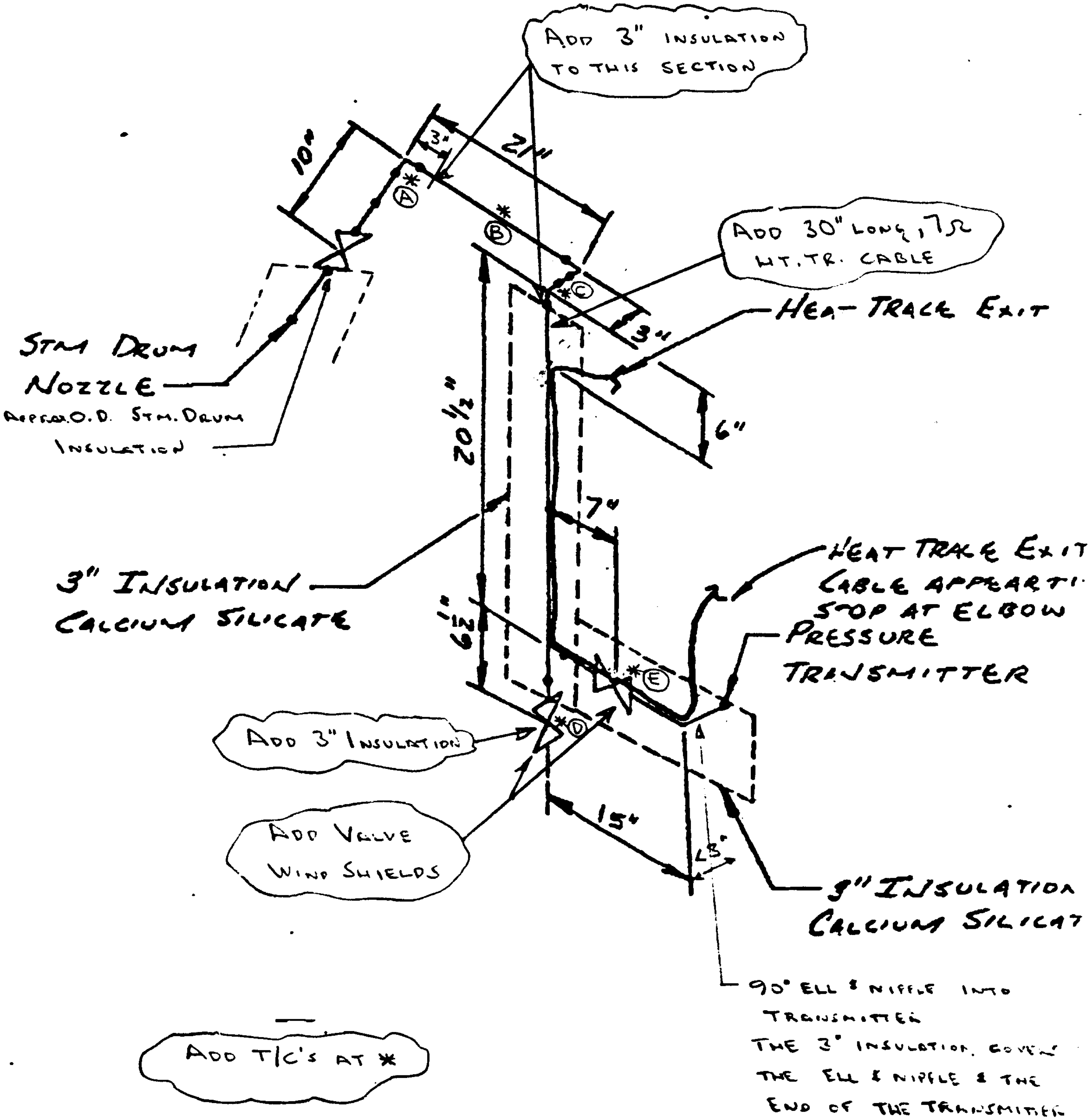
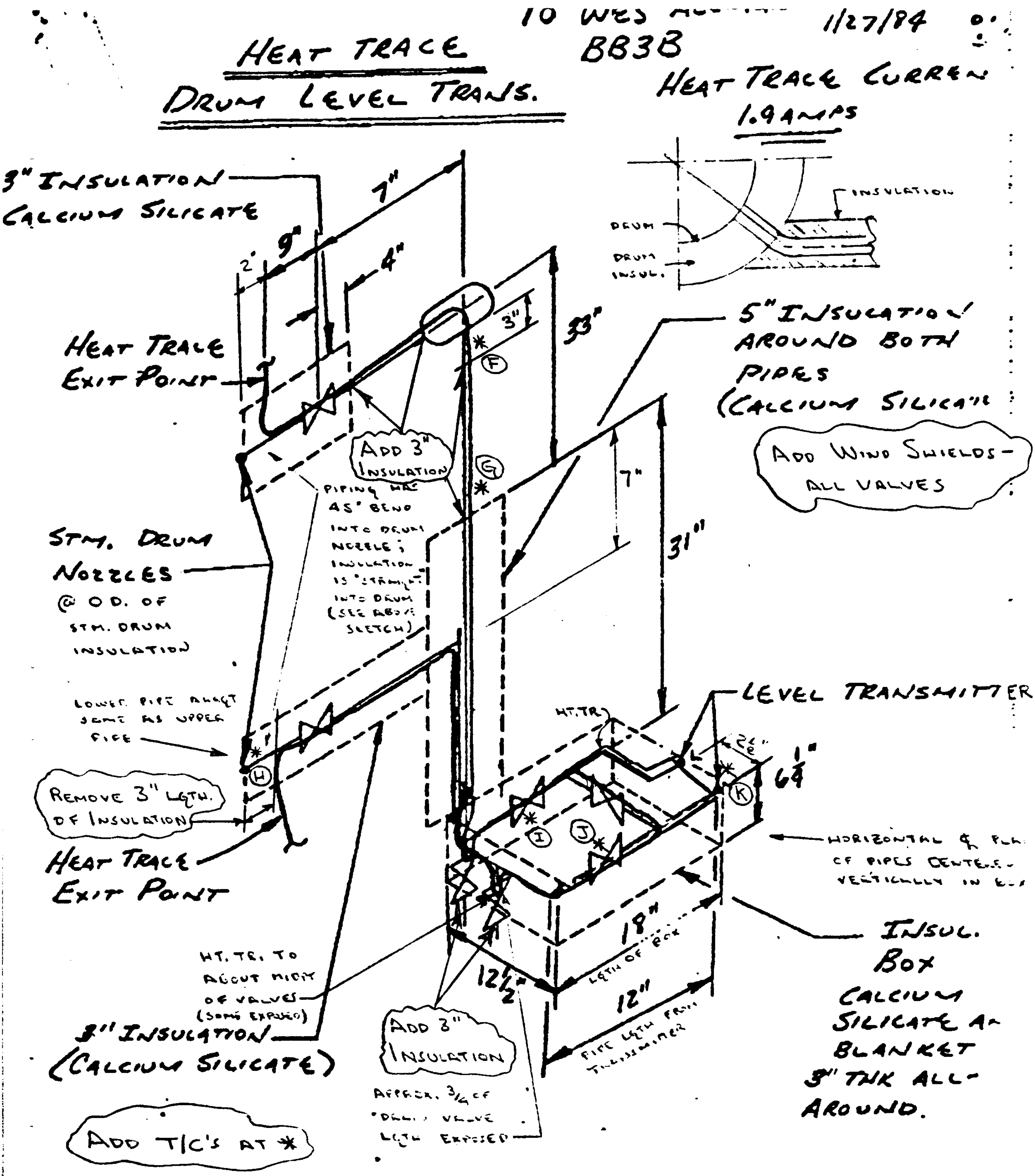


Figure 7.1



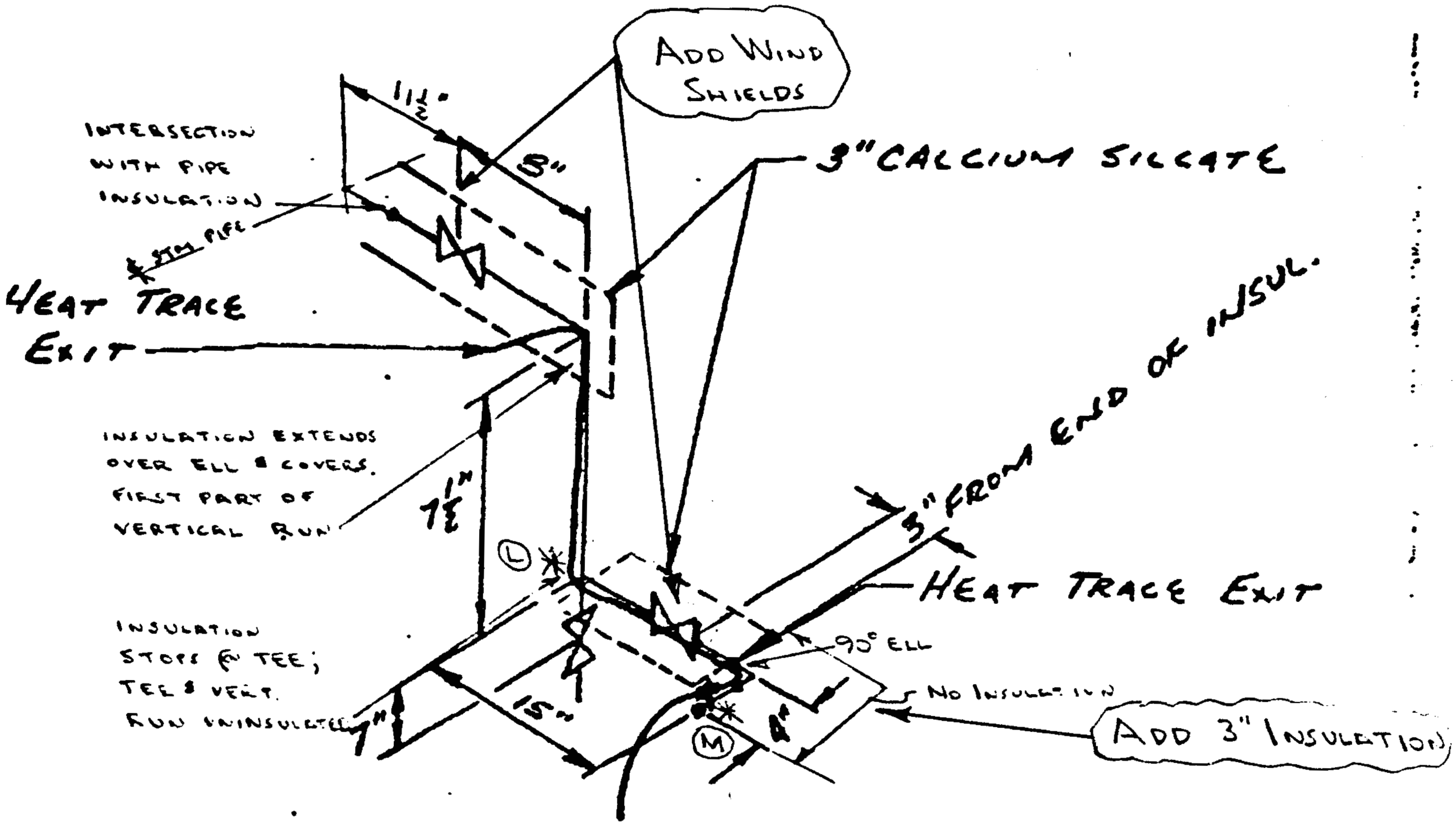
W.A. ALLMAN
JAN 31 1984

FIGURE 7.2

1/27/84

HEAT TRACE
STM DELIVERY PRESSURE TRANSMITTER

HEAT TRACE CURRENT 2.17A



ADD T/C's @ *

FIGURE 7.3

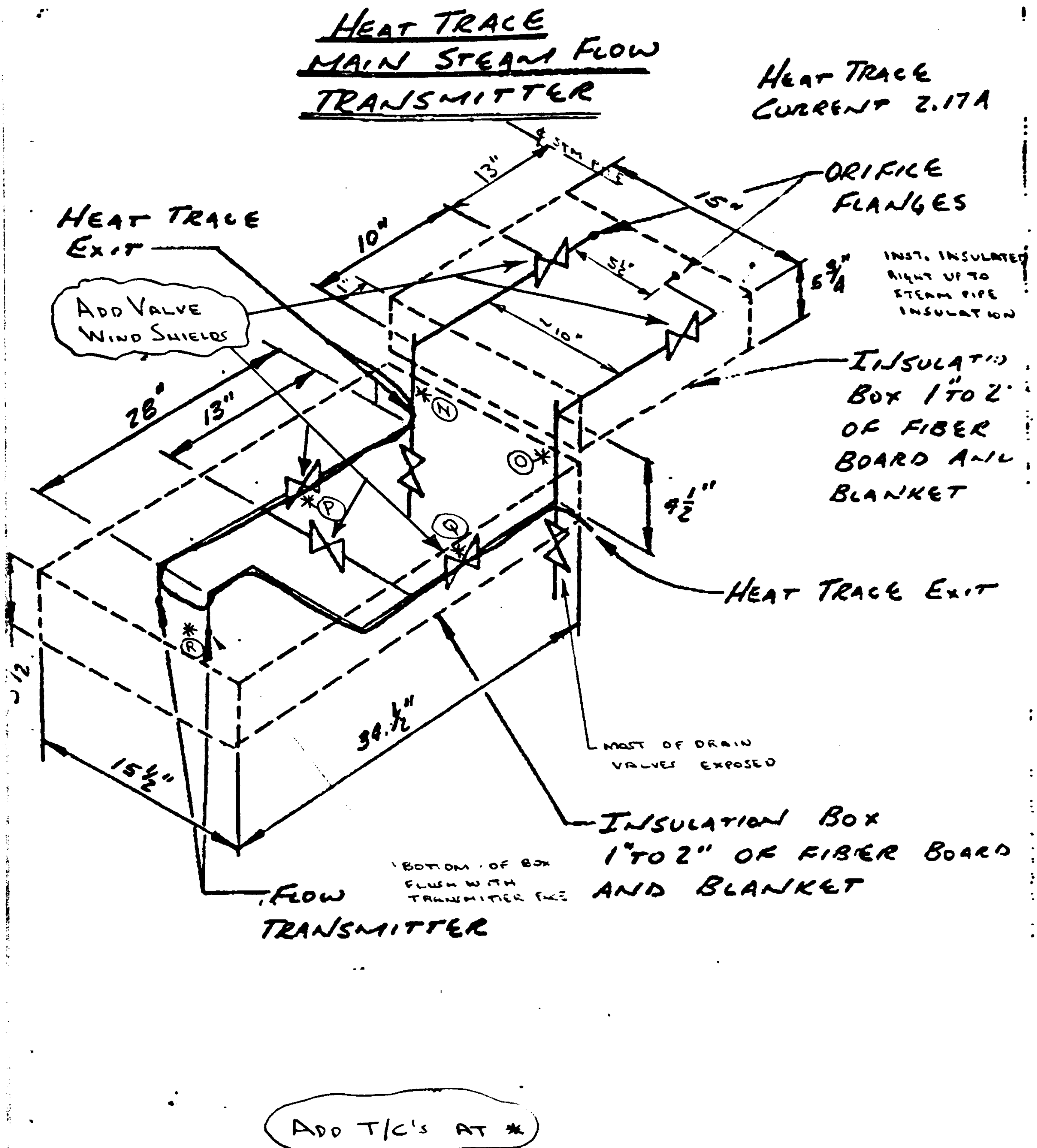

HEAT TRACE
MAIN STEAM FLOW
TRANSMITTER
HEAT TRACE
CURRENT 2.17A
ORIFICE
FLANGES
13"
15"
10"
5½"
5¾"
~10"
1"
INST. INSULATED
RIGHT UP TO
STEAM PIPE
INSULATION
HEAT TRACE
EXIT
ADD VALVE
WIND SHIELDS
INSULATION
BOX 1" TO 2"
OF FIBER
BOARD AND
BLANKET
28"
13"
N
O
P
Q
R
4½"
HEAT TRACE EXIT
MOST OF DRAIN
VALVES EXPOSED
34½"
15½"
INSULATION BOX
1" TO 2" OF FIBER BOARD
AND BLANKET
BOTTOM OF BOX
FLUSH WITH
TRANSMITTER FACE
FLOW
TRANSMITTER
ADD T/C'S AT *

FIGURE 7.4

1/27/84

Heat Trace Feedwater Pressure Transmitter

Heat Trace Current 2.17A

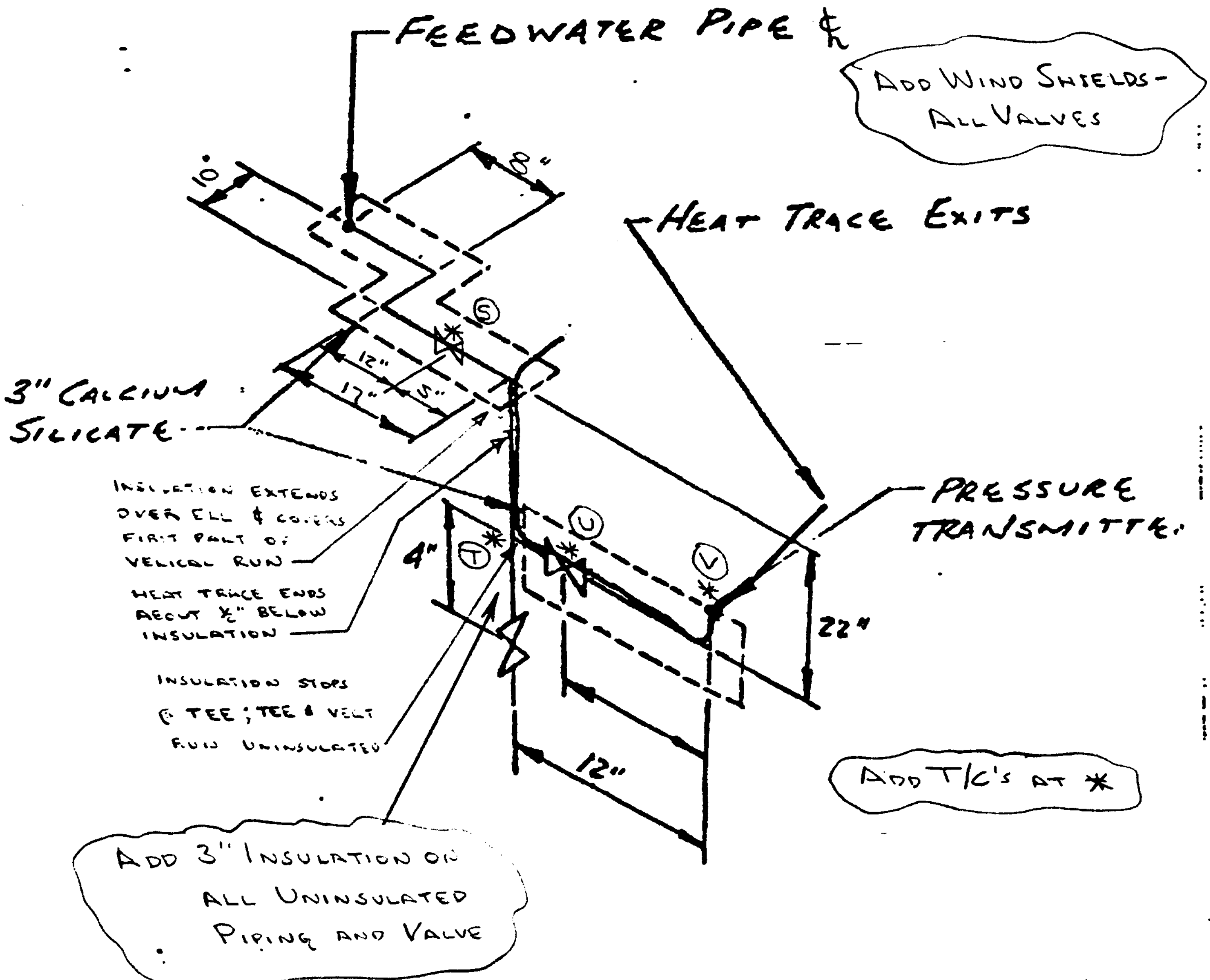
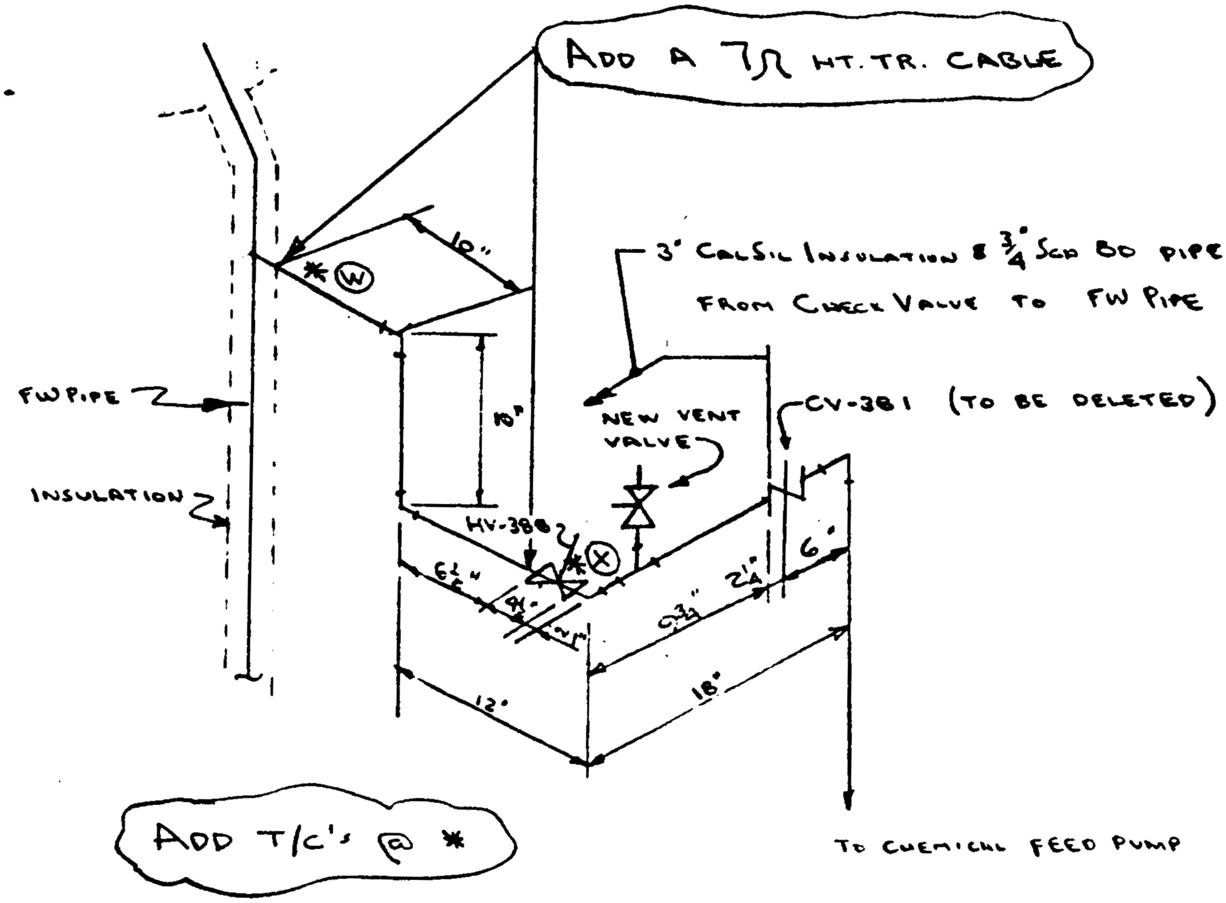


Figure 7.5

CHEMICAL FEED LINE



BEW TO PROVIDE HEAT TRACE FROM FW PIPE TO ISOLATION VALVE HV-388; CRTF TO PROVIDE HT. TR. FROM ISO. VALVE TO PUMP AREA.

FIGURE 7.6

Revised EHAC Set Points for Heater Circuits On/Off

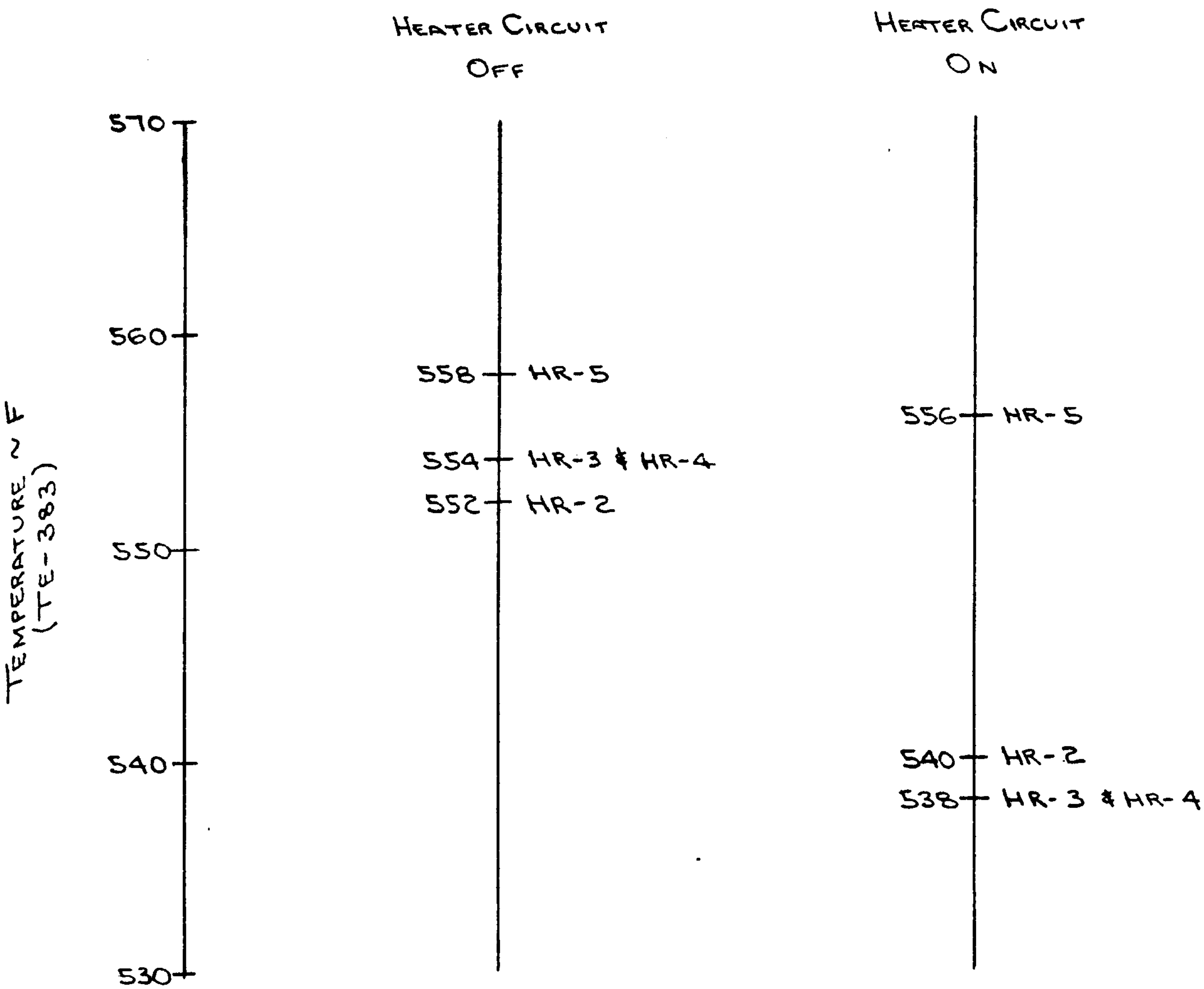


Figure 8.1

MSEE: TABLE 6.5 MAXIMUM NON-SHOCK SERVICE PRESSURE RATINGS FOR CARBON STEEL FLANGES (CATALOG VALUES)

	MAX. PRESSURE, PSIG				
	800°F	850°F	900°F	925°F	950°F
2" 900# RF WN FLG	1100	900	670	565	465
2" 1500# " " "	1830	1500	1115	945	770
2" 2500# " " "	3050	2500	1855	1570	1285
2½" 1500# " " "	1830	1500	1115	945	770

The change in allowable pressures are as follows:

1. $P_{850F} = \frac{900}{1100} P_{800F} = 0.8182\, P_{800F}$

2. $P_{900F} = \frac{670}{900} P_{850F} = 0.7444\, P_{850F}$

3. $P_{925F} = \frac{565}{670} P_{900F} = 0.8433\, P_{900F}$

4. $P_{950F} = \frac{465}{565} P_{925F} = 0.8230\, P_{925F}$

APPENDIX C

Pre-Operational Checkout List

SGS STAND-ALONE CHECKOUT

I. Valve Calibration

			Initials/Date
A	FCV-301		EB 7/28/83
B	FCV-321		EB 7/28/83
C	FCV-331		EB 7/28/83
D	FCV-341		
E	FCV-384		RLD 7/28/83 OPEN/CLOSED W/SWITCH
F	FCV-381		RLD 7/28/83
G	FCV-382		RLD 7/28/83
H	FCV-351	(CRTF System)	RLD 7/28/83
I	FCV-411	(CRTF System)	

II. Thermocouple Indication - Verify reading, proper channel, and comparison of EMCON and Network 90, if applicable.

A. Control T/C's

		READING AMB. °F	
1	TE-382	68	RLD 7/7/83
2	TE-383	83	
3	TE-384	78	
4	TE-386	91	
5	TE-331	68	
6	TE-332	78	
7	TE-301	90	
8	TE-388	82 °F	RLD 7/28/83

REMARKS:

B. Heat Trace T/C's

			READING AMB.	
1	AB 3117	HT-1	63.7	RLD 7/13/83
2	BCG 8118		63.7	
3	JEJ 3213	HT-2	65.2	
4	KDK 3214		63.4	
5	FG 3320	HT-3	78.4	
6	IJ 3321		74.6	
7	FL 3322		75.1	
8	MN 3421	HT-4	70.8	
9	NO 3422		91.2	
10	OQ 3423		63.6	

11	RS 3509	HT-5	59.9	RLD 7/13/83
12	UT 3510		55.8	
13	SV 3511		55.6	
14	YZ 3215	HT-6	59.7	
15	WX 3424		66.7	
16	AABB 2219	HT-7	63.3	
17	AABB 2220		59.7	
18	CCDD 2120	HT-8	58.5	
19	CCDD 2121		57.5	
20	EEGG 4117	HT-9	60.1	

REMARKS:

C. Informational T/C's

		AMB. READING °F	
1	6005	82	RLD 7/13/83
2	6006	102	
3	6007	81.3	
4	6008	DEFECTIVE NOT USED	
5	6009	83.1	
6	6010	DEFECTIVE NOT USED	
7	6011	81.3	
8	6012	81.1	
9	6013	81.6	
10	6014	81.0	
11	6015	79.8	
12	6016	79.5	
13	6017	T/C NOT USED	
14	6018	T/C NOT USED	
15	6019	T/C NOT USED	
16	6020	82.4	
17	6021	88.6	
18	6022	86.3	
19	6023	78.2	
20	6024	82.4	
21	6025	81.7	
22	6026	85.8	
23	6027	78.4	
24	6028	79.4	
25	6029	79.6	
26	6030	85.7	
27	6031	93.8	
28	6032	95.8	
29	6033	95.0	

30	6034	95.0	RLD 7/13/83
31	6035	95.2	
32	6036	81.6	
33	6037	90.4	
34	6038	81.2	
35	6039	86.8	
36	6040	81.6	
37	6041	80.7	
38	6042	84.6	
39	6043	83.1	
40	6044	101.7	
41	6045	82.4	
42	6046	83.5	
43	6047	83.3	
44	6048	81.4	
45	6049	83.2	
46	6050	111.1	
47	6051	99.3	
48	6052	83.4	
49	6053	87.3	
50	6054	T/C NOT USED	

REMARKS:

CHECKED END TO END FROM SGS TO ACUREX ON 7/18/83 TO INSURE PROPER CHANNEL CONNECTION. ALL TEMPS WITHIN REASONABLE RANGES.

III. Heat Trace Cable -- Check resistance, megger, and heating capability for 1/2 hour.

A. Check resistance, megger, and AMP of each circuit

	RESISTANCE	MEGGER	AMP	
1. HT-1	40.91	OK	6A	RLD 7/19/83
2. HT-2	74.15	OK	3.1A	
3. HT-3	47.82	OK	4.8A	
4. HT-4	38.83	OK	6.0A	
5. HT-5	54.48	OK	4.2A	
6. HT-6	91.11	OK	2.5A	
7. HT-7	26.48	OK	9.0A	
8. HT-8	12.65	OK	20 A	
9. HT-9	64.68	OK	1.1	
10. HT-10	67.17	OK	1.4	

REMARKS: HT-4 PRIMARY CABLE 3412 FOUND DEFECTIVE AND SWITCHED WITH 3412 REDUNDANT. ONE 3412 REDUNDANT CABLE REMAINING. HT-10 CABLE 4628 NOT IN FREEZE PROTECTION CIRCUIT AT THIS TIME.

B. Verify heating capability or each heat trace zone for 1/2 hour of operation.

	INITIAL - °F	FINAL - °F		
1. HT-1	94.9	158.9	RLD	7/21/83
	97.8	152.1		
	86.7	109.0		
	88.8	130.9		
	108.3	209.3		
	121.9	233.1		
	99.5	203.7		
	90	136.9		
	98.1	181.6		
	108.9	243		
	129.1	238.8		
	132.2	237		
	103.4	172.8		
	99	110		
	101.4	117.7		
	88.2	98		
	85	95.4		
	87.6	100.3		
	87.5	107.1		
	86.1	93.6		

REMARKS: Zones HT-7 and 8 lag the rest of the system and will probably be turned on early to permit uniform heating. HT-7 and 8 are the evaporator and superheater.

IV. Circulation Heater - Energize each circuit and monitor amperage. Verify TE-388 on HR-5 heater.

		AMP.		
A	HR-1	39/37/39	RLD	7/30/83
B	HR-2	20/19/20		
C	HR-3	14/14		
D	HR-4	13/13		
E	HR-5	12/11		

REMARKS: WHEN ENERGIZING HR-5, THE TE-388 TEMPERATURE IMMEDIATELY JUMPS 30°F INDICATING THAT THE TE-388 THERMOCOUPLE IS ON THE PROPER HEATER

V. Boiler water circulation pump — Verify rotation, verify sensing relay operational, verify coolant flow switch contact closed, and Amp per phase.

A.	Rotation		RLD 6/7/83
B.	Sensing Relay Energized		RLD 7/30/83
C.	Coolant Flow Switch Closed		RLD 7/30/83
D.	Amperage/Phase	4 - L1 4.5 - L2 4 - L3	RLD 7/30/83

REMARKS:

VI. Transmitters -- Calibrate

A	FT-311	RLD 6/23/83
B	FT-381	RLD 6/23/83
C	LT-311	RLD 6/23/83
D	PT-386	BE 6/24/83
E	PT-383	BE 6/24/83
F	PT-321	MS 7/18/83
G	FT-321	FACTORY CALIBRATED
H	FT-382	FACTORY CALIBRATED
I	PT-382	FACTORY CALIBRATED
J	PT-384	FACTORY CALIBRATED

REMARKS: FT-321 WILL REQUIRE ADJUSTMENTS IN ZERO AND SPAN DURING OPERATION. PT-382 ZERO WAS SET FOR A 4 psi SHIFT IN THE READING ON THE N90.

VII. Electrical Check SGS to N90/EMCON

A.	Check manual signals and set points from EMCON	RLD/TG 6/27/83
B.	Check valve, transmitter, and T/C signals to EMCON and N90 for consistance	RLD/TG 6/27/83

REMARKS:

APPENDIX D

Signed Off SGS Integrated Test Procedures

4.2.1 SGITP#1 Initial Control Loop Checkout

PURPOSE: The control loop checkout of 9 controllers. Each control loop will be tested at normal conditions and with steps response tests to introduce transient flows, temperatures or pressures.

DESCRIPTION: Using parts of GSGP#2 (manual SGS Startup), the SGS, HRFS, and TSS will be brought up to On Line (30% loading) incrementally. Each of the 6 HRFS and 2 of the TSS control loops will be checked out during the startup, once the system conditions will allow their automatic control. The system condition at the end of the test is On Line at 30% loading.

OBJECTIVES:

a) Checkout of system and components

b) Control loop tuning of:
- Immersion Heater Control
- Feedwater Pump Pressure
- Deaerator Pressure Control (partial)
- Cold Sump Level Control
- Hot Sump Level Control (partial)
- Feedwater Flow/Steam Drum Level Control
- Steam Pressure Control
- Feedwater Temperature Control (partial)

c) Instrumentation checkout

d) Demonstration of control stability

e) Test crew familiarization with system operation

CONTROL LOOP TUNING SUCCESS CRITERIA: A feedback control loop shall have a response time that is suitable for the function being performed, and the response shall be well-damped over the operating range. It shall be a design goal that closed-loop responses exhibit damping equivalent to 0.5 to 1.0 in a second-order system over the operating range, with no limit cycling under steady state conditions.

SGITP#1

Each of the instrumentation channels involved in this test will be checked out by observing the displays on the EMCON console. The actual measurements will be checked for reasonableness with Network 90 readings and expected values.

When going through a complete SGS startup, the HRFS requires a TBD hours warmup period with 390°F water circulation prior to accepting SGS steam flow.

STEP	DESCRIPTION	VERIFICATION
1.	Using GSGP#2 (manual SGS Startup) Empty to Diurnal Shutdown sequence, perform steps 1 thru 6.	JWH (10/11/83)

NOTE

The next activity will be the checkout of the DTC-451 Deaerator Immersion Heater Control.

2.	Perform the control loop tuning activity of the DTC-451 Deaerator Temperature Control.	PERFORMED BY CRTF PRIOR TO SGS TESTING

NOTE

Perform GSGP#2 (Empty to Diurnal Shutdown sequence) step 10 prior to reaching 170°F (TT-451).

~~3.~~	~~Perform GSGP#2 (Empty to Diurnal Shutdown sequence) step 7 thru 10.~~	
4.	Perform a step response test to introduce step changes in the DTC-451 temperature set point (normally 390°F with 217 psi).	
	a) Set FCV 432 in manual with 100% output (all flow to DA).	
	b) Increase the set point to 395°F (232 psi).	
	c) Increase the set point to 400°F (246 psi).	
	d) Return the set point to 390°F.	JWH (10/12/83)

NOTE

The next activity will be a partial control loop checkout of the FCV 401 Feedwater Pump Pressure Control. Should the control loop, during the pressure variation tests, show incorrect response, accomplish the control loop tuning engineering activity. Following this, return to the initial portion of the checkout and reaccomplish the control loop checkout.

- FW Pump pressure range: 1230 to 1280 psig

5.	Activate FCV 432 Deaerator Pressure Control with a set point of 233 psi. (Pressure should return to 233 psi and temperature to 390°F.)	JWH (10/12/83)

STEP	DESCRIPTION	VERIFICATION

6. *With the DA at 390°F and 233 psi, perform a step response test to introduce low amplitude pressure changes into the partial feedwater flow (FCV 411 is closed). Using increments, change the FCV 401 set points as specified below. Maintain the specified condition until the pressure control settles.*

   a) *Decrease the set point from 1250 to ~~1240~~ 1230 psi.*

   b) *Increase the set point from ~~1240~~ 1230 to ~~1260~~ 1270 psi.*

   c) *Decrease the set point from ~~1260~~ 1270 to 1250 psi.* JWH (10/12/83)

7. *Repeat step 6 except change to higher amplitude pressure changes.*

   a) *Decrease the set point to 1210 psi.*

   b) *Increase the set point to 1290 psi.*

   c) *Decrease the set point to 1210 psi.*

   d) *Increase the set point to 1250 psi.* JWH (10/12/83)

NOTE

Continue to monitor PT-401 pressure until the FWP Pressure control loop is fully checked out. If the control loop shows an indication of being unstable, accomplish the control loop tuning activity.

8. *Perform GSGP#2 (Empty to Diurnal Shutdown) steps 7 ~~11~~ thru 9 ~~13~~.* JWH (10/12/83)

NOTE

The next activity will be a partial control loop checkout of the FCV 432 Deaerator Pressure Control. Should the control loop, during the pressure and flow variation tests, show incorrect response, accomplish the control loop tuning engineering activity. Following this, return to the initial portion of the checkout and reaccomplish the control loop checkout.

- *Deaerator pressure range: 0 to 275 psig*
- *Deaerator operational temperature range: 390 to 410°F*

9. *Perform the FCV 432 Deaerator Pressure Control loop tuning activity using a set point of 233 psi.* PERFORMED BY CRTF PRIOR TO SGS TESTING

STEP *DESCRIPTION* *VERIFICATION*

10. *Perform a step response test to introduce low amplitude pressure changes in the Deaerator. Increase the DTC-451 temperature set point to 410°F to increase the deaerator pressure to 275 psi. Maintain conditions until the pressure control settles.* PERFORMED WHEN STEAM FLOW IS > 800°F & 2.0Klb/h

a) Decrease the FCV 432 deaerator pressure set point to 220 psig. (391°F)

b) Decrease the FCV 432 deaerator pressure set point to 210 psig. (388°F)

c) Reset the FCV 432 deaerator pressure set point to 233 psi. (395°F)

~~*d) Reset the DTC 451 set point to 390°F.*~~ ______

NOTE

Continue to monitor PT-432 pressure until the Deaerator Pressure control loop is fully checked out. If the control loop shows an indication of being unstable, accomplish the control loop tuning activity.

11. *Perform GSGP#2 (Empty to Diurnal Shutdown) steps* ~~*16*~~ 10 *thru* ~~*20.*~~ 22 JWH 11/17/83

NOTE

Manually position FCV 431 to control delivery steam pressure (PT-321) at 1100 psig and FCV 421 to control feedwater temperature at 545°F throughout the following steps until the control loops are actually checked out.

NOTE

If feedwater flow is not the same as the steam flow, the steam drum water level will either become too high or too low; hence, the operator should expect a low or high level alarm from LT-311.

12. *Verify that all TSS (Table A) heat traced systems and the RS heat trace systems (in Table 4.2-1) are operating and that all temperatures, with the exception of the following list, are greater than 480°F.*

* (265) LOW - WILL KEEP DRAIN LINES OPEN DURING SGS FILL

TEH 217	*TEH 236*
TEH 223	*TEH 238*
TEH 224	*TEH 239*

JWH 11/17/83

STEP	DESCRIPTION	VERIFICATION
13.	Align/verify valves as follows:	

Valve	Description	Position
Receiver		
FCV 101	Salt Flow Cont.	Closed
FCV 102	Salt Flow Cont.	Closed
FCV 151	CST Level Cont.	Closed
FCV 152	CSBP Bypass	Open
FCV 161	Hot Salt Flow Cont.	Closed
FCV 162	Cold Salt Flow Cont.	Open
FCV 199	Bypass Valve	Open
Thermal Storage		
FCV 201	Cold Salt Flow Cont.	Closed
FCV 211	CST Isolation	Closed
FCV 221	Hot Salt Flow Cont.	Closed
FCV 231	HST Isolation	Closed
FCV 241, FCV 242	Prop. Htr. Isolation	Closed
HV 281	Hot Sump Bypass	Closed
HV 282, HV 283	Olin Salt Loop	Closed

N/R

STEP	DESCRIPTION	VERIFICATION
14.	Perform GSGP#2, Diurnal Shutdown to Warm Standby sequence, steps 2 thru ~~10.~~ 28	JWH 10/17/83

T/C	DESCRIPTION	ACUREX CHANEL #
TEH-130	Downcomer - Heater K	305
TEH-131	Riser - Heater H	300
TEH-132	Downcomer - Heater L	306
TEH-133	Riser - Heater I	301
TEH-134	Riser - Heater I	302
TEH-135	Riser - Heater J	303
TEH-136	Riser - Heater J	304
TEH-137	Downcomer - Heater M	307
TEH-138	Downcomer - Heater M	308
TEH-139	Downcomer - Heater L	309

Table 4.2-1 RS Heat Trace Instrumentation (Partial)

STEP	DESCRIPTION	VERIFICATION
15.	Verify that Cold Salt Storage Tank Level is greater than 30 inches.	N/A

<u>NOTE</u>

If the salt level is less than 30 inches ensure the Hot Salt Storage Tank level is commensurate with test requirements (as determined in the Pretest Meeting).

16.	Verify FCV 201 is closed.	N/A
17.	Open FCV 211.	N/A

<u>CAUTION</u>

If salt level is the Cold Sump is greater than 60 inches, visually check the Cold Sump Vent.

18.	Verify Cold Sump Level (LT 201) is less than 60 inches.	N/A
19.	Verify the Cold Sump Level (LT 201) is greater than 50 inches prior to continuing (open FCV 201 to obtain salt level if required.)	N/A

<u>NOTE</u>

The next activity will be the control loop checkout of the Cold Sump Level Control. Should the control loop, during flow rate changes or step response tests, show incorrect response or inadequate damping, accomplish the control loop tuning engineering activity. Following this, return to the low level salt flow condition and reaccomplish the control loop checkout. (If this activity has been previously accomplished, continue at step 33.)

THIS LOOP WAS TUNED AND CHECKED OUT DURING PERFORMANCE OF RITP#1

- Cold Sump Level (LT 201) limits: 60 inches maximum.

20.	Verify the salt level in the Cold Storage Tank is between 30 to 135 inches.	N/A
21.	Start the Cold Salt Pump and verify outlet pressure (PT 180) is greater than 170 psi prior to continuing.	
22.	Open FCV 151 to 20% to provide a low level salt flow.	
23.	Perform the Cold Sump Level Control (FCV 201) tuning activity using a set point of 25 inches.	

STEP *DESCRIPTION* *VERIFICATION*

24. *Perform a step response test to introduce low amplitude flow transients into the 20% salt flow rate. Using 10% increments, change the FCV 151 setting as specified below. Maintain the specified setting until the level settles.*

   a) Decrease to 10%
   b) Increase to 20%
   c) Increase to 30%
   d) Decrease to 20%

ALREADY COMPLETED RITP#1

25. *Over a 10 second time period, change the FCV 151 setting from 20% to 50% (medium flow).*

26. *Repeat step 24 for the 50% flow rate as follows:*

   a) Decrease to 40%
   b) Increase to 50%
   c) Increase to 60%
   d) Decrease to 50%

27. *Over a 10 second time period, change the FCV 151 setting from 50% to 90% (high flow).*

28. *Repeat step 24 for the 90% flow rate as follows:*

   a) Decrease to 80%
   b) Decrease to 70%
   c) Increase to 80%
   d) Increase to 90%
   e) Increase to 100%

29. *Perform a step response test to introduce higher amplitude flow transients into the salt flow rate. Change the FCV 151 setting as specified below, maintaining the setting until the level settles.*

   a) Decrease to 80%
   b) Decrease to 60%
   c) Increase to 80%
   d) Increase to 100%
   e) Decrease to 70%

30. *Perform GSGP#2 (Diurnal Shutdown to Warm Standby sequence) steps 15 thru 37. Disregard the control loops activation in steps 31 and 32 - the flow, temperature, and pressure controls must be manually maintained until the control loops are checked out.* N/A

STEP 14 REDLINED TO COVER THIS.

STEP DESCRIPTION *VERIFICATION*

NOTE

THE SGS IS NOW IN THE WARM STANDBY CONDITION.

31. *Verify that the Hot Storage Tank Level is greater than ~~TBD~~ 60 inches (determined in Pretest meeting).* JWH 11/17/83

NOTE

The Hot Sump salt level will be manually controlled by FCV 221 until the control loop is checked out. Maintain the Hot Sump level at 15 ± 3 inches.

32. *Perform GSGP#2 (Warm Standby to On Line Condition) steps 1 thru ~~12~~ 11.* JWH 11/17/83

33. *During the following activity of increasing salt temperature, verify the operation of controls of PT-432 for controlling FCV 432 so that deaerator pressure is held constant at 233 psi and all energy is being rejected by the cooling water circuit and the dry cooling towers.* JWH 11/17/83

34. *Using a temperature ramp rate of 100°F per 6 minutes, gradually and simultaneously open FCV 351 while closing FCV 341 to achieve 850°F at TE-382 (superheater salt inlet Temperature). Maintain approximately a constant 10% salt flow (7600 lbs/hr) through the SGS.* THIS WAS ACCOMPLISHED BY USING PROPANE HTR. TO SLOWLY INCREASE HOT TANK TEMP. RATE ≈ 100°F/HR.

NOTE

The salt temperature will be maintained at 850°F to provide a minimum steam flow to the HRFS and allow the following control loop checkouts.

NOTE

The next activity will be a partial control loop checkout of the Hot Sump Level Control. It will be tested now at 10% salt flow and later at salt flows that provide 30% and 60% steam loads. Should the control loop, during flow rate changes or step response tests, show incorrect resonse or inadequate damping, accomplish the control loop tuning engineering activity. Following this, return to the low level salt flow condition and reaccomplish the control loop checkout. THIS LOOP WAS TUNED ON 11/15/83 AND 11/16/83.

- *Hot Sump level (LT-221) limits: 15 to 41 inches*

35. *Note the FCV 221 setting to mannually maintain the 15 inch salt level: _____%. Perfom the control loop tuning of the Hot Sump Level Control using a set point of 15 inches.* JWH 11/15/83

STEP *DESCRIPTION* *VERIFICATION*

36. *Perform a step response test to introduce low amplitude valve setting changes on FCV 221 (to change Hot Sump level) and verify correct recovery. Change the FCV 221 settings as specified below and then activate automatic control. Allow the control loop to settle prior to changing conditions.*

a) Decrease 10% from the step 35 setting and allow the sump level to decrease. Activate the Hot Sump Level Control.

b) Increase 10% from the step 35 setting and allow the sump level to increase. Activate the Hot Sump Level Control.

c) Increase 20% from the step 35 setting and allow the sump level to increase. Activate the Hot Sump Level Control. 11/16/83

NOTE

The next activity will be a partial control loop checkout of the FCV 411 Feedwater Flow/Steam Drum Level Control. (This FCV 411 checkout will be using level feedback only with low steam flow rate. A more complete checkout, using the 3-term controller, will be accomplished in SGITP#2 with higher steam flow.) Should the control loop, during flow rate changes or step response tests, show incorrect response, accomplish the control loop tuning engineering activity. Following this, return to the initial portion of the checkout and reaccomplish the control loop checkout.

- *Steam Drum water level (LT-311) limits: 0 ± 4 inches*

- *Feedwater operational temperature (TE-386) limits: 500 to 575°F*

TUNED ON 11/17/83

37. *Perform a step response test to introduce water level changes in the steam drum. Decrease the steam drum water level by blowing down, as required, using HV-382 and HV-383 to the levels specified below. Maintain each condition until the level control settles.*

a) Decrease to -1 inch. Activate the Steam Drum Level Control.

STEP DESCRIPTION VERIFICATION

b) *Deactivate the control. Decrease to -2 inches. Activate the Steam Drum Level Control.*

c) *Deactivate the control. Decrease to -4 inches. Activate the Steam Drum Level Control.* JWH 11/17/83

38. *Note the FCV 411 setting from 37.c) once the level control settles:* __*__ % JWH 11/17/83 * PERFORMED AT HIGHER STEAM FLOW RATE

39. *Perform a step response test to introduce low to medium amplitude flow changes in the feedwater flow and verify correct recovery. Using 10% increments, change FCV 411 settings as specified below, maintaining each setting until the control settles.*

a) *Decrease 10% from the step 38 setting. Activate the Feedwater Flow Control.*

b) *Increase 10% from the step 38 setting. Activate the Feedwater Flow Control.*

c) *Decrease 20% from the step 38 setting. Activate the Feedwater Flow Control.*

d) *Increase 20% from the step 38 setting. Activate the Feedwater Flow Control.*

e) *Decrease 30% from the step 38 setting. Activate the Feedwater Flow Control.* JWH 11/17/83

NOTE

If feedwater flow is not the same as the steam flow, the steam drum water level will either become too high or too low; hence, the operator should expect a low or high level alarm from LT-311. Beware: large pressure swings can also affect deviations in drum level.

NOTE

The next several steps are to verify the FCV 401 Feedwater Pump Pressure Control performance.

40. *Note the feedwater flow rate at FT-411:* __*__ *lbm/hr.* JWH 11/17/83 * FLOW VARIED DURING LT-311 CONTROL CHECKOUT

41. *Perform a step response test to introduce low amplitude flow changes into the feedwater flow (FT-411). Change the FCV 411 valve settings to achieve the flow rates specified below. Maintain the specified condition until the pressure control settles.*

STEP	DESCRIPTION	VERIFICATION
	a) *Deactivate the Steam Drum Level Control (FCV 411).*	
	b) *Decrease the feedwater flow through FT-411 by* 500 *lbm/hr from the step 40 flow rate.*	
	c) *Increase the feedwater flow through FT-411 by* 500 *lbm/hr from the step 40 flow rate.*	
	d) *Decrease the feedwater flow through FT-411 by* 1000 *lbm/hr from the step 40 flow rate.*	
	e) *Increase the feedwater flow through FT-411 by* 1000 *lbm/hr from the step 40 flow rate.*	JWH 11/17/83
42.	*Activate the FCV 411 Steam Drum Level Control with a set point of 0 inches; verify proper recovery.*	JWH 11/17/83
43.	*Note the FCV 431 setting:* * VARIES *%*	JWH 11/17/83

NOTE

The next activity will be a partial control loop checkout of the FCV 431 Steam Pressure Control. Should the control loop, during the step response test, show incorrect response, accomplish the control loop tuning activity. Following this, return to the initial portion of the checkout and reaccomplish the control loop checkout. (Continue to manually control the feedwater temperature, FCV 421, at 545°F). This control loop cannot be fully checked out until steam is generated at full rated flow (greater than 11,500 lbm/hr).

THIS LOOP WAS TUNED ON 11/16/83 AND CHECKED OUT ON 11/17/83.

STEP	DESCRIPTION	VERIFICATION
44.	*Perform a step response test to introduce low to medium amplitude valve setting changes on FCV 431 and verify correct recovery. Using 5% increments, change FCV 431 settings as specified below. Allow the control to settle prior to changing condition.*	THE METHOD FOR CHECKING THIS LOOP WAS TO VARY THE STEAM FLOW (ON FT-311) FROM ∅ TO ≈ 8.0K lbm/hr.
	a) *Activate the Steam Pressure Control.*	
	b) *Increase 5% from the step 43 setting. Activate the Steam Pressure Control.*	
	c) *Increase 10% from the step 43 setting. Activate the Steam Pressure Control.*	
	d) *Decrease 5% from the step 43 setting. Activate the Steam Pressure Control.*	
	e) *Decrease 10% from the step 43 setting. Activate the Steam Pressure Control.*	

STEP DESCRIPTION VERIFICATION

f) Increase 20% from the step 43 setting. Activate the Steam Pressure Control. JWH 11/17/83

45. Once the Steam Pressure Control settles, note the FCV 421 setting: _______% * N/A
* SEE NOTE ON NEXT PAGE

NOTE

The next activity will be a partial control loop checkout of the FCV 421 Feedwater Temperature Control. Should the control loop, during the step response tests, show incorrect response, accomplish the control loop tuning engineering activity. Following this, return to the initial portion of the checkout. (This control loop cannot be fully checked out until the salt/steam temperatures are at rated values.)

- Feedwater Heater operational temperature limits: 540 to 560°F

46. Perform the FCV 421 Feedwater Temperature Control loop Tuning activity using a set point of 560°F. N/A

47. Perform a step response test to introduce low to medium amplitude valve setting changes on FCV 421 and verify correct recovery. Using 10% increments, change FCV 421 settings as specified below. Allow the control to settle prior to changing condition.

a) Activate the Feedwater Temperature Control.

b) Increase 10% from the step 45 setting. Activate the Feedwater Temperature Control.

c) Decrease 10% from the step 45 setting. Activate the Feedwater Temperature Control.

d) Increase 20% from the step 45 setting. Activate the Feedwater Temperature Control.

e) Decrease 20% from the step 45 setting. Activate the Feedwater Temperature Control.

f) Increase 30% from the step 45 setting. Activate the Feedwater Temperature Control. N/A

48. Repeat step 47 except this time FCV 331 will be varied at 20% increments to provide temperature changes. The FCV 421 control loop is still activated; verify correct response.

STEP DESCRIPTION VERIFICATION

a) Decrease to 80%
b) Decrease to 60%
c) Decrease to 40%
d) Increase to 60%
e) Increase, to 100%

N/A

This completes the initial control loop checkout, SGITP#1. It is now the Test Conductor's option to continue into SGITP#2 (Hot Salt Flow with Transients) or shutdown the system to Diurnal Shutdown.

NOTE

a) To shutdown the system, perform GSGP#3 starting at step 3.

b) To continue into SGITP#2, maintain the present condition and verify salt levels in the Cold and Hot Storage Tanks are commensurate with test requirements (as determined in the Pretest Meeting).

12/08/83 - FROM THE RESULTS OF YESTERDAY'S SGS TESTING (AND ATTEMPT TO TUNE FCV 421), THIS LOOP WILL NOT BE FUNCTIONAL IN SGS OPERATION. THE FCV 421 VALVE AND THE FEEDWATER HEAT EXCHANGER CAN NOT PROVIDE THE DESIRED HEATING OF THE FEEDWATER GOING TO THE SGS. TEST RESULTS SHOWED THAT MAXIMUM FEEDWATER HEATING (DELIVERY STEAM AT RATED TEMP AND FLOW) WAS ONLY:

- 505°F AT TE-421 AT MINIMUM FLOW (≈ 4.0K lbm/hr AT FT-311).
- 430°F AT TE-421 AT HIGH FLOW (≈ 11.0 Klbm/hr AT FT-311).

* WITH NO CHANGE IN THE HRFS CONFIGURATION, FEEDWATER HEATING WILL CONSIST OF KEEPING FCV 421 OPEN AND ACCEPTING WHATEVER HEATING THE FWH EXCHANGER CAN PROVIDE.

IN FOR INFO [illegible] ONLY

4.2.2 SGITP #2 Hot Salt Flows with Transients

PURPOSE: This test will checkout the remaining SGS control loops during the initial, low level hot salt flows. The SGS will be brought up to the On Line, 100% load condition.

DESCRIPTION: Starting with the SGS in the on line 30% loading, 1 TSS and 2 SGS control loops are checked out. The SGS steam loading is then increased to 60%, and 100% with transient hot salt flows introduced at each level. The SGS is maintained in the On Line, 100% load condition for 1 hour. Following this test activity, the SGS operation transitions to the Diurnal Shutdown Mode.

OBJECTIVES:

a) Checkout of system and components.

b) Control loop tuning:

- Hot Sump Level Control (final portion)
- Evaporator Salt Inlet Temperature Control
- Steam Delivery Temperature Control
- Steam Pressure Control

c) Instrumentation Checkout

d) HRFS response to step input changes

e) Demonstration of control stability

f) Test crew familiarization with system operation

CONTROL LOOP TUNING SUCCESS CRITERIA: A proportional feedback control loop shall have a response time that is suitable for the function being performed, and the response shall be well-damped over the operating range. It shall be a design goal that closed-loop responses exhibit damping equivalent to 0.5 to 1.0 in a second-order system over the operating range, with no limit cycling under steady state conditions.

Rec'd
[illegible]
1-2-84

SGITP#2

Each of the instrumentation channels involved in this test will be checked out by observing the displays on the EMCON console. The actual measurements will be checked for reasonableness with Network 90 readings and expected values.

STEP DESCRIPTION VERIFICATION

NOTE

If the system was shutdown to Diurnal Shutdown at the end of SGITP#1:

a) Perform CSGP#1 Pretest Checklist, and

b) Perform CSGP#2 (manual SGS Startup), Diurnal Shutdown to Warm Standby sequence and Warm Standby to On Line sequence thru step ~~7~~. 19. ________

If going from SGITP#1 straight into SGITP#2, verify salt levels in the Hot and Cold Storage Tanks are commensurate with test requirements (as determined in the Pretest Meeting).

1. Verify that all TSS (Table A) heat traced systems are operating and that all temperatures, with the exception of the following list, are greater than 500°F.

TEH 217	TEH 236
TEH 223	TEH 238
TEH 224	TEH 239

NOT REQUIRED DUE TO ABOVE REDLINE

N/A

2. Verify that the Hot Storage Tank Level is greater than TBD inches. N/A

NOTE

Manually control FCV 301 to achieve and maintain a salt temperature of 850°F at TE-301. Manually control FCV 331 to achieve and maintain a steam temperature of 950°F at TE-332.

STEP	DESCRIPTION	VERIFICATION
3.	Turn on the Hot Salt Pump if turned off following SG1TP#1, and verify outlet pressure (PT-382) is greater than TBD psi prior to continuing.	N/A
4.	Gradually open FCV 351 while closing FCV 341 to achieve the temperature ramp rate specified below at the superheater salt inlet TE-382. Maintain approximately a constant 10% salt flow (7600 lbs/hr) thru the SGS. • Temperature ramp rate: 100°F (TE-382) steps at 6 minute intervals (1000°F/hr)	
5.	Verify full closure of FCV 341.	
6.	When the salt inlet flow to the superheater consists of only hot salt (valve FCV 341 closed; valve FCV 351 positioned for 10% salt flow (7600 lbs/hr)), transfer control of the steam delivery pressure to FCV 321 as follows: a) Deactivate the FCV 431 Steam Flow Control. Manually position FCV 431 to allow the specified steam flow. b) Gradually open valve FCV 351 while adjusting valve FCV 321 position to maintain SGS steam delivery pressure (PT-321) at 1100 +50, -0 psig.	
	NOTE When FCV 351 is 100% open, steam delivery pressure is controlled by positioning FCV 321.	
7.	As load increases, control steam delivery pressure to 1100 psig by manually positioning FCV 321.	

NOTE

To simulate the turbine loading, FCV 431 will be varied to increase the steam volume being dumped to the deaerator (automatically by changing set points or manually by changing the valve position). These specific valve settings will be determined by experience in changing FCV 431 to obtain the required salt flow rate at FT-311.

STEP	DESCRIPTION	VERIFICATION
8.	Gradually open FCV 321 and modulate FCV 431 to achieve a FT-311 steam flow rate of approximately 3,500 lbs/hr (30% load).	________
9.	Note the FCV 221 setting (automatic control): _____%	COMPLETED 11/30/83 JWH
10.	Perform a step response test to introduce low amplitude valve setting changes on FCV 221 (to change Hot Sump level) and verify correct recovery. Change the FCV 221 settings as specified below and then activate automatic control. Allow the control loop to settle prior to changing conditions:	
	a) Decrease 10% from the step 9 setting and allow the sump level to decrease. Activate the Hot Sump Level Control.	
	b) Increase 10% from the step 9 setting and allow the sump level to increase. Activate the Hot Sump Level Control.	
	c) Increase 20% from the step 9 setting and allow the sump level to increase. Activate the Hot Sump Level Control.	COMPLETED 12/2/83 JWH

NOTE

The next activity will be the control loop checkout of the FCV 301 Evaporator Salt Inlet Temperature Control. Should the control loop, during flow rate or temperature variations, show incorrect response, accomplish the control loop tuning engineering activity. Following this, return to the initial portion of the checkout and reaccomplish the complete control loop checkout.

- Evaporator salt inlet temperature (TE-301) limits: 500 to 880 °F

TUNING 11/17/83

11.	Activate the Evaporator Salt Inlet Temperature Control FCV 301 with a set point of 850°F.	________

STEP	DESCRIPTION	VERIFICATION
12.	Perform a step response test to introduce temperature transients to the evaporator salt inlet temperature and verify correct control response. Change FCV 301 to obtain the temperatures specified below (TE-301) and then activate automatic control. Allow the control to settle prior to changing condition.	
	a) Deactivate the FCV 301 control and increase its setting to decrease the temperature to 800°F. Activate the Evaporator Salt Inlet Temperature Control.	46:19 850°F 49:04 800°F RAPID DROP TO 809°F THEN FLUCTUATION TO 8[illegible] 49:59 800°F
	b) Deactivate the FCV 301 control and increase its setting to decrease the temperature to 750°F. Activate the Evaporator Salt Inlet Temperature Control.	53:20 757°F RAPID DECREASE T[illegible] 757°F. DIFFICUL[illegible] OBTAINING 750°F [illegible] TO LACK OF COLD SA[illegible] FLOW RESET TO [illegible]
	c) Deactivate the FCV 301 control and decrease its setting to increase the temperature to ~~880~~ 870°F. Activate the Evaporator Salt Inlet Temperature Control.	COLD SUMP ≈565°F 58:55 760° 59:30 869° RAPID INCREASE T[illegible] 869°F THEN FLUCT[illegible] TO 855° TO 866°F
13.	Gradually open FCV 341 while closing FCV 351 to reduce the TE-382 superheater salt inlet temperature to 800°F. Maintain the salt flow (FT-321) approximately constant throughout. Do not exceed the temperature ramp rate of 100°F/6 minutes. Verify correct Evaporator Salt Inlet Temperature Control response.	

-02 1017
08:17 909
13:41 765
16:06 799 75.00
FCV 341
FCV 351 20
798

NOTE

FCV 321 is controlling steam pressure under manual control. With a lower SH salt inlet temperature, steam pressure will want to drop, and must be compensated for by FCV 321. Steam flow is maintained by manually positioning FCV 431.

14.	Reverse the step 13 activity to reclose FCV 341 and open FCV 351. Again maintain the salt flow rate constant and do not exceed 100°F/6 minutes.	

~~248~~
~~26.5~~
23.6 1.10
26.6 2.10
798
14:25 907
20:39 1005
30:05

NOTE

The next activity will be the control loop checkout of the Steam Delivery Temperature Control FCV 331. Should the control loop, during flow rate or temperature variations, show incorrect response, accomplish the control loop tuning engineering activity. Following this, return to the initial portion of the checkout and reaccomplish the complete control loop checkout.

- Steam Delivery temperature (TE-332) limits: 950 ± 40 °F.

TUNED ON 11/17/83

STEP	DESCRIPTION	VERIFICATION
15.	Activate the Steam Delivery Temperature Control FCV 331 with a set point of 950°F.	JWH 12/07/83

16. Perform a step response test to introduce temperature transients to the delivery steam temperature and verify correct control response. Change FCV 331 to obtain the temperatures specified below (TE-332) and then activate automatic control. Allow the control to settle prior to changing condition.

33:20 950°F
34:17 896°F
FAST RESPONSE AND UNDERSHO AND TO 885° AND RESET TO 900° 10 SEC

a) Deactivate the FCV 331 control and increase its setting to decrease the temperature to 900°F. Activate the Steam Delivery Temperature Control.

12/19

b) Deactivate the FCV 331 control and increase its setting to decrease the temperature to 850°F. Activate the Steam Delivery Temperature Control.

c) Deactivate the FCV 331 control and decrease its setting to increase the temperature to 990°F. Activate the Steam Delivery Temperature Control. JWH 12/07/83

37:42 1039
43:46 987
49:

17. Repeat steps 13 and 14 to verify correct Steam Delivery Temperature Control response. This time use 950°F for the lower TE-382 temperature.

6.84 6.77 STD

18. Gradually open FCV 321 and modulate FCV 431 to achieve a FT-311 steam flow rate of approximately 7,000 lbs/hr (60% load). Note the FCV 321 setting: 64 %

19. Note the FCV 221 setting (automatic control): ___ % Repeat step 10 using this new setting as the base from which to make the valve setting changes. COMPLETED 11/30/83

20. Vary the FCV 321 settings as specified below and verify correct operation of all activated control loops. Allow temperatures, pressures, and flow rates to stabilize prior to changing condition.

		FT-311	PT-321	TE-331	TE-332	TE-3
13:42	a) Decrease 10% from step 18 setting.	6.27	865	1032	950	51
	b) Decrease 20% from step 18 setting.	COULD NOT COMPLETE. TE-359 WILL DECREASE TO LOW. CAUSING SALT FREE				
13:44	c) Return to step 18 setting.	6.88	1040	1038	950	51
13:50	d) Increase 10% from step 18 setting.	1262psi AT PT-353 LIMITS US GOING TO 10% DUE TO LIFTING OF RELIEF VALVE.				
	e) Return to step 18 setting.	6.95	1104	1035	950	523

COMPLETED 11/30/83

12/20

STEP	DESCRIPTION	VERIFICATION
21.	Gradually open FCV 321 and modulate FCV 431 to achieve a FT-311 steam flow rate of 11,580 lbs/hr (100% load).	________

PT-321 FT-311 TE-301 TE-321 ET-311

~~1050~~ 11.2 850 950 ± .2"

13:56 979 11.5

964

NOTE

The next activity will be the control loop checkout of the Steam Pressure Control FCV 321. Should the control loop, during steam flow rate variations, shown incorrect response, accomplish the control loop tuning engineering activity. Following this, return to the initial portion of the checkout and reaccomplish the control loop checkout. TUNED ON 12/01-02/83

- Steam Pressure (PT-321) operational limits: 1100 ± 50 psig.

22. Activate the FCV 321 Steam Pressure Control with a set point of 1100 psig. RLP

23. Perform a step response test to introduce low to medium amplitude pressure transients to the main steam pressure and verify correct control response. Manually change FCV 431 to obtain the flow rates specified below at FT-311. Allow the control loop to settle prior to changing conditions.

12/20

			FT-321	PT-321	TE-3??	TE-321	TE-3?
SH SAT 1069		a) Close FCV 431 to obtain an ~~11,000~~ 10.19 lbs/hr flow rate.					
60 psig TO	2nd REC.	b) Close FCV 431 to obtain a 10,500 lbs/hr flow rate. 9.44	98.4	1099	520	1019	9
	2nd REC	c) Close FCV 431 to obtain a 10,000 lbs/hr flow rate. 8.84	66.3	1101	518	1016	9
	2nd	d) Open FCV 431 to obtain an 11,000 lbs/hr flow rate. 9.64	64	1100	520	1019	9
14:20 ~~14:20~~	3rd	e) Open FCV 431 to obtain a 12,000 lbs/hr flow rate. 9.44		1097	521	1014	9.5
14:26 1039		f) Close FCV 431 to return to 11,580 lbs/hr flow rate. 10.1	73.	1101	527	~~1019~~ 1020	9

24. Maintain this On Line, 100% load condition for 1 hour. Monitor control loop performance in this steady state operation. ________

25. Perform GSCP#3 (manual SGS shutdown) from the On Line condition to Diurnal Shutdown. ________

26. Perform GSCP#6, SGS Post Test Checklist (applicable sections only). ________

8690 15 MAY operating & maintain full SAT flow.

4.2.3 SGITP#3 Diurnal Shutdown (No Salt Flow) - Hold Overnight

PURPOSE: Maintain the SGS in the Diurnal Shutdown mode for a 12 hour, night time period to verify SGS integrity.

DESCRIPTION: The SGS will be brought to the Diurnal Shutdown mode following SGITP#2. In this operating state, the SGS will be maintained for a 12 hour period to verify subsystem performance. Note: This test does not have to be performed overnight. It can be performed during the day when test personnel are available.

OBJECTIVES:

a) Checkout of system and components

b) Verify system performance at minimum operating conditions

c) Test crew familiarization with maintaining SGS in the Diurnal Shutdown mode

CRTF/MMC PRETEST CHECKLIST

TEST PHASE: SGS TESTING

TEST IDENTIFICATION: SGITP#3

DATE OF TEST: 12/07/83 - 12/08/83

PLANNED START TIME: 1600

PLANNED COMPLETION TIME: 12/08/83 0800

RESPONSIBLE OPERATING PERSONNEL:	PRIMARY	BACKUP
TEST CONDUCTOR (MMC)	HENK	LENZ
CONTROLS ENGINEER (MMC)	N/R	
CONSOLE OPERATOR (CRTF)	EVANS	
OPERATION/SAFETY ENGINEER (CRTF)	HOLMES	EVANS
RS/HRFS OPERATOR (CRTF)	GREIGO	
SGS/TSS OPERATOR (CRTF)	MATTHEWS	

TEST FILE: Test File Number N/A has been approved for this test.
Startup includes N/A heliostats.
The highest liquid outlet temperature expected for the test is N/A °F salt, 555 °F water/steam.

TEST CONFIGURATION: DIURNAL SHUTDOWN CONFIGURATION (GSGP#2)
LT-311 RAISED TO 15.5" FOR OVERNIGHT MAINTAINING.
* THE TEST WILL NOT BE MANNED OVERNIGHT

APPROVALS:

John W. Henk — 12/08/83
MMC Test Conductor — Date

Ralph L Daniels — 12/08/83
B&W ~~MMC Controls~~ Engineer — Date

JT Holmes — 12/8/83
CRTF O/S Engineer — Date

<u>SGITP#3</u>

This test activity involves the maintaining of the steady state Diurnal Shutdown mode for a 12 hour period. Once the configuration is achieved, it will require a minimum test team involvement to monitor the three subsystems during the night time activity.

STEP	DESCRIPTION	VERIFICATION

NOTE

The SGITP#2 final configuration is to return the SGS, TSS, and HRFS to the Diurnal Shutdown mode. If entering this test from any other test configuration, perform the appropriate portions of SGSP#2 (manual SGS Startup) or GSGP#3 (manual SGS Shutdown).

1. Verify operation of the trace heater circuits on the SGS salt lines, shells of evaporator and superheater (see Table 4.1-1), and the TSS (see Table A) except for those listed below. Ensure that all temperatures are greater than ~~500°F~~ 480°F ~~(including drain lines and valves).~~ — 12/07/83

TEH 217	TEH 236	TEH 318
TEH 223	TEH 238	TEH 319
TEH 224	TEH 239	6040 → 6043 (INFO)

   JWH

2. Verify operation of HR-5 circulation heater circuit by checking for a contact closure on the OIU. — JWH

3. Bring the steam drum water level to ~~+6~~ +16 inches (The level should remain above ~~-4~~ -15 inches throughout the test period.) — JWH

4. Maintain this configuration for a ~~12~~ 16 hour period.

   a) Monitor the SGS and TSS heat trace circuits (step 1) and ensure they remain greater than ~~500°F.~~ 480°F — JWH

NOTE

The intent of Diurnal Shutdown is to be able to "walk away" from the system overnight. Therefore, during this test no water level or pressure adjustments should be required. The unit should be observed to assure the shutdown condition is maintained properly, or determinations made that adjustments to the operating procedure are required.

NOTE: LT-311 DROPPED DOWN TO 0.5" BY 08:00 12/08/83 WHILE MAINTAINING SGS TEMP. & PRESSURE.

JWH 12/08/83

4.2.4 SGITP#4 Load Following Test - 10%/Minute

PURPOSE: This test will verify SGS performance during a 10% steam load per minute ramping. Starting at a 30% load, the SGS will be ramp loaded up to 100% and back down to 50%.

1/10/84

DESCRIPTION: The SGS will be started from the Diurnal Shutdown mode. Using the manual SGS Startup procedure (GSGP#2), the SGS is first brought up to the On Line, 10% load condition and then to a 30% load. It is then ramped up to 100% and back to 50%. The 30%, 100%, and 50% steady state load conditions will each be maintained for 30 minutes. The test will end with the SGS being returned to the Warm Standby mode.

OBJECTIVES:

a) Checkout of system and components

b) Verification of control loop performance during load ramping

c) Demonstration of control stability

d) Test crew familiarization with system performance

DATA:! FT 382
FT 321
FT 411
FT 311
TE 384 PT 321 FT 381
TE 332 PT 384

STEP	DESCRIPTION	VERIFICATION
1.	Perform GSGP#2 (manual SGS startup) Diurnal Shutdown to Warm standby sequence.	RDC
2.	Perform GSGP#2 (manual SGS Startup) Warm Standby to On Line Sequence, (This will achieve the on line, 30% load condition.).	RDC
3.	Maintain the 30% steady state load condition for ~~30~~ 30 E minutes. Monitor all control loop performance.	RDC

NOTE

The next activity will be the load following test in which the SGS steam loading will be ramped up to 100% at a 10%/minute rate. Verify control loop performance during the ramping.

4. Using a ramp rate of 10% SGS steam loading per minute, modulate FCV 431 to achieve the steam flow rates specified below at FT-311. Note the FCV 431 settings to achieve the specified flows.

a) 4,630 lbs/hr (40% load).	FCV 431 64 %	55	
b) 5,790 lbs/hr (50% load).	FCV 431 69 %	64	
c) 6,950 lbs/hr (60% load).	FCV 431 75 %	67	
d) 8,100 lbs/hr (70% load).	FCV 431 79 %	75	
e) 9,270 lbs/hr (80% load).	FCV 431 83 %	78	
f) 10,420 lbs/hr (90% load).	FCV 431 87 %	10,690	
g) 11,580 lbs/hr (100% load).	FCV 431 ______ %		RDC 1~~4~~:55

5. Maintain the 100% SGS steam loading for 30 minutes. ______

STEP	DESCRIPTION	VERIFICATION
6.	Using a ramp rate of 10% SGS steam loading per minute, modulate 431 to achieve the steam flow rates specified below at FT-311. The FCV 431 settings noted before may be used to obtain the required flow. ~~15:19~~	7/27/84
	a) 10,420 lbs/hr (90% load) FULL LOAD 15:19 81	
	b) 9,270 lbs/hr (80% load) ~~15:02~~ 15:20:02 77	
	c) 8,100 lbs/hr (70% load) 15:21:03 73	
	d) 6,950 lbs/hr (60% load) 15:22:07 65	
	e) 5,790 lbs/hr (50% load) 15:23:26 60	RDC
7.	Maintain the 50% SGS steam loading for 30 minutes.	RDC
8.	Gradually close FCV 321 to achieve a 10% salt flow rate (7600 lbs/hr at FT-321).	~~[illegible]~~
9.	Perform GSCP#3 (manual SGS Shutdown) steps 1 thru 8. This will bring the SGS to Warm Standby.	

This completes the Load Following Test, SGITP #4. It is assumed that the test activity will continue into SGITP#5 (Alternate Diurnal Shutdown - Hold Overnight) from the Warm Standby mode.

COMPLETED 5/10/84 [signature]

4.2.6 SGITP#6 Feedwater Loss Safe Shutdown

PURPOSE: From 50% and full steam load conditions, upon reducing the feedwater flow to zero, the control system safely shuts down the SGS to the Diurnal Shutdown mode.

DESCRIPTION: Starting from the Warm Standby mode, the SGS is manually brought to the On Line, 50% load condition. A feedwater flow trip will be performed and, by automatic and operator actions, the SGS taken to the ~~Diurnal Shutdown~~ WARM STANDBY mode. The SGS is then brought to the On Line, 100% load condition and again tripped by a feedwater loss indication. Upon shutting down the SGS, the final configuration will be the Diurnal Shutdown mode.

OBJECTIVES:

a) Demonstrate control system performance in reacting to a feedwater trip
   - ~~Unit~~ EQUIPMENT Protection System
   - Master Control System
   - Network 90

b) Verify the structural integrity of the SGS

c) Demonstrate proper interaction between the SGS, TSS, and HRFS

d) Test crew familiarization with system reaction to trips

W.A. ALLMAN
MAY 18 1984

CRTF/MMC PRETEST CHECKLIST

TEST PHASE: SGITP#6

TEST IDENTIFICATION: FEEDWATER LOSS SAFE SHUTDOWN

DATE OF TEST: 5/10/84

PLANNED START TIME: 14:15

PLANNED COMPLETION TIME: 14:45

RESPONSIBLE OPERATING PERSONNEL:	PRIMARY	BACKUP
TEST CONDUCTOR (MMC)	SALOFF	
CONTROLS ENGINEER (MMC)	N/A	
CONSOLE OPERATOR (CRTF)	NELSON	
OPERATION/SAFETY ENGINEER (CRTF)	HOLMES/EVANS	
RS/HRFS SUPPORT OPERATOR (CRTF)	N/A	
SGS/TSS OPERATOR (CRTF)	GRIEGO	

TEST FILE: Test File Number N/A has been approved for this test.
Startup includes ________ heliostats.
The highest liquid outlet temperature expected for the test is _____°F salt, _____°F water/steam.

TEST CONFIGURATION: HOT SALT FROM HOT TANK, TURBINE OFF LINE

APPROVALS:

SHSaloff 5/10/84
MMC Test Conductor Date

N/A
MMC Controls Engineer Date

[signature] 5/10/84
CRTF O/S Engineer Date

ITP PRETEST MEETING

TEST I/D: S&ITP #6

TEST FILE #: N/A

Using the MCS Specification's Instrumentation Listings, define the data to be recorded and the data rate required during the performance of the specific integrated test.

Identifier	Description	Data Rate

CRTF/MMC SAFETY CHECKLIST

Test ID $\underline{\text{SGITP \#6}}$ Date $\underline{5/10/84}$

Test Title N/A

		O/S
1.	Site Occupants	
	Communications Established to all manned control points	2TM
	Safety Equipment In Place	2TM
	1. OSHA Protective Gloves	
	2. Fire Retardent Coveralls	
	3. Hard Hats/Face Shields	
	4. Approved Fire Extinguishers	
2.	Solar Only	
	"Test In Progress" Lights ON in the tower	N/A
	Non-Test Personnel Informed and In Secure Location	
	Generator ON (Freq. OK)	
	Field Monitor on call after solar startup	
	Communications Established	
	Tower Top Baracade up	
	Gates Closed and posted with red lights or signs	
	Field Clear, Ready for Startup	
3.	Control Room Locked	
4.	Beam UP Command Shall Be Given Only After Above Checklist Is completed By O/S Engineer	

System Returned To A Safe Configuration ______

CRTF/MMC PRETEST CHECKLIST

TEST PHASE: SGITP #6

TEST IDENTIFICATION: FEEDWATER LOSS SAFE SHUTDOWN

DATE OF TEST: 4/27/84

PLANNED START TIME: 13:00

PLANNED COMPLETION TIME: 14:00

RESPONSIBLE OPERATING PERSONNEL:	PRIMARY	BACKUP
TEST CONDUCTOR (MMC)	SALOFF	
CONTROLS ENGINEER (MMC)	N/A	
CONSOLE OPERATOR (CRTF)	EVANS	
OPERATION/SAFETY ENGINEER (CRTF)	HOLMES/EVANS	
RS/HRFS OPERATOR (CRTF)	N/A	
SGS/TSS OPERATOR (CRTF)	GRIEGO	

TEST FILE: Test File Number N/A has been approved for this test.
Startup includes ______ heliostats.
The highest liquid outlet temperature expected for the test is ______ °F salt, ______ °F water/steam.

TEST CONFIGURATION: PROPANE HEATER SUPPLYING HOT SALT, TURBINE OFF LINE,

APPROVALS:

[signature] 4/27/84
MMC Test Conductor Date

N/A
MMC Controls Engineer Date

[signature] 4/27/84
CRTF O/S Engineer Date

ITP PRETEST MEETING

TEST I/D: SGITP#6

TEST FILE #: N/A

Using the MCS Specification's Instrumentation Listings, define the data to be recorded and the data rate required during the performance of the specific integrated test.

Identifier	Description	Data Rate

CRTF/MMC SAFETY CHECKLIST

Test ID SGITP #6 Date 4/27/84

Test Title FEEDWATER LOSS SAFE SHUTDOWN

1.	Site Occupants	O/S
	Communications Established to all manned control points	LE
	Safety Equipment In Place	✓
	1. OSHA Protective Gloves	✓
	2. Fire Retardent Coveralls	✓
	3. Hard Hats/Face Shields	✓
	4. Approved Fire Extinguishers	✓
2.	Solar Only NA	
	"Test In Progress" Lights ON in the tower	
	Non-Test Personnel Informed and In Secure Location	
	Generator ON (Freq. OK)	
	Field Monitor on call after solar startup	
	Communications Established	
	Tower Top Baracade up	
	Gates Closed and posted with red lights or signs	
	Field Clear, Ready for Startup	
3.	Control Room Locked	
4.	Beam UP Command Shall Be Given Only After Above Checklist Is completed By O/S Engineer	
	System Returned To A Safe Configuration	

SG1TP#6

This integrated test can be accomplished at any point following completion of SG1TP#2.

When encountering a feedwater loss trip (steam drum level LOW or BWCP failure), the control systems will accomplish the following actions:

a) ~~Unit~~ EQUIPMENT Protection System

- ~~Turn off the Hot Salt Pump~~
- Shut off steam flow to turbine (FCV 501) 900 PSI
- ~~Reverse power direction relay opens generator circuit breaker~~

b) EMCON (automatic)

- Dump steam to the Deaerator (FCV 431)
- Maintain control of the HRFS

c) Network 90

- Shut off salt flow by closing FCV 301, FCV 341, and FCV 351

d) Operator Action (at EMCON console)

- Shutdown SGS, HRFS, and TSS to Diurnal Shutdown Mode

STEP	DESCRIPTION	VERIFICATION
1.	Perform GSGP#1 Pretest Checklist.	[initials] [initials] 5/1
2.	Perform GSGP#2 (Manual SGS Startup), Warm Standby to On Line sequence. (This will achieve the on line, 30% load condition.)	[initials] [initials] 5/1
3.	Gradually manually increase FCV 431 to achieve a FT-311 steam flow rate of approximately 5,790 lbs/hr (50% load). Maintain this condition for 5 minutes.	14:05 [initials] 14:14
~~4.~~	~~Input a -6 inch simulated signal at LT-311 (steam drum water level low) to trip the system.~~	

~~NOTE~~

4. ~~As an alternate method to trip the level,~~ place the FCV 411 control in manual and reduce the feedwater flow until the trip level is reached.

LT-311 (-10)

Aborted #2 test

5. Verify proper response of the following control systems:
   a) ~~Unit~~ EQUIPMENT Protection System (TR-381) ✓
   b) Master Control System ✓
   c) Network 90 ✓

EPS TRIP OK
5/10/84

LT-311 -13.5
With FCV-411 Closed
and HV-488 closed
Hot temp into evap.

TR-381
TR-588

STEP	DESCRIPTION	VERIFICATION
6.	Verify all SGS ~~(Table A.1-1)~~ and TSS ~~(Table A)~~ trace heater circuits are operating and that all temperatures, with the exception of the following list, are greater than 500°F. AS LISTED IN CONTROL ROOM PRETEST CHECKLIST. CHANNEL / CHANNEL TEH 217 137 — TEH 236 140 TEH 223 138 — TEH 238 141 TEH 224 139 — TEH 239 142	SB 5/10/8
~~7.~~	~~Perform GSGP#3 (manual SGS Shutdown) steps 8 thru the end of the sequence.~~ ~~NOTE~~ ~~The SGS is now in the Diurnal Shutdown mode.~~	
8.	Perform GSGP#2 (manual SGS Startup), following sequences: ~~a) Diurnal Shutdown to Warm Standby, and~~ b) Warm Standby to On Line condition. TE382 900°F	SB 5/10
9.	Gradually manually increase FCV 431 to achieve a 77 FT-311 steam flow rate of approximately ~~11,580~~ lbs/hr (100% load). Maintain this condition for 5 minutes. FCV-321 100%	15:(?) 15:(?) SB
10.	~~Input TBD signal (BWCP failure)~~ to trip the system. DISCONNECT CURRENT SENSOR ON BWCP ~~NOTE~~ ~~As an alternate method to trip the feedwater system, turn off the FWP and wait until the steam drum water level reaches its trip level.~~	SB 5/10
11.	Verify proper response of the following control system: a) ~~U~~EPS (TR-382) ✓ b) MCS ✓ c) Network 90 ✓	SB 5/10
12.	Perform GSGP#3 (manual SGS Shutdown) ~~steps 8~~ thru the end of the sequence.	N/A
13.	Perform GSGP#6 Post Test Checklist.	N/A

GO TO SGITP #7 SB 5/10

This SGITP Completed
15:12 5/10/84
S Baloth

CRTF/MMC PRETEST CHECKLIST

TEST PHASE: SGITP #9

TEST IDENTIFICATION: Steam Gen Tests From EMCON

DATE OF TEST: 3/29/84

PLANNED START TIME: 700

PLANNED COMPLETION TIME: 1700.

RESPONSIBLE OPERATING PERSONNEL:	PRIMARY	BACKUP
TEST CONDUCTOR (MMC)	Brzezcik	Lenz
CONTROLS ENGINEER (MMC)	NA	
CONSOLE OPERATOR (CRTF)	Nelson	
OPERATION/SAFETY ENGINEER (CRTF)	Holmes	
RECEIVER/HRFS OPERATOR (CRTF)	J. Clark	
SGS/TSS OPERATOR (CRTF)	L. Clark	Matt.
FIELD MONITORS (CRTF)	NA	

TEST FILE: Test File Number NA has been approved for this test.

Startup includes ______ heliostats.

The highest liquid outlet temperature expected for the test is ______ °F salt.

TEST CONFIGURATION: No Boost Pump in Line Simultaneous Program Charge and SGS Operation

APPROVALS:

[signature] 3/29/84

MMC Test Conductor Date

NA

MMC Controls Engineer Date

[signature] 3/29/84

CRTF O/S Engineer Date

CRTF/MMC SAFETY CHECKLIST

Test ID [illegible] Date Thurs 3/29/84

Test Title SGS Operation

		O/S
1.	Site Occupants	
	Communications Established to all manned control points	SPM
	Safety Equipment In Place	
	1. OSHA Protective Gloves	
	2. Fire Retardent Coveralls	
	3. Hard Hats/Face Shields	
	4. Approved Fire Extinguishers	
2.	Solar Only	
	"Test In Progress" Lights ON in the tower	N/A
	Non-Test Personnel Informed and In Secure Location	
	Generator ON (Freq. OK)	
	Field Monitor on call after solar startup	
	Communications Established	
	Tower Top Baracade up	
	Gates Closed and posted with red lights or signs	
	Field Clear, Ready for Startup	
3.	Control Room Locked	
4.	Beam UP Command Shall Be Given Only After Above Checklist Is completed By O/S Engineer	
	System Returned To A Safe Configuration	N/A

SGITP#9

3/20/84 & 3/29/84

This test procedure will set up the conditions for performing SGITP#2 and will then direct which SGITPs to perform and the order. When accomplishing the actual specified SGITP, obtain a new copy of that SGITP and insert it in the OFFICIAL TEST COPY BOOK immediately following SGITP#9.

During the performance of this test, there is to be no actions made from the Bailey Operator's Console. If there are any "MONITORS" at this console, ensure the Test Conductor has approved this function.

Verify sufficient hot salt to support test requirements. If more hot salt is required, use GSGP#4 (Propane Heater) or the RS/CS to charge and build up the hot salt supply.

The Pretest and Post Test Checklists called out for performance by the individual SGITPs may be disregarded (Test Team decision) if proceeding directly from one SGITP into another.

STEP	DESCRIPTION	VERIFICATION
1.	Perform ~~GSGP#~~7 AS MARKED AND GSGP#2A MCS/Network 90 Integration of Control Checklist.	MEB 3/20
2.	Perform GSGP#1 SGS Pretest Checklist.	MEB 3/20

NOTE

Because the initial portion of GSITP#2 (Hot Salt Flow with Transients) includes the control loop tuning of 4 controllers, the following steps will start up the SGS to the On Line, 30% load condition and then direct the accomplishment of portions of SGITP#2.

STEP	DESCRIPTION	VERIFICATION
3.	Perform GSGP#2 (manual SGS Startup) for the following sequences:	
	a) Diurnal Shutdown to Warm Standby sequence,	MEB 3/20
	b) Warm Standby to On Line sequence. TUNE FCV-491	MEB 3/20
		MEB 3/20
4.	Note the FCV 431 valve setting to maintain the 30% load condition (3,500 lbs/hr): 45%	MEB 3/20

FCV-421 WIDE OPEN

TE 421 350

FCV-431 = 55%

FT-311 = 3~~4~~ K/lb

12:30 Start Test

STEP	DESCRIPTION	VERIFICATION
5.	Vary the FCV 431 settings (from the step 4 setting) as specified below and verify correct control loop operation. Allow temperatures, pressures, and flow rates to stabilize prior to changing condition. 30% → 3.41 → 55%	
	a) Decrease to 25% loading (2,900 lbs/hr) — 2.4 Klbs	51% FCV-431
	b) Decrease to 15% loading (1,800 lbs/hr) — 1.81	37%
	c) Increase to 20% loading (2,300 lbs/hr) — 2.	47%
	d) Return to step 4 valve setting (30% loading)	MEB 3/29/8
6.	Gradually manually increase FCV 431 to achieve a FT-311 steam flow rate of approximately 7,000 lbs/hr (60% load). 6.8 Klbs @ 74%	MEB 3/29/8
7.	Note the FCV 431 valve setting to maintain the 60% load condition (7,000 lbs/hr): 74%	MEB 3/29/8
8.	Vary the FCV 431 settings (from the step 7 setting) as specified below and verify correct control loop operation. Allow temperatures, pressures, and flow rates to stabilize prior to changing condition. FCV-431	
	a) Decrease to 50% loading (5,800 lbs/hr) 69% 5.8Klbs	
	b) Decrease to 40% loading (4,600 lbs/hr) 63% 4.7Klbs	
	c) Increase to 50% loading (5,800 lbs/hr) 69% 5.8Klbs	
	d) Return to step 7 valve setting (60% load) 74% 6.88Klbs	MEB 3/29/84
9.	Gradually manually increase FCV-431 to achieve a FT-311 steam flow rate of 11,580 lbs/hr (100% load). 9.8Klbs/hr at 85% FCV 431	MEB 3/29
10.	Perform SGITP#2 (Hot Salt Flow with Transients) step 23 thru the end of the procedure.	MEB 3/29
11.	Perform SGITP#3 Diurnal Shutdown (No Salt Flow) - Overnight Test. OK overnight 3/30/84 MEB	Has Been Accomp. Before and will be overrn
12.	Perform SGITP#4 Load Following Test.	MEB 3/29/84
~~13.~~	Perform SGITP#5 Alternate Diurnal Shutdown (with salt cycling) - Overnight Test.	
14.	Perform SGITP#6 Feedwater Loss Safe Shutdown Test.	
15.	Perform SGITP#7 Salt Flow Loss Safe Shutdown Test.	
16.	Perform SGITP#8 Manual Sequence Demonstration.	

FW Temp 388

FW Temp 394°F

initial lockup and cooldown from 16:03 to 17:33

Shutdown 18:00

SGITP#2

STEP	DESCRIPTION	VERIFICATION
21.	Gradually open FCV 321 and modulate FCV 431 to achieve a FT-311 steam flow rate of 11,580 lbs/hr (100% load).	________

NOTE

The next activity will be the control loop checkout of the Steam Pressure Control FCV 321. Should the control loop, during steam flow rate variations, shown incorrect response, accomplish the control loop tuning engineering activity. Following this, return to the initial portion of the checkout and reaccomplish the control loop checkout.

- Steam Pressure (PT-321) operational limits: 1100 ± 50 psig.

22. Activate the FCV 321 Steam Pressure Control with a set point of 1100 psig. ________

FW Temp = 393°F

23. Perform a step response test to introduce low to medium amplitude pressure transients to the main steam pressure and verify correct control response. Manually change FCV 431 to obtain the flow rates specified below at FT-311. Allow the control loop to settle prior to changing conditions.

FT-311		FCV-431
8.9	a) Close FCV 431 to obtain an 11,000 lbs/hr flow rate.	82%
8.6	b) Close FCV 431 to obtain a 10,500 lbs/hr flow rate.	81%
8.25	c) Close FCV 431 to obtain a 10,000 lbs/hr flow rate.	80%
8.86	d) Open FCV 431 to obtain an 11,000 lbs/hr flow rate.	82%
9.8	e) Open FCV 431 to obtain a 12,000 lbs/hr flow rate.	85% ok
FT-311 100% = 9.4	f) Close FCV 431 to return to 11,580 lbs/hr flow rate.	84% MEB 3/29

13:43 — 14:18

24. Maintain this On Line, 100% load condition for ~~1~~ hour. Monitor control loop performance in this steady state operation. 30+ min. — MEB 3/29

25. Perform GSGP#3 (manual SGS shutdown) from the On Line condition to Diurnal Shutdown. — NA

26. Perform GSGP#6, SGS Post Test Checklist (applicable sections only). — N.A.

GO TO SGITP 4.

SGITP#4

STEP	DESCRIPTION	VERIFICATION
1.	Perform GSGP#2 (manual SGS startup) Diurnal Shutdown to Warm standby sequence.	NA
2.	Perform GSGP#2 (manual SGS Startup) Warm Standby to On Line Sequence, (This will achieve the on line, 30% load condition.).	ON LINE
3.	Maintain the 30% steady state load condition for 30 minutes. Monitor all control loop performance.	NA PREVIOUS TEST TODAY

NOTE

The next activity will be the load following test in which the SGS steam loading will be ramped up to 100% at a 10%/minute rate. Verify control loop performance during the ramping.

FW Temp 400

4. Using a ramp rate of 10% SGS steam loading per minute, modulate FCV 431 to achieve the steam flow rates specified below at FT-311. Note the FCV 431 settings to achieve the specified flows.

			Time	FT-311
2.4	= 30% load.		14:54	
3.9	a) 4,630 lbs/hr (40% load).	FCV 431 58 %	14:55	3.7
4.9	b) 5,790 lbs/hr (50% load).	FCV 431 66 %	14:56	5.09
5.9	c) 6,950 lbs/hr (60% load).	FCV 431 71 %	14:57	6.01
6.9	d) 8,100 lbs/hr (70% load).	FCV 431 75 %	14:58	7.11
7.8	e) 9,270 lbs/hr (80% load).	FCV 431 78 %	14:59	7.7
8.8	f) 10,420 lbs/hr (90% load).	FCV 431 82 %	15:00	8.7
9.8	g) 11,580 lbs/hr (100% load).	FCV 431 85 %	15:01	9.4

MGB 3/29/8

5. Maintain the 100% SGS steam loading for ~~30~~ 10 minutes. MGB 3/29/84

15:04 — 15:14

15:14

20 min
10 min
30 min
70 min Salt inventory Min.

STEP DESCRIPTION **VERIFICATION**

6. Using a ramp rate of 10% SGS steam loading per minute, modulate 431 to achieve the steam flow rates specified below at FT-311. The FCV 431 settings noted before may be used to obtain the required flow. Time FT-311

FW Temp 396°F

9.8 - 100% 14:31

8.8 a) 10,420 lbs/hr (90% load) 1432 @ 8.7

7.8 b) 9,270 lbs/hr (80% load) 14:33 @ 7.8

6.9 c) 8,100 lbs/hr (70% load) 1434 @ 7.0

5.9 d) 6,950 lbs/hr (60% load) 1435 @ 6.2

4.9 e) 5,790 lbs/hr (50% load) 14:36 5.1 MEB 3/29/84

Probably off 1 Scan on Emcon 14:36:05 4.88

7. Maintain the 50% SGS steam loading for ~~30~~ 10 minutes. MEB 3/29/84

14:38 - 14:49

8. Gradually close FCV 321 to achieve a 10% salt flow rate (7600 lbs/hr at FT-321). N-A.-

9. Perform GSGP#3 (manual SGS Shutdown) steps 1 thru 8. This will bring the SGS to Warm Standby. went to SGITP5

This completes the Load Following Test, SGITP #4. It is assumed that the test activity will continue into SGITP#5 (Alternate Diurnal Shutdown - Hold Overnight) from the Warm Standby mode.

COMPLETED 7/19/81

4.2.7 SGITP#7 Salt Flow Loss Safe Shutdown

PURPOSE: ~~From 50% and~~ AT full steam load conditions, upon reducing the salt flow to zero, the control system safely shuts down the SGS to the Warm Standby mode.

DESCRIPTION: Starting from the Diurnal Shutdown mode, the SGS is manually brought to the On Line, 100 ~~50%~~ load condition. A salt flow trip will be performed and, by automatic and operator actions, the SGS taken to the Warm Standby mode. ~~The SGS is then brought to the On Line, 100% load condition and again tripped by a salt flow loss indication.~~ Upon shutting down the SGS, the final configuration will be the Warm Standby mode.

OBJECTIVES:

a) Demonstrate control system performance in reacting to a salt flow trip
   - EQUIPMENT ~~Salt~~ Protection System
   - Master Control System
   - Network 90

b) Verify structural integrity of the SGS

c) Demonstrate proper interaction between the SGS, TSS, and HRFS

d) Test crew familiarization with system reaction to trips.

CRTF/MMC PRETEST CHECKLIST

TEST PHASE: SGITP #7

TEST IDENTIFICATION: SALT FLOW LOSS SAFE SHUTDOWN

DATE OF TEST: 5/10/84

PLANNED START TIME: 15:15

PLANNED COMPLETION TIME: 15:45

RESPONSIBLE OPERATING PERSONNEL:	PRIMARY	BACKUP
TEST CONDUCTOR (MMC)	SALOFF	
CONTROLS ENGINEER (MMC)	N/A	
CONSOLE OPERATOR (CRTF)	NELSON	
OPERATION/SAFETY ENGINEER (CRTF)	NELSON	
RS/HRFS SUPPORT OPERATOR (CRTF)	N/A	
SGS/TSS OPERATOR (CRTF)	GRIEGO	

TEST FILE: Test File Number N/A has been approved for this test.
Startup includes ______ heliostats.
The highest liquid outlet temperature expected for the test is ______°F salt, ______°F water/steam.

TEST CONFIGURATION: HOT SALT FROM HOT TANK, TURBINE OFF LINE

APPROVALS:

S. Saloff 5/10/84
MMC Test Conductor Date

N/A
MMC Controls Engineer Date

R. Nelson 5/10/84
CRTF O/S Engineer Date

ITP PRETEST MEETING

TEST I/D: SGITP#7

TEST FILE #: N/A

Using the MCS Specification's Instrumentation Listings, define the data to be recorded and the data rate required during the performance of the specific integrated test.

Identifier	Description	Data Rate

CRTF/MMC SAFETY CHECKLIST

Test ID SGI7P#7 Date 5/10/84

Test Title SALT FLOW LOSS SAFE SHUTDOWN

1. Site Occupants	**O/S**
Communications Established to all manned control points	JVM
Safety Equipment In Place	JVM
1. OSHA Protective Gloves	
2. Fire Retardent Coveralls	
3. Hard Hats/Face Shields	
4. Approved Fire Extinguishers	
2. Solar Only	
"Test In Progress" Lights ON in the tower	JVM
Non-Test Personnel Informed and In Secure Location	
Generator ON (Freq. OK)	
Field Monitor on call after solar startup	
Communications Established	
Tower Top Baracade up	
Gates Closed and posted with red lights or signs	
Field Clear, Ready for Startup	
3. Control Room Locked	N/A
4. Beam UP Command Shall Be Given Only After Above Checklist Is completed By O/S Engineer	JVM

System Returned To A Safe Configuration JVM

SGITP #7

This integrated test can be accomplished at any point following the completion of SG1TP#2.

When encountering a loss of salt flow trip (Hot, Cold or Booster Pump Sump Level-high), the control systems will accomplish the following actions. These are worst case actions and SGS test configuration specific.

a) ~~Unit~~ EQUIPMENT Protection System (TR-186)

- DEFOCUS HELIOSTATS
- Turn off BOOST PUMP Cold Salt Pump
- Turn off Hot Salt Pump
- Close FCV 531
- Shut off steam flow to turbine (FCV 501)
- ~~Reverse power direction relay~~ open~~s~~ generator circuit breaker

b) Master Control System

- Dump steam to Deaerator (FCV 431)
- Maintain control of HRFS

c) Operator Action (at EMCON console)

- Bring the SGS, TSS, and HRFS to the Warm Standby mode

STEP	DESCRIPTION	VERIFICATION
1.	Perform GSGP#1 Pretest Checklist.	N/A
2.	Perform GSGP#2 (manual SGS Startup) for the following sequences:	
	a) Diurnal Shutdown to Warm Standby.	N/A
	b) Warm Standby to On Line condition. (This will achieve the on line, 30% load condition.)	N/A
		5/10

STEP	DESCRIPTION	VERIFICATION
~~3.~~	~~Gradually manually increase FCV A31 to achieve a FT-311 steam flow rate of approximately 5,790 lbs/hr (50% load). Maintain this condition for five minutes.~~	
~~4.~~	~~Input TBD signal (loss of salt flow) to trip the system.~~	
~~5.~~	~~Verify proper response of the UPS and the MCS.~~	
6.	Verify all SGS ~~(Table 4.1-1)~~ and TSS ~~(Table A)~~ trace heater circuits are operating and that all temperatures, with the exception of the following list, are greater than 500°F. AS LISTED IN CONTROL ROOM PRETEST CHECKLIST.	5/10/84
	TEH 217 CHANNEL 137 · TEH 236 CHANNEL 140	
	TEH 223 138 · TEH 238 141	
	TEH 224 139 · TEH 239 142	
	~~NOTE~~	
	~~The SGS is now in the Warm Standby mode. If maintaining this condition, the CSP would be cycled to maintain water/steam pressure.~~	5/10/84
~~7.~~	~~Perform GSGP#2 (manual SGS Startup), the Warm Standby to On Line condition sequence. This will bring the SGS to the On Line, 30% load condition.~~	TE 382 900°F
	8.4 FCV-321 100%	
8.	Gradually manually increase FCV 431 to achieve a FT-311 steam flow rate of approximately ~~11,580~~ lbs/hr (100% load). Maintain this condition for 5 minutes. TE-181A OF >300°F	5/10 15:1 15:2
9.	Input ~~TBD~~ signal (loss of salt flow) to trip the system.	5/10
10.	Verify proper response of the ~~UPS~~ EPS and MCS, PER ITEM a) P105.	5/10
11.	Perform GSGP#3 (manual SGS Shutdown) ~~steps 6~~ thru the end of the sequence.	5/10
12.	Perform GSGP#6 Post Test Checklist.	5/10

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