Cooperative Agreement
DE-FC03-82SF11675-3

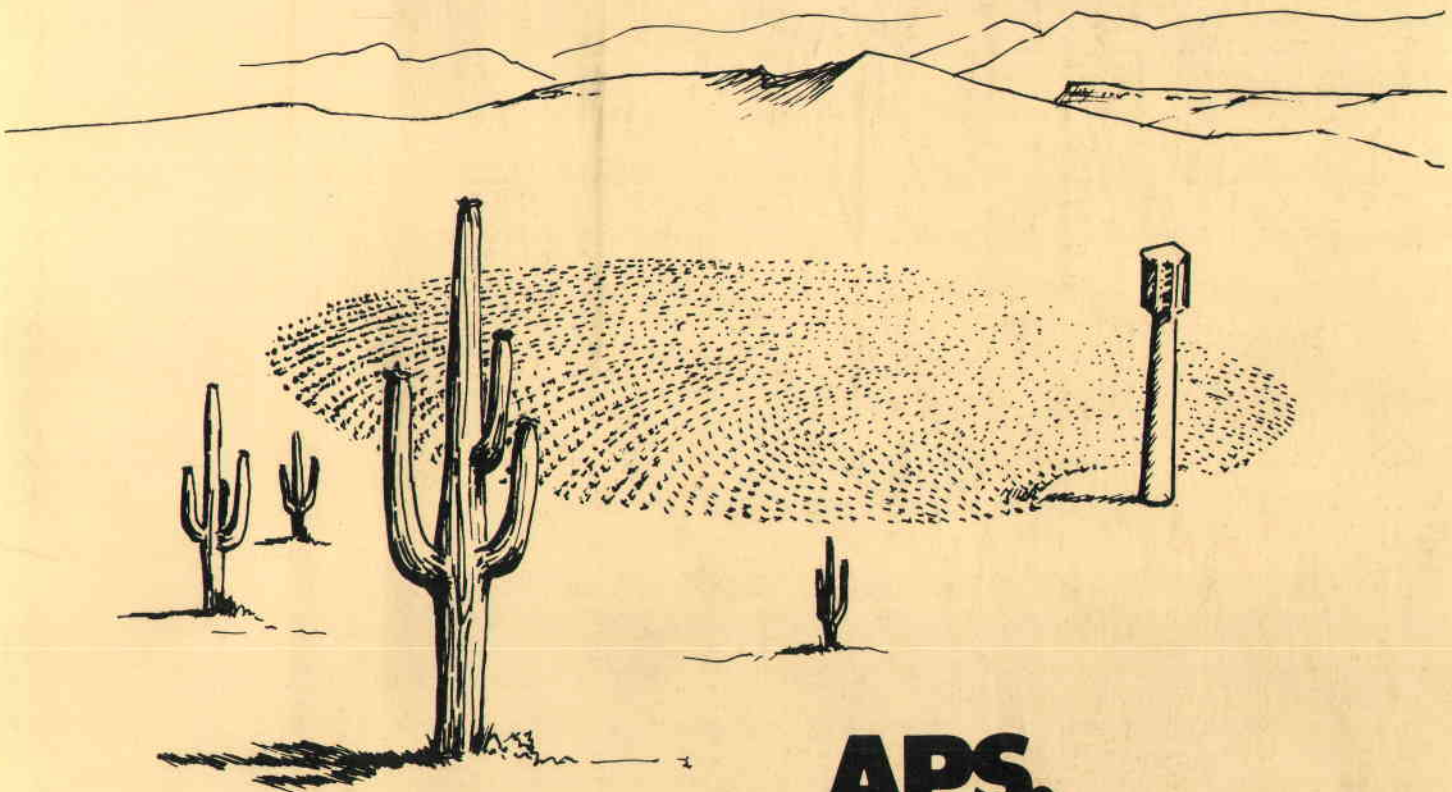
Volume III

Final
Report Draft

August 1983

Specifications

Preliminary Design of a Solar Central Receiver for a Site-Specific Repowering Application (Saguaro Power Plant)



APS.

MARTIN MARIETTA

Black & Veatch
Consulting Engineers

Babcock & Wilcox
a McDermott company

Cooperative Agreement
DE-FC03-82SF11675-3

Volume III

Final
Report Draft
August 1983

Specifications

PRELIMINARY DESIGN OF A SOLAR CENTRAL RECEIVER FOR A SITE-SPECIFIC REPOWERING APPLICATION (SAGUARO POWER PLANT)

Sponsored By:

San Francisco Operations Office
Department of Energy

Period Covered:

October 1982—September 1983

Author:

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ARIZONA PUBLIC SERVICE COMPANY
Phoenix, Arizona 85036

FOREWORD

This report is submitted by the Arizona Public Service Company to the Department of Energy in accordance with provisions of Cooperative Agreement DE-FC03-82SF11675. This final technical report summarizes the work related to the preliminary design, cost, and performance of the Saguaro Power Plant Solar Repowering Project that was performed during the period from September 30, 1982 through September 30, 1983. The final technical report is published in five volumes

Volume I - Executive Summary

Volume II - Preliminary Design

Volume III - System Requirements Specification

Volume IV - Appendixes

Volume V - Drawings

This contract was under the direction of Dr. Keith Rose of the Department of Energy, San Francisco Operations Office, Oakland, CA. Mr. William Peila of Sandia National Laboratories, Livermore, CA, was the Technical Manager.

The efforts performed by the Arizona Public Service team were as follows:

1) Arizona Public Service Company - Overall Program Management; System Economic Analysis; Financial Plan; Preliminary Design Lead;

2) Martin Marietta Corporation - System Requirements Specification Lead; Selection of System Configuration Lead; Solar System Preliminary Design, Analysis, and Performance Estimates; Preliminary Design of the Solar Collector, Solar Master Control, and Thermal Energy Storage; Receiver Configuration Development, Flux Mapping, Sizing, Temperature Profile Analysis, and System Level Analyses; Solar Steam Generator Heat Transfer Salt Systems; Preparation of System Interface Definition Document and System Design Specifications for each of the Solar Systems; and Reproduction of Major Documentation.

3) Black and Veatch Consulting Engineers - Preliminary Design and Analysis for the Solar/ Fossil Interfaces, Site and Site Facilities, All Foundations, Fossil Systems, Electrical Power Generation Systems and Receiver Tower, Existing Saguaro Power Plant Descriptive Data; Piping, Pumps, and Valves; Development Plan Lead; and Capital Cost Collection and Audit.

4) Babcock and Wilcox - Subcontract to Martin Marietta for Solar Receiver and Solar Steam Generator Preliminary Design.

This document was edited and reproduced by Martin Marietta Corporation.

ACKNOWLEDGMENTS

This report has been prepared by Arizona Public Service Company for the Department of Energy with the written contributions of the following personnel:

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1.0 Subsystem Interface Definition Document

MCR-82-639

SUBSYSTEM INTERFACE DEFINITION DOCUMENT

Revision 3

PRELIMINARY DESIGN ENGINEERING SERVICES
FOR SOLAR REPOWERING OF THE SAGUARO POWER PLANT

August, 1983

Martin Marietta Corporation
Denver Division
Denver, CO 80201

Prepared for Arizona Public Service Company
Phoenix, Arizona
Under Subcontract No. RD82-6732

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SUBSYSTEM INTERFACE DEFINITION DOCUMENT

NOTE: TBD denotes values that have yet to be determined.

1.0 DESIGN CONDITIONS

1.1 Receiver Design Point Conditions

1.1.1 Direct Normal Insolation: 950 W/m^2

1.1.2 Time: Noon on Day 35

1.1.3 Visibility: 25 km (15.5 m)

1.2 Balance of Plant Design Point Environmental Conditions

1.2.1 Dry bulb temperature: 38.9°C (102°F)

1.2.2 Wet bulb temperature: 20.6°C (69°F)

1.2.3 Atmospheric pressure: 94.2 kPa (27.82 in. Hga)

1.2.4 Wind speed: 3.5 m/s (7.8 mph)

1.2.5 Wind direction: 135° (Southeast)

1.3 Receiver Tower Location: Longitude - 111°17'10.10"W, Latitude-32°33'8.8"N, Base Elevation - 593 m (1945 ft) AMSL

1.4 Soil Bearing Strength: 191.6 kPa (4000 psf) for undisturbed soil at a depth of 1 m (3 ft)

1.5 Annual Average Daily Direct Normal Insolation: 6.90 kWh/m^2-day

1.6 Maximum Wind Speeds [at 10 m (33 ft) elevation]

1.6.1 Operational: 15.6 m/sec (35 mph)

1.6.2 Survival: 33.5 m/sec (75 mph)

1.6.3 Wind Speed Model
Based on the ANSI A58.1-1982 code.

1.7 Seismic Zone: UBC Risk Zone 2

1.8 Earthquake Ground Acceleration: 0.1 g

1.9 Temperature Extremes: -7 to 46°C (20 to 115°F)

2.0 ELECTRICAL POWER GENERATION SUBSYSTEM

2.1 Maximum Gross Electrical Power at 6.77 kPa (2.0 in. Hg a)
Backpressure: 121.0 MWe
Conditions are: Valves wide open
Throttle Steam flow 126 kg/sec (1.00×10^6 lb/hr)
Throttle pressure 10 MPa (1450 psig)
Throttle temperature 538°C (1000°F)

2.2 Design Repowering Level: 66 MWe (gross)

Conditions are: Backpressure 6.77kPa (2.0 in Hg a)
Throttle Steam flow 65.0 kg/sec (515.8×10^3 lb/hr)
Solar Steam Generator Outlet Stea Flow
65.7 kg/s (521.0×10^3 lb/hr)
Feedwater Flow 66.3 kg/s (526.2 lb/hr)
Throttle pressure 10 MPa (1450 psig)
Throttle temperature 538°C (1000°F)

2.3 Reference Heat Balance (68.2 MWe gross): See Figure 1
Ratio by (66.1/68.2) to obtain correct flowrates and powers.
Reference Heat Balance (30.4 MWe): See Figure 2

2.4 Turbine Throttle Steam

2.4.1 Nominal temperatures at 6.77 kPa (2.0 in. Hg a) backpressure.

Gross Power Level MWe	Throttle Steam Temperature °C (°F)	
	Fossil Only	Solar Only
120	537.8 (1000)	-
100	TBD*	-
80	TBD	-
66	—	537.8 (1000)
60	TBD	537.8 (1000)
40	TBD	537.8 (1000)
30		537.8 (1000)

NOTE: For combined operation, an approximate throttle steam temperature is the steam flow weighted average of the fossil and solar steam temperatures. A more exact calculation would use enthalpies rather than temperatures for the averaging.

2.4.2 Off-nominal temperature limits: See Attachment 1

2.4.3 Nominal throttle pressure: 10.0 MPa ± 138 kPa (1450 psig ± 20 psi)

2.4.4 Off nominal throttle pressure limits: See Attachment 1

* TBD's will be determined early in the Final Design Phase.

2.4.5 Steam flowrates at 6.77 kPa (2.0 in Hg a) backpressure.

Gross Power Level MWe	Throttle Steam Flowrate-kg/sec (1000s lb/hr)	
	Fossil Only	Solar Only
120	126.0 (1000)	---
100	TBD	---
80	TBD	---
66	---	65.0 (515.8)
60	TBD	TBD
40	TBD	TBD
30	TBD	31.7 (251.5)

NOTE: For combined operation the total throttle steam flowrate is equal to the sum of the flowrates from the fossil and from the solar steam generators.

2.5 Final Feedwater Temperature at 6.77 kPa (2.0 in. Hg a) Backpressure.

Gross Power Level MWe	Feedwater Temperature °C (°F)	
	Fossil Only	Solar Only
120	233 (451)	---
100	TBD	---
80	TBD	---
66	---	197 (387)
60	TBD	TBD
40	TBD	TBD
30	TBD	163 (326)

NOTE: For combined operation, an approximate final feedwater temperature can be obtained by adding to the fossil only feedwater temperature corresponding to the combined throttle steam flowrate (See paragraph 2.4.5). A detailed heat balance is required for an accurate determination of final feedwater temperature.

2.6 Gross Heat Rate at 6.77 kPa (2.0 in. Hg a) Backpressure.

Gross Power Level MWe	Gross Heat Rate MWe/MWt (Btu/kWh)	
	Fossil Only	Solar Only
120	0.385 (8868)	---
100	TBD	---
80	TBD	---
66	---	0.3826 (8921)
60	TBD	0.3800 (8979)
40	TBD	0.3636 (9384)
30	TBD	0.3402 (10031)

NOTE: For combined operation, an approximate gross heat rate can be obtained by starting with the fossil only gross heat rate corresponding to the combined throttle steam flowrate and then adding a temperature correction. The temperature correction is:

TBD

An approximate generator gross power can then be calculated from the enthalpies corresponding to the throttle steam and final feedwater approximate temperature and pressure conditions, the throttle steam flowrate and the approximate gross heat rate.

A more accurate determination of gross heat rate and generator gross power would require that a detailed heat balance be performed.

2.7 Auxiliary Electrical Loads

2.7.1 EPGS and Fossil Steam Generator

Gross Power Level MWe	Auxiliary Electrical Loads MWe		
	EPGS	Fossil Steam Generator	
120	4.24	1.67[a]	1.24[b]
100	TBD	-	
80	TBD	-	
66	3.17	-	
60	TBD	-	
40	TBD	-	
30	2.65	-	

[a] All Fossil
[b] 50 MWe Fossil, 70 MWe Solar

2.7.2 General Plant Operations

Auxiliary Power Supply, Compressed Air, Control, Equipment Cooling, Lights and Facilities Chargeable to Unit One: 1.02 MWe at 66 MWe output

2.7.3 Solar Plant at Design Point (MWe) (Preliminary)

	a	b	c
Collector	0.0	0.11	0.11
Pumps			
Cold Salt	0.0	3.12	3.12
Hot Salt	0.55	0.0	0.55
Steam Generator Water			
Cold Salt Attemperation	0.05	0.0	0.05
TOTAL	0.60	3.23	3.83

a - Steam production from storage discharge only.

b - Storage charging from receiver only (receiver + collector + storage charging) - no steam production.

c - Steam production from both receiver and storage discharging.

3.0 FOSSIL STEAM GENERATOR

3.1 Full Load Duty: 316 MWt

3.2 Firing Rates MWt (Btu/hr x 10^{-8}) and combustion efficiency (1%)

Gross Power Level, MWe	Thermal Duty	Firing Rate		Combustion Efficiency
120	316 (10.8)	380	13.0	83.2
100	266 (9.1)	315	10.8	84.0
80	219 (7.42)	259	8.75	84.7
60	167 (5.72)	195	6.70	85.4
40	117 (4.01)	136	4.66	86.0

3.3 When the fossil steam generator is brought on line with the solar steam generator in operation, the two steam temperatures should be matched within 47°C (85°F) before opening the fossil steam generator isolation valve.

4.0 SOLAR STEAM GENERATOR

4.1 Location: Near main plant (See Figure 2)

4.2 Nominal Steady State Duties

4.2.1 Reduced load (30 MWe gross): 86.3 MWt

4.2.2 Design point load (66 MWe gross): 172.5 MWt

4.3 Salt Temperatures

4.3.1 Preheater outlet: 277°C (530°F)

4.3.2 Hot Salt Supply: 566°C (1050°F)

4.3.3 Attemperation Salt Supply: 277°C (530°F)

4.3.4 Superheater Inlet (at design point load): 557°C (1035°F)

4.3.5 Superheater Inlet Attemperation Allowance: 5.6°C (10°F) for excess area, 2.8°C (5°F) for control authority.

4.4 Salt Flowrates

4.4.1 Reduced load

4.4.1.1 Hot Salt: 201.8 kg/sec (1.601×10^6 lb/hr)

4.4.1.2 Attemperation Salt: 163.5 kg/sec (1.297×10^6 lb/hr) (Preliminary)

4.4.1.3 Cold Salt: 224.4 kg/sec (1.781×10^6 lb/hr) (Preliminary)

4.4.2 Design point load

4.4.2.1 Hot Salt: 389.7 kg/sec (3.093×10^6 lb/hr)

4.4.2.2 Attemperation Salt: 65.43 kg/sec (5.190×10^5 lb/hr)

4.4.2.3 Cold Salt: 448.8 kg/sec (3.562×10^6 lb/hr)

4.5 Heat Balances

4.5.1 Design point load: See Figure 3

4.6 Preheater Water Inlet Temperature: 238 ± 3°C (460 ± 5°F)

4.7 Steam Blowdown: 1% of solar steam generator steam flowrate

4.8 Water/Steam Pressure Drop Allocations (psia) (Preliminary)

Item	66 MWe gross Item Allow.	66 MWe gross Item Inlet	30 MWe gross Item Allow.	30 MWe gross Item Inlet
Pressure at turbine inlet	-	1465	-	1465
Main steam piping and flow nozzle	90	1555	21	1486
Solar steam piping	25	1580	6	1492
Superheater and Piping	80	1660	21	1513
Static head	7 (2)	1667	7 (2)	1520
Preheater and Piping	12	1679	6	1526
Feedwater regulator and boiler feed-water pump discharge	195 (1)	1874	412 (1)	1938
Solar feedwater piping	25	1899	6	1944
High pressure heaters	30	1929	8	1952
Boiler feed piping	31	1960	8	1960
Margin	60	2020	60	2020

(1) Assumes that fossil and solar systems are operating in parallel to produce 126.0 kg/sec ($1x10^6$ lb/hr) of steam. Lower steam rates will mean higher pressure drops at regulator.

(2) Reference elevation is ground level at solar steam generator site.

(3) 1 psi = 6.895 kPa.

4.9 Hot Salt Pump Location: Near hot salt storage tank and inside berm.

4.10 When the solar steam generator is brought on line with the fossil steam generator in operation, the two steam temperatures should be matched within 47°C (85°F) before opening the solar steam generator isolation valve.

5.0 SOLAR COLLECTOR FIELD

5.1 Heliostat Characteristics

5.1.1 Area: 58.5 m^2 (630 ft^2)

5.1.2 Reflectivity: 92% (average)

5.1.3 Availability: 99.7%

5.2 Number of Modules: 1

5.3 Type: North

5.4 Number of Heliostats: 4850

5.5 Total Collector Area: 2.839×10^5 m^2 (3.056×10^6 ft^2)

5.6 Field Dimensions and Location: See Figure 5

6.0 SOLAR RECEIVER/TOWER

6.1 Number of Receivers: 1

6.2 Receiver Type: Single Cavity, North-Facing

6.3 Receiver Absorbed Power: 190 MWt

6.4 Receiver Dimensions/Weight

6.4.1 North/South Dimension: 18.5 m (60.7 ft)

6.4.2 East/West Dimension: 28.8 m (94.5 ft)

6.4.3 Height: 54.9 m (180.2 ft)

6.4.4 Weight: 1.50×10^6 kg (3.29×10^6 lb)

6.4.5 Center of gravity location relative to receiver base:

Vertical: 19.09 m (62.64 ft)
North/South: -3.77 m (-12.38 ft)
East/West: .015 m (.05ft)

6.5 Receiver Salt Flowrates

6.5.1 Design point: 429.2 kg/sec (3.406×10^6 lb/hr)

6.5.2 Maximum (control valve wide open): 1.20 x Design Point

6.5.3 Design day power profile: See Figure 6

6.5.4 Maximum power profile: 1.10 x Figure 6

6.5.5 Minimum: 0.05 x Design point when outlet salt temperature is uncontrolled
0.20 x Design point when hot salt is controlled to design outlet temperature.

6.6 Receiver Salt Temperature

6.6.1 Cold Salt: $277 \; ^{+67}_{-11}$ °C ($530 \; ^{+120}_{-20}$ °F)

6.6.2 Hot Salt: When not on salt flow limit, 566 ± 11°C (1050 ± 20°F) except that the 30 minute average shall be 566 ± 1°C (1050 ± 2°F). When on salt flow limit, temperature shall be less than 582°C (1080°F).

6.6.3 Salt Film Temperature: Less than 600°C (1112°F) except for short periods not to exceed 20 min. per event and no more than 10 events per year.

6.7 Absorber Tube Metal: Temperature: Shall not exceed 649°C (1200°F) during steady state operation.

6.8 Tower Dimensions

6.8.1 Height from base of tower to tower/receiver interface: 146 m (479 ft)

6.8.2 Height from base of tower to receiver aperture reference line. 166.3m (545.7 ft)

6.9 Tower Location: See Figure 5

6.10 Base of Tower Elevation: 10.5 m (34.5 ft) above main plant elevation

6.11 Cold Salt Circulation Pump Location: Near cold salt storage tank and inside berm.

7.0 THERMAL STORAGE SUBSYSTEM

7.1 Storage Fluid: Molten Salt (60/40, $NaNO_3/KNO_3$ percent by weight)

7.2 Storage Capacity: 688 MWht (at 172.5 MWt discharge rate)

7.3 Charging Rate

7.3.1 Design: 190 MWt

7.3.2 Maximum: 209 MWt

7.3.3 Minimum: 38.0 MWt to hot tank
9.5 MWt to cold tank

7.4 Discharging Rate

7.4.1 Reduced load: 86.3 MWt

7.4.2 Design point load: 172.5 MWt

7.4.3 Minimum: 8.6 MWt

7.5 Combined Charging and Discharging Rate:

The thermal storage system shall be capable of simultaneous charging and discharging at any rates between the maximum and minimum rates.

7.6 Location: Near main plant and solar steam generator

7.7 Type and Number of Storage Tanks: Hot/Cold, one tank pair

7.8 Salt Flowrates

7.8.1 Charge Rates (hot tank in, cold tank out)

7.8.1.1 Design: 429 kg/sec (3.406×10^6 lb/hr)

7.8.1.2 Maximum: 472 kg/sec (3.747×10^6 lb/hr)

7.8.1.3 Minimum: 85.8 kg/sec (0.681×10^6 lb/hr) to hot tank
21.5 kg/sec (0.170×10^6 lb/hr) to cold tank

7.8.2 Discharge Rates (hot tank out, net cold tank in)

7.8.2.1 Reduced load: 194.9 kg/sec (1.546×10^6 lb/hr)

7.8.2.2 Design point load: 389.7 kg/sec (3.093×10^6 lb/hr)

7.8.2.3 Minimum: 19.5 kg/sec (0.155×10^6 lb/hr)

7.9 Salt Temperatures

7.9.1 From receiver to storage: $566 \begin{smallmatrix}+17\\-11\end{smallmatrix}$ °C ($1050 \begin{smallmatrix}+30\\-20\end{smallmatrix}$ °F)

7.9.2 From storage to receiver: $277 \begin{smallmatrix}+67\\-11\end{smallmatrix}$ °C ($530 \begin{smallmatrix}+120\\-20\end{smallmatrix}$ °F)

7.9.3 From storage to solar steam generator: $566 \begin{smallmatrix}+6\\-17\end{smallmatrix}$ °C ($1050 \begin{smallmatrix}+10\\-30\end{smallmatrix}$ °F)

7.9.4 From solar steam generator to storage: 277 ± 11°C (530 ± 20°F)

7.10 Allowable Heat Losses

7.10.1 Full hot tank: 200 kWt

7.10.2 Empty (heel only) hot tank: 195 kWt

7.10.3 Full cold tank: 75 kWt

7.10.4 Empty (heel only) cold tank: 73 kWt

7.11 Drain Tank Location: Near solar steam generator

7.12 Salt Heater and Salt Reconditioning Equipment

7.12.1 Salt Heater Functions: Initial melting of prilled salt and as a source of heat for the salt when the receiver is inoperable for extended periods.

7.12.2 Salt Heater Location: Near solar steam generator

7.12.3 Heater salt flowrate: 2.054 kg/sec (16,300 lb/hr)

7.12.4 Future Reconditioning process: NO_2 gas absorption, unreacted NO_2 is absorbed in sodium hydroxide/sodium sulphite scrubber

7.12.5 Future Reconditioning Equipment Location: Near cold salt storage tank and inside berm

7.12.6 Reconditioning flowrate: TBD

7.13 Storage Tank Ullage Gas: Dry air

8.0 MATERIALS OF CONSTRUCTION

8.1 Metals in Contact with Molten Salt:

Material	Temperature Range
Carbon Steel SA516 GR 70 - plate	≤343°C (650°F)
Carbon Steel A106 GR B - piping	≤343°C (650°F)
2 1/4 Chrome - 1 Moly A335 GR P22	343°-468°C (650°-875°F)
Nickel Alloy (Incoloy 800) - hot salt tank liner and absorber tubes	>468°C (875°F)
Stainless Steel 304 for all other applications	>468°C (875°F)

8.2 High Pressure Water/Steam Piping

8.2.1 Water: Carbon Steel A-106, Gr B

8.2.2 Steam: Low Chrome-Moly A335, Gr P22

8.2.3 Material selection for water/steam applications will generally be based on the design temperature and service conditions in accordance with the following.

(1) Carbon steel piping materials will be used for design temperatures less than or equal to 399°C (750°F).

(2) 1-1/4 per cent chromium alloy steel piping materials will be used for design temperatures greater than 399°C (750°F) and less than or equal to 510°C (950°F).

(3) 2-1/4 per cent chromium alloy steel piping materials will be used for steam and water service with design temperatures greater than 510°C (950°F).

9.0 PROPERTIES OF MOLTEN SALT

9.1 Composition: 60% $NaNO_3$, 40% KNO_3 by weight

9.2 Heat Capacity

C_p = 1532 watt sec/kg - °C

C_p = 0.366 Btu/lb °F

9.3 Density

$\rho = 2102.6 - 0.6684T$ kg/m^3 for T in °C

$\rho = 132.0 - 0.02318T$ lb/ft^3 for T in °F

9.4 Viscosity

$\mu = 1.886\times10^{-2} - 9.610\times10^{-5}T + 1.799\times10^{-7}T^2 - 1.155\times10^{-10}T^3$ Pa sec, T in °C

$\mu = 49.89 - 0.1379T + 1.389\times10^{-4}T^2 - 4.790\times10^{-8}T^3$ lb/ft hr, T in °F

9.5 Thermal Conductivity

$K = 0.06705\,(T+273.15)^{0.326}$ watts/m-°C, T in °C

$K = 0.0320\,(T+459.67)^{0.326}$ Btu/hr-ft-°F, T in °F

9.6 Melting/Freezing Temperature Range

221 to 245°C

429 to 473°F

9.7 Heat of Fusion

$\Delta H_f = 1.089 \times 10^5$ watt sec/kg

$\Delta H_f = 46.8$ Btu/lb

ATTACHMENT 1

SAGUARO UNIT NO. ONE TURBINE

PERFORMANCE SPECIFICATIONS

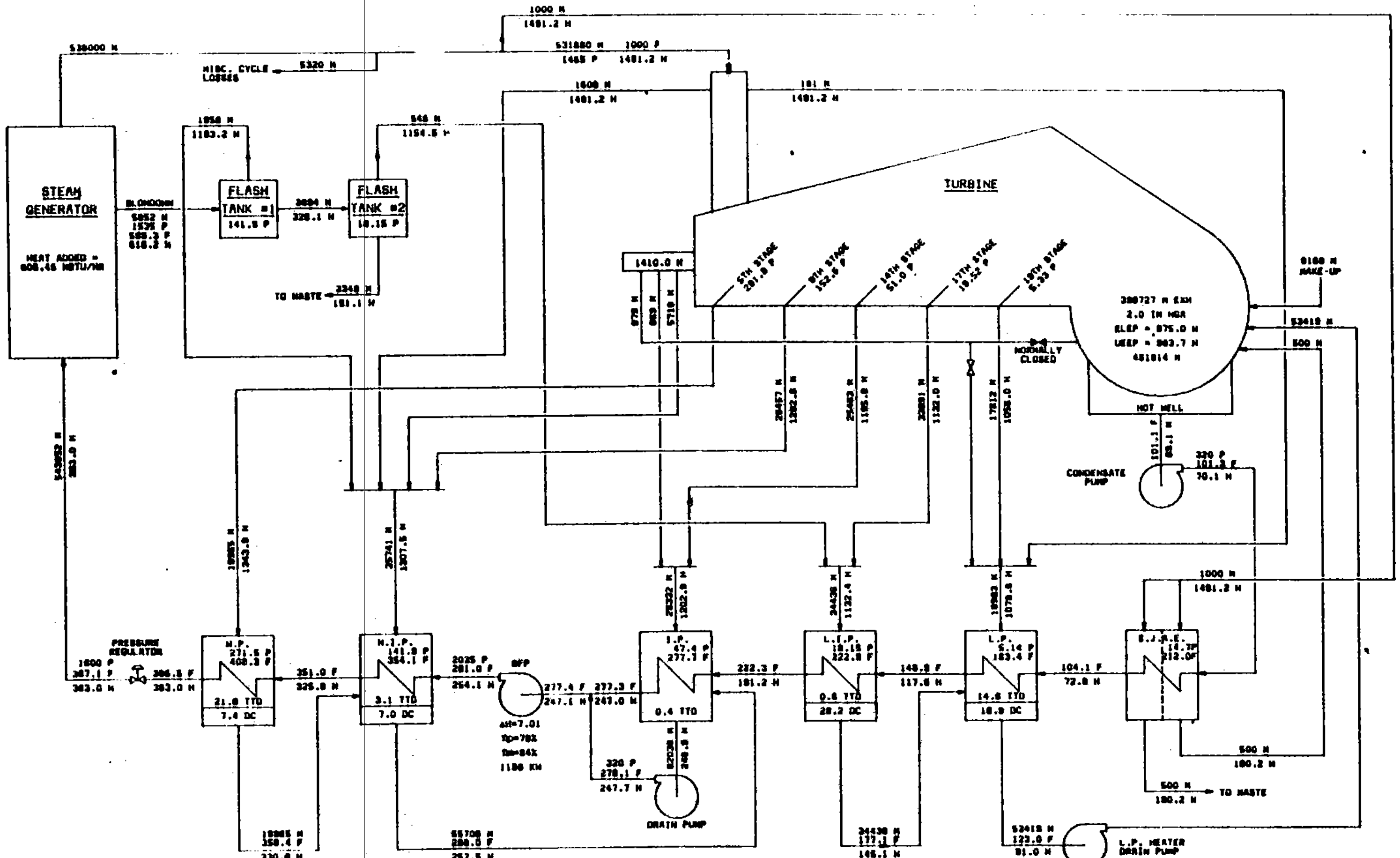
ALLOWABLE PRESSURE VARIATION

The steam pressure at the turbine main steam valve shall average not more than 1522 psi gage over any 12 month operating period. In maintaining this 12 month average, the pressure shall not exceed 1595 psi gage except during abnormal conditions when the pressure may swing momentarily to 1885 psi gage but the aggregate duration of such swings shall not exceed 12 hours per 12 month operating period.

ALLOWABLE TEMPERATURE VARIATIONS

The steam temperature at the turbine main steam valve shall average not more than 1000°F over any 12 month operating period. In maintaining this average, the temperature shall not exceed 1015°F except during abnormal conditions resulting in temperatures not in excess of 1025°F for operating periods not more than 400 hours per 12 month operating period nor 1050°F for swings of 15 minutes duration or less, aggregrating not more than 80 hours per 12 month operating period.

This data is from: "General Electric Turbine Instruction Book", GEI-40551 for Turbine No. 99666 abnd 99698.



NOTES:

1. HP AND HIP HEATER PARAMETERS PER HEATER SPEC SHEETS
2. IP, LIP, AND LP HEATER PARAMETERS PER AFS HEAT BALANCE
3. CYCLE ARRANGEMENT PER FIGURE E-4 OF VOLUME III JULY 1980 SAGUARO REPOWERING CONCEPTUAL DESIGN REPORT
4. BFP SUCTION AND DISCHARGE CONDITIONS PER EBASCO DRAWING NO. D-122887
5. HEATER PARAMETERS ADJUSTED FOR OFF-DESIGN PERFORMANCE
6. SI UNIT CONVERSIONS ARE AS FOLLOWS:
   LB/HR×0.000126=KG/SEC
   PSIA×0.006894=MPa
   (°F-32)×0.556=°C

GENERATOR

GENERATOR LOSS = 1193 KW
MECHANICAL LOSS = 609 KW
GENERATOR OUTPUT = 68,202 KW

$$GTHR = \frac{538000(1481.2)+5852(616.2)-543852(363.0)}{68202} = 8821 \text{ BTU/KW-HR}$$

$$NTHR = \frac{538000(1481.2)+5852(616.2)-543852(363.0)}{68202-1188} = 9080 \text{ BTU/KW-HR}$$

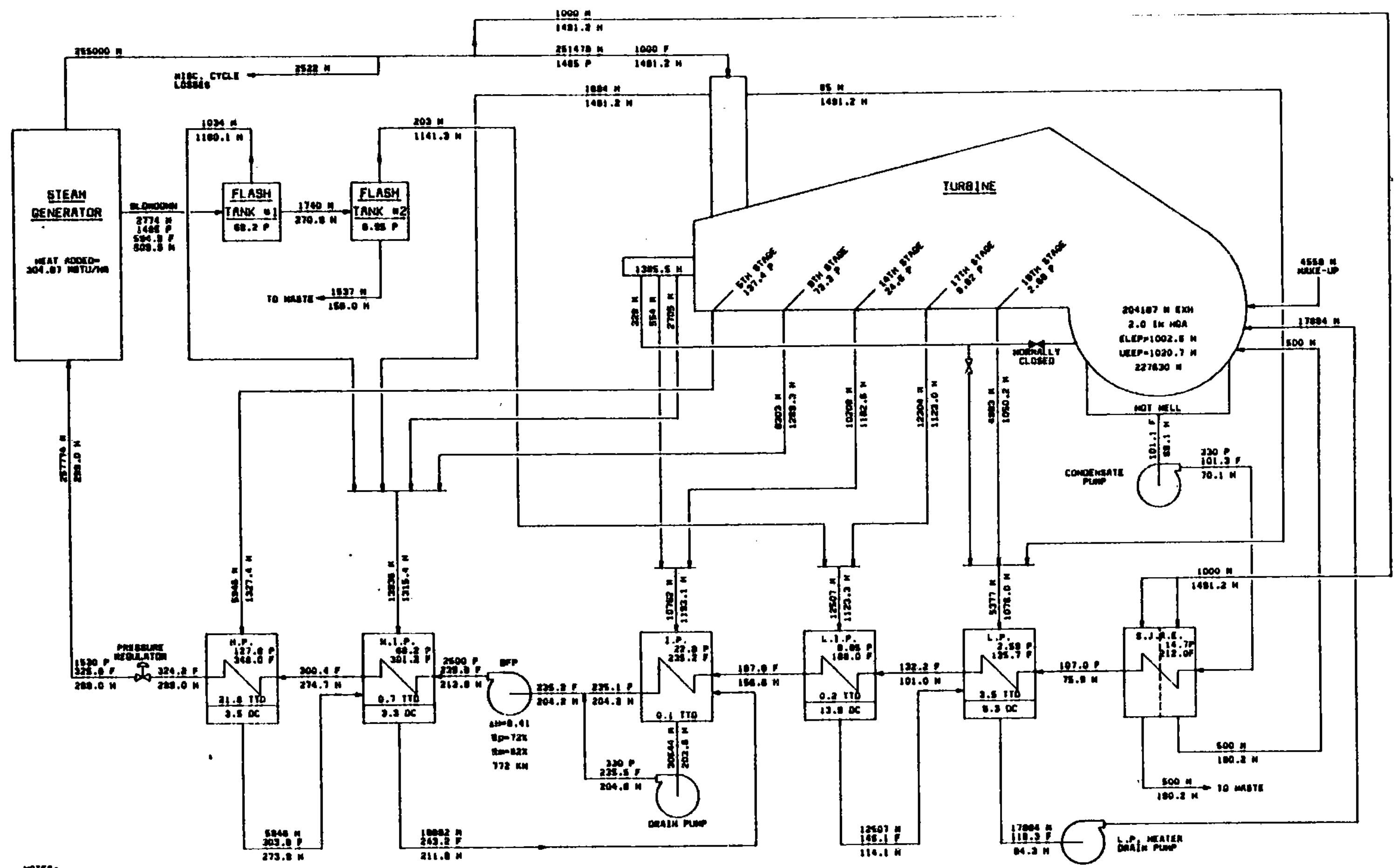
DESIGN CHARACTERISTICS

120,000 KW MAX 2.0 IN HG ABS 0% MU
TC2F-23" LSB 3600 RPM
1450 PSIG 1000F
GEN: 147058 KVA @ 30 PSIG H_2 0.85 PF

LEGEND

W = LBM/HR
H = BTU/LBM
F = DEG. FAHRENHEIT
P = PSIA

Figure 1 Turbine Cycle Heat Balance 68 MWe Gross



NOTES:

1. HP AND HIP HEATER PARAMETERS PER HEATER SPEC SHEETS
2. IP, LIP, AND LP HEATER PARAMETERS PER APS HEAT BALANCE
3. CYCLE ARRANGEMENT PER FIGURE E-4 OF VOLUME III JULY 1980 SAGUARO REPOWERING CONCEPTUAL DESIGN REPORT
4. BFP SUCTION AND DISCHARGE CONDITIONS PER EBASCO DRAWING NO. D-122887
5. HEATER PARAMETERS ADJUSTED FOR OFF-DESIGN PERFORMANCE
6. SI UNIT CONVERSIONS ARE AS FOLLOWS:
   LB/HRx0.0001259=KG/SEC
   PSIAx0.006894=MPa
   (°F-32)x0.555=°C

GENERATOR

GENERATOR LOSS	= 904	KW
MECHANICAL LOSS	= 605	KW
GENERATOR OUTPUT	= 30383	KW

$$GTHR = \frac{255000(1481.2)+2774(509.8)-257774(288.0)}{30383} = 10031 \text{ BTU/KW-HR}$$

$$NTHR = \frac{255000(1481.2)+2774(509)-257774(288.0)}{30383-772} = 10282 \text{ BTU/KW-HR}$$

DESIGN CHARACTERISTICS

120,000 KW MAX 2.0 IN HG ABS 0% MU
TC2F-23" LSB 3600 RPM
1450 PSIG 1000F
GEN: 147059 KVA @ 30 PSIG H_2 0.85 PF

LEGEND

W = LBM/HR
H = BTU/LBM
F = DEG. FAHRENHEIT
P = PSIA

Figure 2 Turbine Cycle Heat Balance 30 MWe Gross

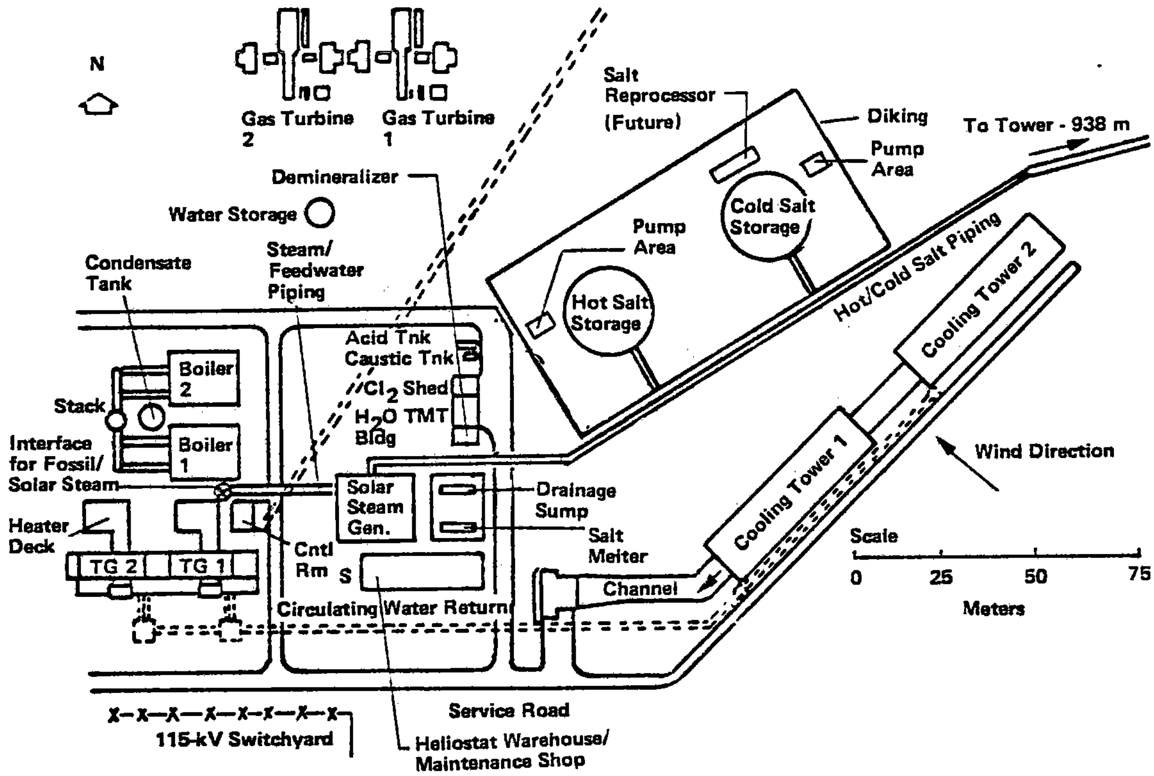


Figure 3 Solar Equipment Location

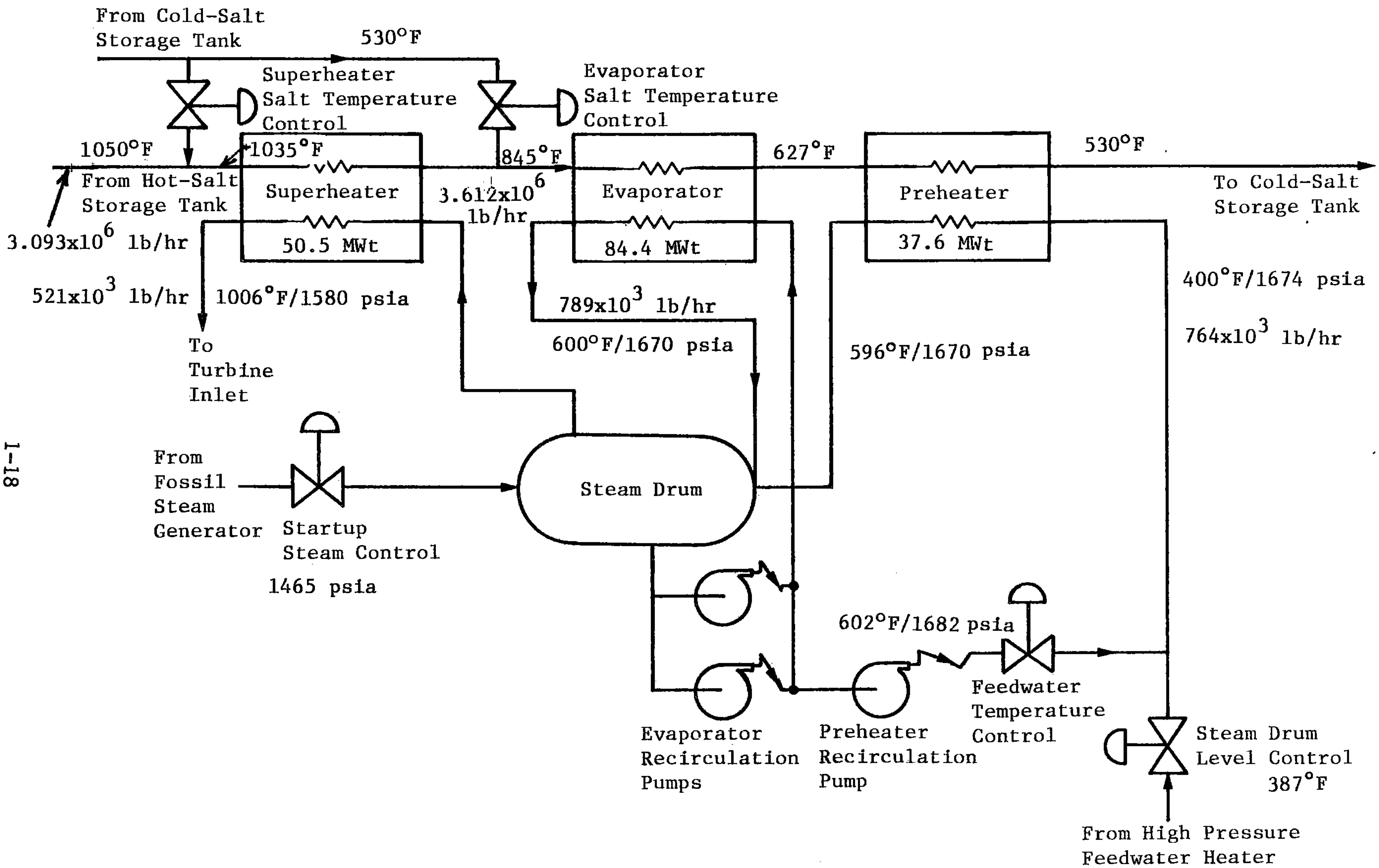


Figure 4 Solar Steam Generator Heat Balance—66 MWe

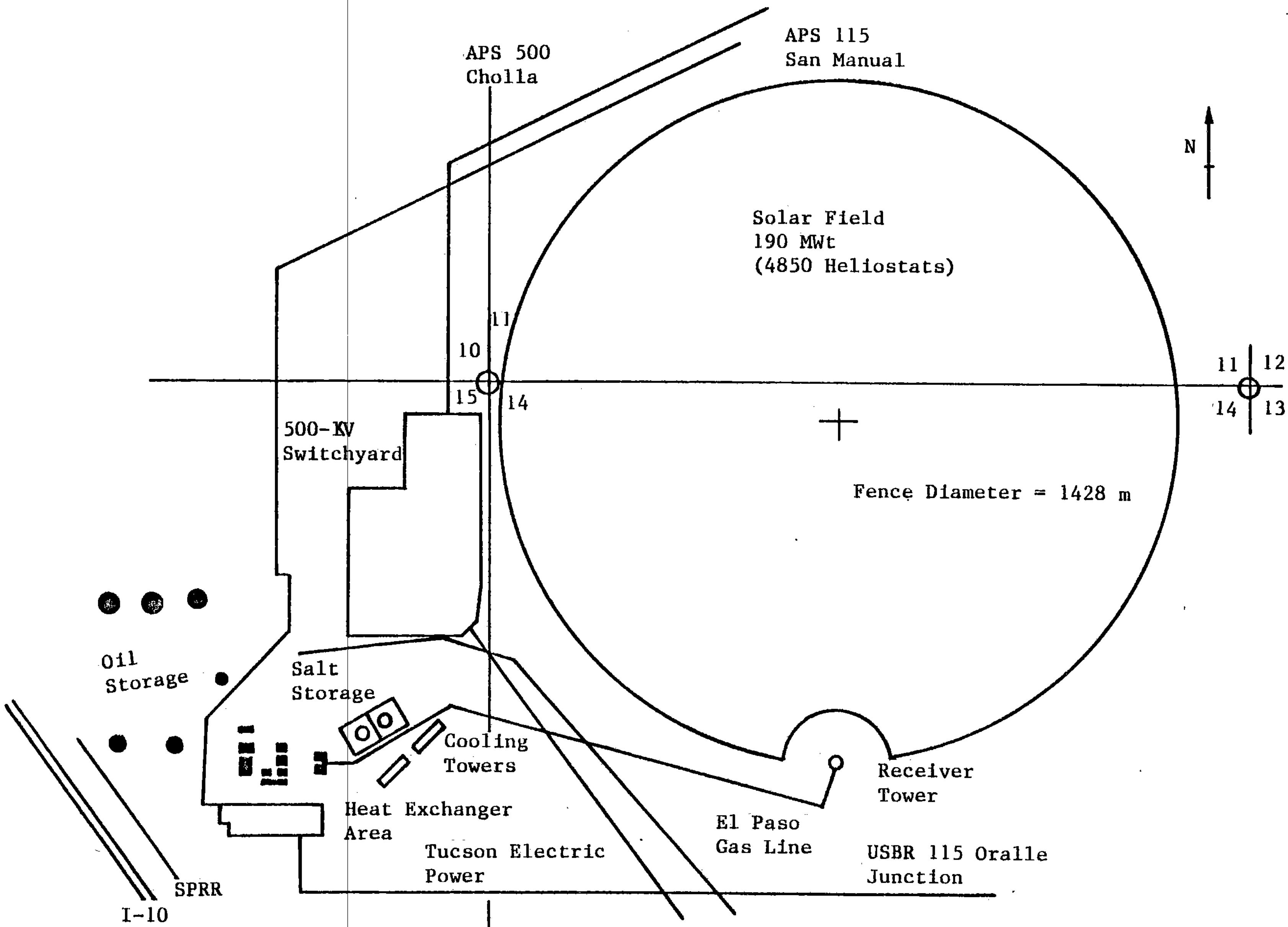


Figure 5 Collector Field Location

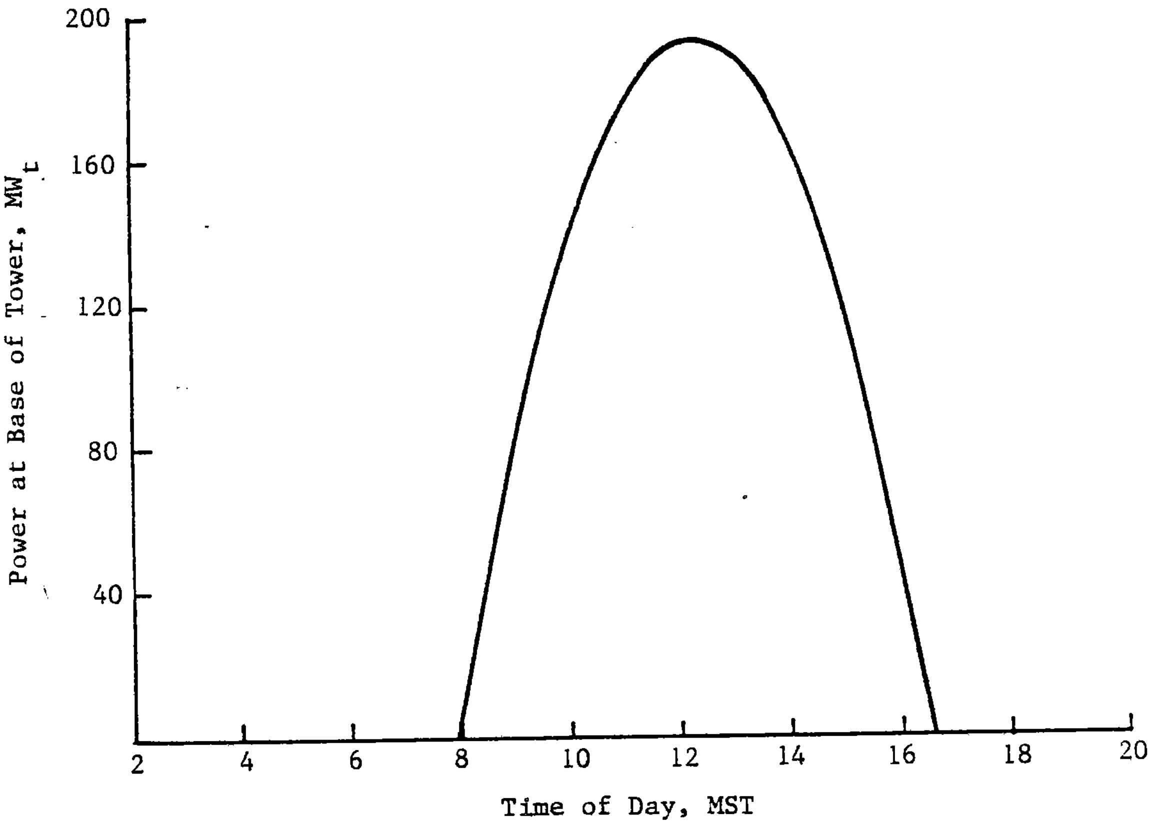


Figure 6 Peak Solar Profile on Design Day 35

2.0 Solar Collector Subsystem Specification

MCR-82-640

SOLAR COLLECTOR SUBSYSTEM SPECIFICATION

PRELIMINARY DESIGN ENGINEERING SERVICES
FOR SOLAR REPOWERING OF THE
SAGUARO POWER PLANT

August 1983

Martin Marietta Aerospace
Denver Aerospace
Denver, Colorado 80201

Prepared for Arizona Public Service Company
Phoenix, Arizona
Under Subcontract No. RD82-6732

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LIST OF TABLES AND FIGURES

1.0 CATEGORY DESCRIPTION

1.1 CATEGORY IDENTIFICATION

(1) Category Name Solar Collector
(2) Category Code CS-

1.2 FUNCTION

The solar collector supplies radiant thermal energy to the receiver by reflecting and focusing incident direct normal isolation onto the receiver surfaces. This is done in a manner that satisfies all receiver heat flux requirements and that satisfies plant operational demands.

1.3 PROCESS DESCRIPTION

The solar collector consists of an array of individually controlled heliostats and associated control hardware that enables the system to capture, reflect, and concentrate available solar energy onto the receiver. This is done in a manner that satisfies receiver heat flux requirements during all solar isolation periods. In addition, the solar collector responds to commands from the master control for emergency defocusing of the reflected energy to protect the receiver from damage and to command the heliostats to selected orientations to protect them during environmental extremes. Maintenance operations include periodic tracking accuracy verification using the beam characterization system, mirror washing operations, and any necessary repairs.

1.4 INTERFACING SYSTEMS

Systems that have a significant interface with the solar collector are listed in Table 1-1.

Table 1-1 Interfacing Systems

System	System Code
AC Power Supply--120/208 V	APA
Essential Service ac	API
Control House/Instrument Repair	BSC
Intraplant Communication	CMA
Commercial Telephone	CMD
Master Control System	COG
Grounding and Lightning Protection	EEB
Raceways	EEC
Weather Monitoring	INF
Collector Field Lighting	LTL
Fencing and Security	STD
Grading and Drainage	STF
Land	STJ
Receiver System	RSA

1.5 BOUNDARIES

The overall physical boundaries of the solar collector are shown in Figure 1-1. Additional boundaries not shown on the figure are as follows:

1) Boundaries between the heliostat and the AC power supply;

2) Boundaries between the HAC and the essential service ac;

3) Boundaries between the HAC and the master control system;

4) Boundaries between the heliostat pedestal/foundation and the land;

5) Boundaries between the reflected solar flux and the receiver;

6) Boundaries between the HAC and the weather station;

1.6 DEFINITION OF TERMS AND ABBREVIATIONS

Aim Point - The common centroid of flux patterns produced by several heliostats on a target plane; or the point of intersection of the centerlines of the beams produced by several heliostats.

Aim Point Strategy - The specified distribution of aim points on a target to achieve a desired flux pattern on the receiver absorbing surfaces.

Aperture - The opening through which the reflected solar energy from the collector field passes into the receiver cavity.

Canting - The process of displacing each mirror panel on a heliostat so that rays from the center of the sun reflected from analogous points of all the mirror panels converge to a common point that is at a desired distance (canting distance) from the heliostat.

Computer Leveling - A process by which heliostat aiming errors (because of pedestal tilt, encoder misalignment, etc) are mathematically corrected using data obtained from the beam characterization system.

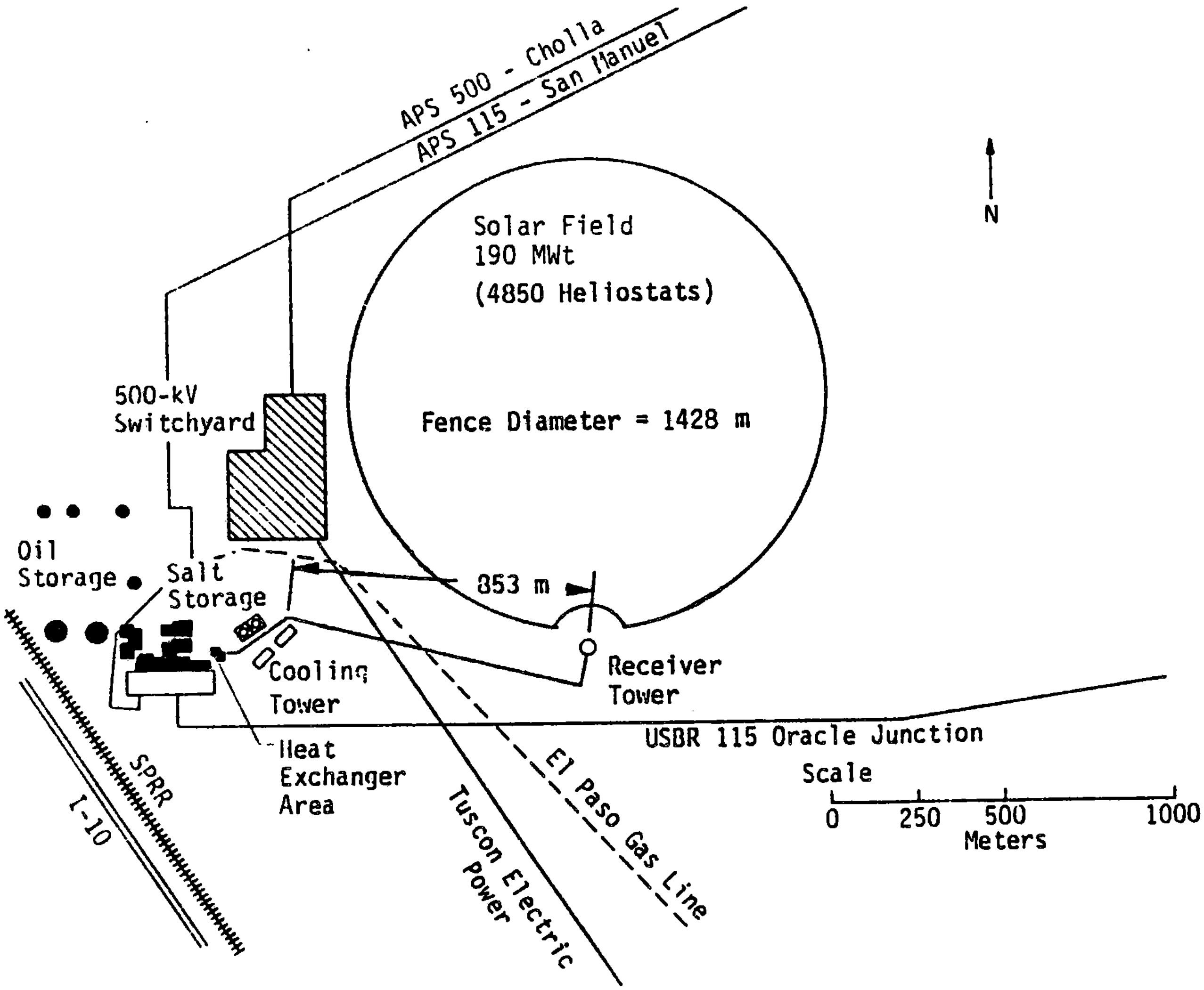

Figure 1-1 Solar Collector Physical Boundary

CRT - Cathode ray tube, normally used to interface with computer systems.

Defocusing (of Heliostats) - The act of moving heliostat beams from their aim point to the standby point.

Focusing (of Heliostats) - The act of moving heliostat beams from the standby point to the aim point.

HAC - Heliostat array controller

HC - Heliostat controller

HFC - Heliostat field controller

Mirror Curvature - A method of beam size reduction where the mirror panels are given a concave shape such that rays from the center of the sun reflected from any point on the mirror panel intersect at a common point which is at a selected distance (focusing range) from the mirror panel.

Slant Range - The distance from the heliostat to the target.

Slew Rate - Maximum angular speed of heliostat reflective surface movement.

Spillage - Radiation reflected from the collector system that misses the receiver aperture.

Standby Point - Off-target aim point from which focusing onto the target can be achieved.

Stow - A heliostat orientation or command to an orientation such that the plane of the mirrors is approximately parallel to the ground and the mirror surface is facing downward.

TBD - To Be Determined

2.0 CATEGORY DESIGN CRITERIA

2.1 SUPPORTIVE DOCUMENTATION

The supportive documentation for the system design criteria is as follows.

Project Design Manual - Saguaro Solar Repowering, Volume I.

2.2 CODES AND STANDARDS

The significant codes and standards that will apply to the solar collector are as follows.

1) Uniform Building Code, 1982 Edition by International Conference of Building Officials

2) American Society of Civil Engineers Transactions, Volume 126, Part II, 1961, Paper No. 3269, Wind Forces on Structures

3) American National Standards Institute (ANSI)

   A58.1-1982 - Building Code Requirements for Minimum Design Loads in Buildings and Other Structures

   C1 - National Electric Code

4) Electrical Institute of America, RS232C, Communication Standard

5) Institute of Electrical and Electronics Engineers (IEEE) codes as applicable.

6) American Institute of Steel Construction (AISC) Manual of Steel Construction, 8th edition.

7) Standards of American Concrete Institute (ACI)

8) MIL-STD-810C, Environmental Test Method, Method 510, "Dust".

2.3 REGULATORY REQUIREMENTS

The solar collector will comply with all applicable state laws, local ordinances, and the requirements of the federal Occupational Safety and Health Act, Title 29, Part 1910 - Occupational Safety and Health Standards.

2.4 QUALITY LEVEL CLASSIFICATION

TBD.

2.5 NATURAL PHENOMENA

2.5.1 Operational Design Criteria

The solar collector will be capable of operating in appropriate combinations of the following environments.

1) Solar elevation - The solar collector shall be capable of operating when the sun angle above the horizon is equal to or greater than 175 mrad (10°);

2) Temperature - The solar collector shall operate normally in ambient air temperature from -7 to 46°C (20 to 115°F);

3) Wind - The solar collector will function in wind speeds up to 15.7 m/s (35 mph). The solar collector will initiate stow procedures at 15.7 m/s (35 mph). These windspeed specifications are for a reference height of 9.1 m (30 ft) above the ground and assume a maximum operational wind rise rate of 0.01 m/s/s (1.3 mph/min).

2.5.2 Survival Design Criteria

The solar collector will be capable of surviving the following environments without damage:

1) Temperature - The solar collector shall survive ambient air temperatures from -7 to 50°C (20 to 122°F);

2) Wind - The heliostats shall survive and will drive, in winds of 22 m/s (50 mph) and dust devils with wind speed up to 17 m/s (38 mph) with the heliostat in any orientation. With heliostats in stow position, the solar collector shall survive a maximum wind (including gusts) of 33.5 m/s (75 mph) with a $\pm$113 mrad (6.5 deg) angle of attack relative to horizontal;

3) Rain - The solar collector shall survive a maximum rainfall of 11.6 cm (4.6 in.) per 24-hr period.

4) Ice/snow - The solar collector will survive deposits of ice to 5.08 cm (2 in.) on one surface of the heliostats, or maximum snow loads of 239 Pa (5 lb/ft^2).

5) Hail - With heliostats in any position, the solar collector will survive 1.91 cm (0.75 in.) diameter, 0.9 specific gravity hail at 19.8 m/s (65 ft/s) velocity without damage.

6) Sandstorm environment - With heliostats in the stow position, the solar collector shall experience no pitting or permanent loss of reflectivity after being exposed to flowing dust comparable to the conditions described by Method 510 of MIL-STD-810C.

7) Combined Environments - The solar collector shall survive uniform deposits of 5.08 cm (2 in.) thick ice maximum or 239 Pa (5 lb/ft^2) snow maximum combined with 12 m/s (27 mph) wind maximum with the heliostat in any orientation.

8) Earthquake - The solar collector shall survive peak ground accelerations and seismic design loads calculated in accordance with the 1982 UBC conditions. The applicable UBC risk zone is 2.

9) Lightning - The solar collector shall have lightning protection so that damage to a heliostat adjacent to a direct lightning strike should be minimized. The heliostat control hardware adjacent to a direct lightning strike shall be protected. Total destruction of a single heliostat and its controller subjected to a direct lightning strike is acceptable. For design purposes, the maximum lightning strike current shall be limited to 200,000 amperes.

2.6 INTERFACING SYSTEMS

The interface description and applicable criteria to be met at the interface boundary between the solar collector and the systems listed in Table 1-1 are described below.

2.6.1 Ac Power Supply (120 V) (APA)

The solar collector will interface with the field power wiring at each heliostat junction box to obtain power for the heliostat drive motors. Power supply cabling will be capable of supplying 120-Vac, 6-amperes to each heliostat junction box. Average power required per heliostat shall not exceed 15 watts. The power cabling shall be routed through the heliostat pedestal from the ground to the heliostat controller. At least four standard, three prong 110-Vac electrical outlets (weatherproof) shall be provided at each heliostat. The outlets shall be easily accessible for use by maintenance personnel.

2.6.2 Essential Service ac (API)

An uninterruptible 120-Vac power source shall be provided to the HAC, its peripheral equipment, and to the BCS equipment in the control house. The BCS video camera (Section 5.5.3 of Volume II) located in the field shall be provided with uninterruptable 120-Vac power.

2.6.3 Control House/Instrument Repair (BSC)

The HAC, BCS processor, and associated peripheral equipment shall be located in the control house.

2.6.4 Intraplant Communication (CMA)

Two-way communication with the tower shall be provided to the operator in the control room using Gaitronic communications.

2.6.5 Commercial Telephone (CMD)

A telephone shall be located in the control room.

2.6.6 Master Control System (COG)

The solar collector shall interface with the master control system at the HAC. The HAC shall be configured such that the MCS can automatically achieve integrated control of, or alarm the solar collector. Types of interface signals for plant operations include the following.

1) Control commands;
2) Operational data requests;
3) Operational/alarm data outputs.

2.6.7 Grounding and Lightning Protection (EEB)

All electrical components in the solar collector shall be insulated and grounded. Lightning protection shall be provided to satisfy the requirements listed in Section 2.5.2 of this document.

2.6.8 Raceways (EEC)

Except for the heliostat field power wiring and fiber-optic signal cabling, all electrical wiring shall be routed to the solar collector through raceways.

2.6.9 Weather Monitoring (INF)

The HAC shall be provided current weather information so that it can initiate stow procedures if required to protect the heliostats from damage.

2.6.10 Collector Field Lighting (LTL)

The heliostat field shall be equipped with permanent lighting to illuminate the service road and the security fence along the field boundary.

2.6.11 Collector Field Security (STD)

Solar collector security shall be provided by a fence, lights, and the plant security personnel.

2.6.12 Grading and Drainage (STF)

The heliostat field shall be graded. Drainage shall be provided to route rain water away from the heliostats.

2.6.15 Land (STJ)

The solar collector will interface with the land at the heliostat pedestal/foundation.

2.6.16 Receiver (RSA)

The solar collector shall concentrate the redirected energy into the receiver aperture. The aperture is a vertical, north facing square 18.3x18.3 m (60x60 ft). The center of the aperture is 166 m (545 ft) above ground level. Energy from the solar collector shall meet the following requirements:

1) The maximum power level incident on the receiver absorbing surfaces may not exceed 230 MW_t (785×10^6Btu/hr). The absorber surface configuration is shown in Figure 2-1.

2) The maximum energy flux (direct) incident on the receiver absorbing surfaces may not exceed 55.5 w/cm^2 (176×10^3Btu/hr-ft^2).

3) The maximum solar power incident at any time on any receiver external non absorbing surfaces shall not exceed 6.0 MW_t (20.5×10^6 Btu/hr).

The solar collector shall, to meet these limits, be capable of executing any necessary heliostat aiming strategy, and shall be capable of beam size adjustment techniques including canting.

2.7 OPERATING CONDITIONS

The solar collector shall be capable of functioning in the following operating modes, within the constraints listed in Sections 2.6.6, 2.9, and 2.10.

2.7.1 Normal Operating Modes

1) Acquisition - This mode shall bring the heliostat from a stow position to a standby position in less then 15 min. The standby position will be specified by the HAC via command to the heliostat control system.

2) Power - This mode shall direct the reflected beams from the standby position to the assigned aimpoint of that heliostat by command from the HAC. The control system shall be capable of obtaining full power or reducing the flux in the receiver to zero.

3) Preheat - This mode of operation will use small groups of heliostats to preheat receiver absorber panels with reflected solar energy. This will be possible for any isolation condition.

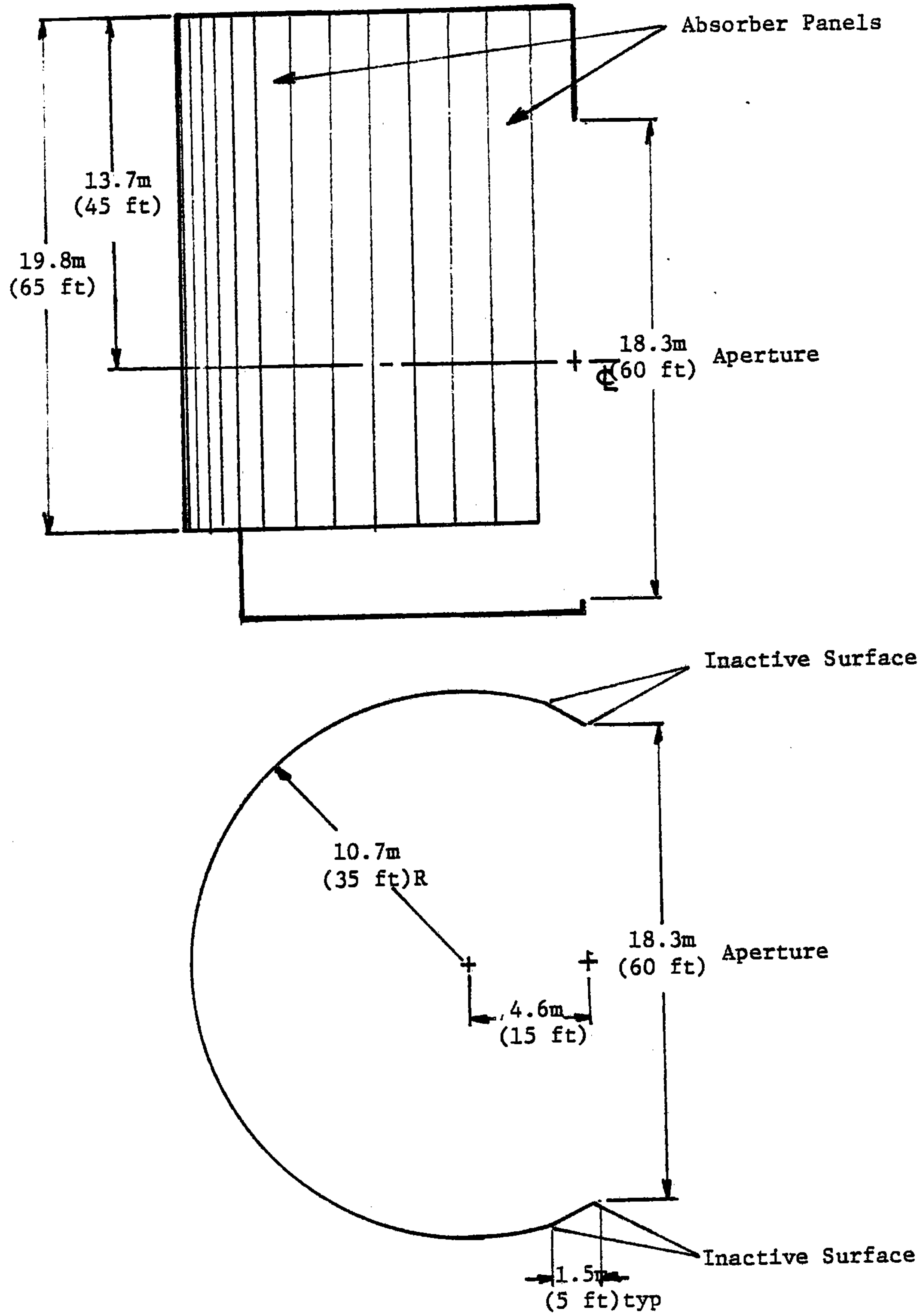

Figure 2-1 Receiver Absorber Configuration

4) Tracking - This mode shall direct the centroid of the reflected solar energy distribution from each heliostat at its assigned aimpoint on the receiver. This position shall be maintained while allowing for the rotation of the Earth until instructed otherwise by the control system.

5) Standby - In this mode, the reflected beam shall track a specified standby position located away from any receiver or tower surfaces. The heliostat control system shall be capable of maintaining standby when the sun is obscured, i.e., tracking without the sun for reference.

6) Manual control - In this mode, the heliostat position shall be individually controlled from the heliostat location for maintenance and setup of that heliostat. All other modes of control for that heliostat shall be locked out when in the manual control mode of operation.

7) Stow - For normal operations, each heliostat shall be capable of being returned to the stowage position in less than 15 min when starting from the standby position. The stowage position shall consist of the reflective surfaces of the heliostats facing and parallel to the ground.

8) BCS target/leveling update - This mode of operation shall be used to verify or correct heliostat pointing accuracy and computer leveling. In this mode, the HAC shall command the heliostat to point at the center of the BCS target. If the beam centroid is not pointed correctly, commands will be sent by the HAC to the HC to bring the image to the center of the target. Changes shall then be made in the pointing algorithm to correct for the inaccuracy.

2.7.2 Emergency Operating Modes

(1) Emergency shutdown (normal field power) - The solar collector shall have the capability to defocus all heliostats from the receiver within 90 sec following an emergency defocus command initiated by the master control system or the HAC. The heliostats will be in stow position in less than 15 min after the 90-sec period.

(2) Emergency shutdown (loss of field power) - In this situation, the normal collector field power supply is interrupted for more than 10 cycles, causing the heliostats to cease normal operations. If the solar collector was functioning in the tracking mode before the power cutoff, severe damage could occur to the receiver as the collector field aim points drift because of the motion of the sun. To prevent this receiver damage, a backup power supply shall be available to provide electric power to the solar collector. Further, the collector control system shall include at least one predefined defocusing strategy that allows all heliostat beams from the solar collector to be off the tower and receiver aperture within 90 sec after the initial loss of power occurrence. Collector control system components located in the control house shall be supplied with electric power from the uninterruptible 120-Vac power supply to prevent loss of data and control capabilities during this loss of power incident.

2.8 REDUNDANCY

The solar collector itself requires no large amount of redundancy because of the great number of independent heliostats, drive motors, and controllers that make up the system. The HAC computer system will consist of a set of identical, dual-redundant computers with automatic switchover to the backup computer should the prime computer fail. The main communications buses (HAC to HFC) and critical peripheral devices will be redundant. Two printers will be available with a magnetic tape unit for backup. Power supply to the heliostats shall be guaranteed through the use of multiple redundant power buses configured in such a manner that the failure of any one power bus shall not cause a loss of power to more than one sixth of the heliostats in the field.

2.9 FUNCTIONAL CONSTRAINTS

2.9.1 The solar collector shall be capable of supplying the receiver absorbing surfaces with 209 MW_t (713 x 10^6Btu/hr) at noon on day 35 assuming the following environmental conditions

1) Isolation - 950 W/m^2 (301.3 Btu/hr-ft^2);

2) Temperature - At least -7°C (20°F);

3) Windspeed - 5.1 m/s (16.7 ft/s) at 9 m (30 ft) above ground;

4) Atmospheric visibility - 25 km (15.5 mi).

2.9.2 The maximum power level incident on the receiver absorbing surfaces shall at no time exceed 230 MW_t. If the receiver is incapable of accepting all of the power delivered by the solar collector, individual heliostats shall be placed in the standby position (or stowed) until the receiver power limitation is no longer exceeded.

2.9.3 The solar collector shall be capable of supplying the receiver absorbing surfaces with 471 x 10^3 MWh_t (1.61 x 10^{12} Btu) per year, assuming an annual direct normal isolation of 2.52 MWh/m^2 (9.26 x 10^4 Btu/ft^2).

2.9.4 The annual average reflectivity of the heliostats shall be maintained at 92%.

2.9.5 Redirected solar energy flux levels (including energy directed from the heliostat field as well as redirected and reradiated energy from other portions of the receiver) on the receiver absorbing surfaces shall be controllable, using a suitable aiming strategy or equivalent scheme, so that the maximum absorber tube temperature does not exceed 649°C (1200°F). Maximum fluxes on absorber surfaces may not exceed 80% of those specified in Figure 2-2. These flux limits are applicable for any portion of the absorber tubes.

2.9.6 Focusing and defocusing of heliostats shall be controlled to comply with the flux limitations on external structure and internal nonabsorbing surfaces as detailed in Section 2.6.16.

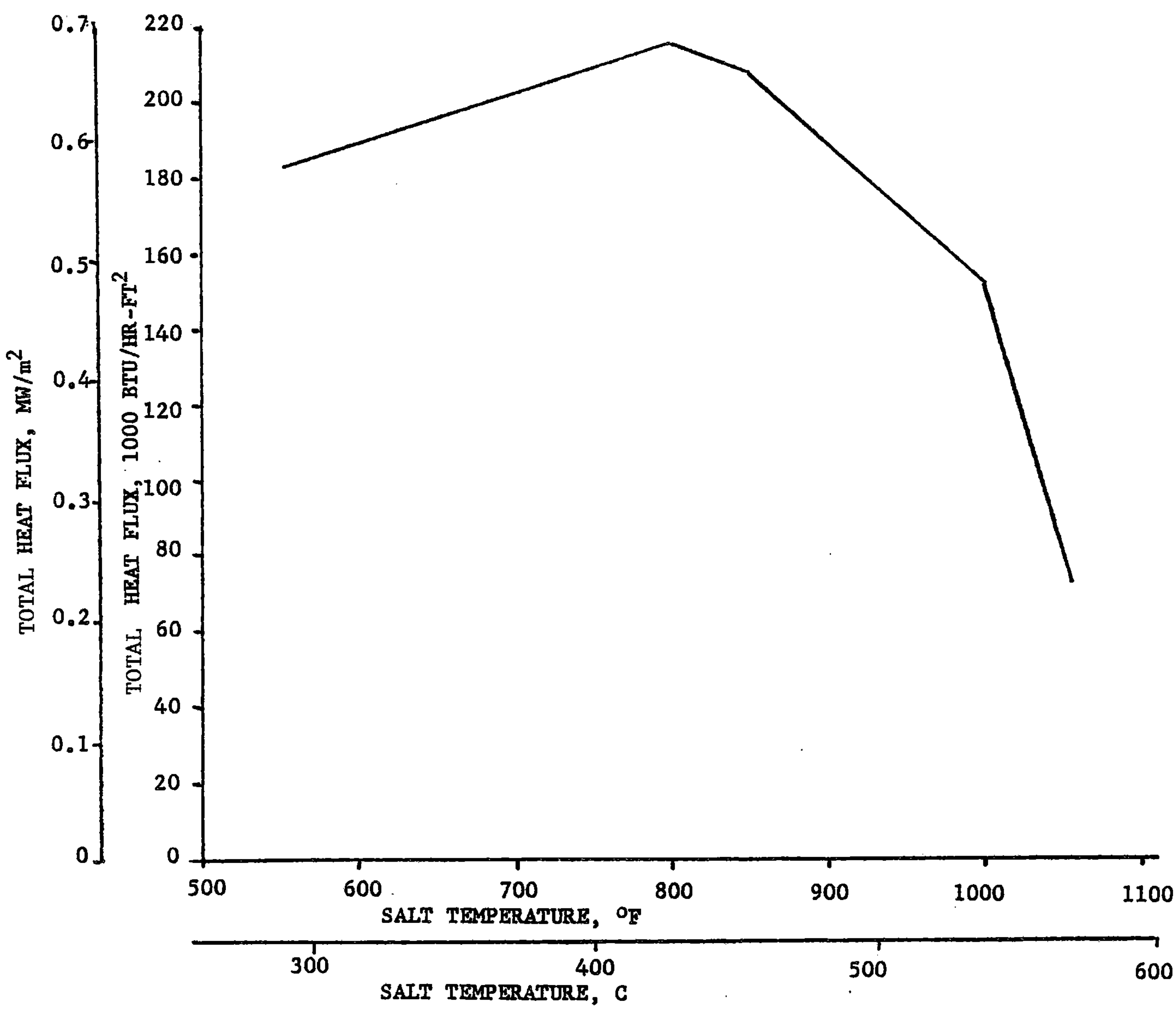

Figure 2-2 Flux Vs Salt Temperature

2.10 PHYSICAL CONSTRAINTS

The solar collector shall be located within the boundaries specified in Section 1.5. Adequate clearance shall be provided around each heliostat to permit free movement of the mirror assembly in any possible configuration. The heliostat design shall allow the heliostats to be placed in the facedown stow position.

2.11 PROCESS CONTROL

Control of the solar collector shall be accomplished using a distributed computer control network. A typical network could consist of the heliostat array controller (HAC), a set of peripherals, data buses, associated input/output equipment, and fiber-optic cables for communication with the heliostats. Commands from the HAC are relayed to one of 152 heliostat field controllers (HFC) that are located at every 32nd heliostat. The commands are then relayed to the heliostat controller (HC), a microcomputer located at each heliostat junction box. This microcomputer provides the logic to turn the drive motors on and off as required. The position of the heliostat reflective surface is determined by means of incremental optical encoders in concert with the HC. This type of control system, or equivalent, shall be used to provide collector field control.

2.12 TESTING

The tests shown in Table 2-2 will be performed to functionally verify the performance of the solar collector.

Table 2-2 Solar Collector Checkout and Testing

Solar Collector Operating Mode Tests
- Heliostat checkout with diagnostic tool
- HAC/HFC/HC heliostat checkout
- Computerized leveling with BCS
- Beam quality
- Tracking accuracy
- Software matrix verification

Plant Startup Tests
- Heliostat operation demonstration
- Heliostat controls verification
- HAC/heliostat communications
- BCS demonstration

Environmental tests of the heliostat, control system and components will be conducted to verify operation over the applicable environmental requirements listed in Section 2.5 of this specification. The mirror assembly will undergo a series of tests to verify the environmental life and elimination of corrosion. The quality of heliostat design will be verified by structural deflection, beam quality, gravity sag, and tracking accuracy tests.

2.13 SAFETY

The solar collector shall be designed to minimize hazards to operating and service personnel, the public, and equipment. Electrical components shall be insulated and grounded. Any moving elements shall be shielded to avoid entanglements, and safety override controls/interlocks shall be provided for servicing. The requirements of the Occupational Safety and Health Administration, and the National Fire Protection Association shall be fully satisfied.

3.0 SYSTEM DESIGN CRITERIA--HELIOSTATS

3.1 SYSTEM IDENTIFICATION

1) System name--Heliostat;

2) System code--CSA;

3) Purchase specification--62.4001.

3.2 FUNCTION

The function of the heliostat is to reflect and focus incident solar energy to an assigned aimpoint in the receiver aperture plane.

3.3 DESCRIPTION

The heliostat shall consist of a stationary pedestal and foundation supporting a combined azimuth and elevation drive mechanism and reflective assembly. The reflective assembly shall consist of reflective surfaces of the most cost effective size and reflectivity, and a support structure. A heliostat controller (HC) or equivalent device shall control the movement of the drive mechanism and reflective assembly as directed by the collector control system.

3.4 CODES AND STANDARDS

The heliostats will be designed and constructed in accordance with the codes and standards listed in Section 2.2 of this document.

3.5 SIZING CRITERIA

3.5.1 Performance Requirements

The following requirements have been established for designing and evaluating individual heliostats to attain a maximum overall field performance and efficiency.

3.5.1.1 <u>Maximum Beam Pointing Error (tracking accuracy)</u> - This shall be limited to 1.5 mrad standard deviation for each gimbal axis (azimuth and elevation) under the following conditions:

1) Wind - None;

2) Temperature - -7 to 46°C (20 to 115°F);

3) Gravity effects - At all elevation and azimuth angles of the heliostat reflective assembly (except gimbal lock position) that could occur in a heliostat field;

4) Heliostat location - Any position in the field.

Pointing error is defined as the difference between the aim point and measured beam centroid for all of the above conditions for any tracking aim point (on target or at standby).

3.5.1.2 Beam Quality - Quality shall be such that a minimum of 90% of the reflected energy at target slant range shall fall within the area defined by the theoretical beam shape plus a 1.4-mrad fringe width. The theoretical beam shape shall be determined by the latest version of the HELIOS computer program, available from Sandia National Laboratories, Albuquerque, NM 87185. Inputs to HELIOS program shall be established to match the heliostat under consideration.

Heliostat beam quality shall be met throughout 60 days without realignment. Beam quality requirements are applicable under the following conditions:

1) Wind - None;

2) Temperature - -7 to 46°C (20 to 115°F);

3) Gravity effects - At all elevation and azimuth angles of the heliostat reflective assembly (except gimbel lock) that could occur in a heliostat field;

4) Sun location - At least 0.175 rad (10°) above horizon, any time of year;

5) Heliostat location - Any position in the field and any slant range;

6) Operating mode - Tracking on the plant receiver;

7) Facet alignment - As planned for the plant.

3.5.1.3 Reflectivity - The average total solar specular reflectivity between washings shall be at least 0.92. Estimated washing frequency, technique, equipment, and rational will be provided by the heliostat manufacturer.

3.5.2 Operational Control Mode Requirements

The control and drive system of each heliostat shall be installed such that they have the capability to direct the reflected beam to a specified standby position off the receiver and then, on command, direct the beam to the aperture and its assigned aimpoint. The HC or equivalent shall be capable of directing the drive system of each heliostat to respond to commands from the heliostat field controller (or equivalent) or the heliostat array controller for all operating modes listed in Section 2.11 of this document. Heliostat drive mechanisms and control systems must be capable of resolving control singularity problems ("over the shoulder" limits or gimbal lock) within 10 minutes.

3.5.3 Heliostat Environmental Criteria

The heliostats will operate and survive the environmental conditions listed in Section 2.5 of this document. Heliostat drive mechanisms and control hardware shall be environmentally sealed.

3.5.4 Maintenance

The heliostats shall be designed so they require no scheduled routine field maintenance with the exception of periodic mirror washing. The washing procedure and schedule shall be as required to remove dust and grime accumulations and to satisfy the solar collector annual average reflection requirements. Heliostat washing equipment shall use environmentally benign washing fluids, and shall include a water recovery system. A method shall be provided for rapid identification of faulty heliostats. (For example, firmware could be included in the heliostat controller that would notify the HAC in the event of a drive unit, software, or other type of failure. This information could be displayed on a CRT in the control house). The heliostats shall be designed to provide a 30-year life. Sufficient supplies of all necessary collector field spare components shall be maintained at the plant to minimize downtime caused by component failure.

3.5.5 Mechanical Constraints

The mechanical constraints for the heliostats are listed below.

Stow position	Mirrors face down
Gimbal rotation	Azimuth, $\pm$4.71 rad ($\pm$270°) from reference; Elevation, $\pm$1.66 rad ($\pm$95°) from reference; (reference is mirror normal vector horizontal, pointing east)
Stowage rate	15 minutes from any position (4.71 rad (270°) maximum travel);
Minimum slew rate	314 mrad/min (18°/min) or greater

3.5.6 Stability Criteria

3.5.6.1 Reflective Surface Static Deflections (Gravity Sag) - This shall be limited by the overall structural support to an effective 1.7

mrad standard deviation for a field of heliostats in a 12 m/s (27 mph) wind. Wind deflections (dynamic deflections) of the foundation, pedestal, drive mechanism, torque tube, and mirror support members shall be included, but not the slope errors because of gravity and temperature effects. Wind deflection limits apply to the mirror normal (not reflected beam) for each axis fixed in the reflector plane. Both beam quality and beam pointing are affected. Satisfaction of these deflection requirements will be verified by prototype and/or end article testing.

To assure that the net slope errors of a field of heliostats is less than 1.7 mrad, the rms value of the slope errors taken over the entire reflective surface of an individual heliostat, computed under a 12 m/s (27 mph) wind and any heliostat orientation (but excluding foundation deflection), shall be limited to 3.6 mrad for a single heliostat. This limit represents a 3-sigma value for the field derived by subtracting pedestal deflection (see 3.5.6.2) from the total surface slope error (1.7 - 0.5 = 1.2 mrad std dev x 3 = 3.6 mrad 3-sigma). The conditions under which this requirement applies are:

1) Wind, including gusts - 12 m/s (27 mph) at 9 m (30 ft) elevation;

2) Temperature - -7 to 46°C (20 to 115°F);

3) Heliostat Location - any position in the field at any time of the year;

4) Gravity effects - Not included;

5) Mirror module waviness - None;

6) Facet alignment error - None.

3.5.6.2 Foundation - The heliostat foundation shall be designed (considering subsurface geology and soil conditions) so that dynamic deflection caused by wind loads (12 m/s [27 mph] maximum operating windspeed) and dead weight of the heliostat will not result in elastic deflection of the foundation about any axis (tilt or rotation) greater than 0.5 mrad (3 sigma). This 0.5 mrad limit shall be included in the 1.7 mrad structural support deflection limit for any environmental condition, excluding earthquake. Permanent deflection about any axis shall not be greater than 0.45 mrad (3 sigma) for the maximum survival windspeed of 33.5 m/s (75 mph) with the heliostat in stow position, and 22 m/s (50 mph) with the heliostat in any orientation. The permanent deflection allowance of 0.45 mrad may be increased to 2.5 mrad if computer leveling is used to make corrections after high wind conditions.

The specified deflections are applicable at the foundation-to-heliostat interface located on a plane parallel to and approximately 50.88 mm (2 in.) above the pier concrete surface, which is represented by the underside of the heliostat pedestal mounting flange. If there is no foundation-to-heliostat interface as described above, an imaginary interface shall be defined by a horizontal plane that is approximately 150 mm (5.9 in.) above ground.

3.5.6.3 Drive Mechanism - Azimuth and elevation drives shall not drift from last command positions due to environmental loading.

3.6 MATERIALS SELECTION

Heliostats be constructed of materials that minimize environmentally induced degradation, maximize durability and performance, and remain cost effective. To maximum extent possible, standard materials shall be used.

4.0 SYSTEM DESIGN CRITERIA--COLLECTOR CONTROL AND INSTRUMENTATION

4.1 SYSTEM IDENTIFICATION

1) System name - Collector control and instrumentation,

2) System code - CSD,

3) Purchase specification--62.4001.

4.2 FUNCTION

The function of the collector control system is to initiate and address operational commands to and receiver status information from the heliostat controllers (HCs). The collector control system must respond to master control system commands and requests, interface with the beam characterization system, and provide a reliable time base.

4.3 DESCRIPTION

The collector control system shall consist of a central computer system (called the heliostat array controller or HAC) located in the control house, which is in communication with every heliostat in the field. If necessary, microprocessors equipped with input/output electronics (called heliostat field controllers, or HFCs) may be distributed throughout the field to reduce the data processing load otherwise imposed on the HAC. The HFCs would provide the interface between the HAC and the HCs. A possible configuration would have each HFC controlling up to 32 heliostats. The HFCs would determine individual heliostat azimuth and elevation position requirements, transmit these requirements to the HC, transmit status and data to the HAC, initiate safe stowage commands on loss of HAC communications, and otherwise provide control of HC groups.

The HAC shall consist of, as a minimum, a set of dual-redundant, identical computers with automatic switchover to the backup computer should the prime computer fail. The peripheral equipment for each computer shall include an operator's console with CRT and a disk system for storage of operational software and data. Peripheral equipment that may be switched between the two computers shall include at least two line printers, a magnetic tape drive, and a WWVB receiver/clock to maintain the accuracy of the time base. Interfaces shall be available to communicate with the HFC, the master control system, and the beam characterization system. A hardwired communications circuit between the receiver and the HAC shall provide for automatic defocusing upon loss of receiver coolant flow.

Deviations from this configuration are acceptable, but must be justified.

4.4 CODES AND STANDARDS

The collector control system shall be designed and constructed in accordance with the Electrical Institute of America Communication Standard RS-232C, and with all applicable codes of the Institute of Electrical and Electronics Engineers.

4.5 SIZING CRITERIA

4.5.1 Performance Criteria

4.5.1.1 The collector control system shall satisfy the operational mode requirements listed in Section 2.11 of this document.

4.5.1.2 The collector control system software shall provide automatic compensation for pedestal and reflective assembly tilt and/or rotation (computer leveling). The algorithm shall use data from the BCS to determine the tilt coefficients described above, as well as other biases inherent in each heliostat.

4.5.1.3 The HAC software shall be capable of identifying and commanding a specific heliostat by its number.

4.5.1.4 The HAC software shall have the capability to command any group of heliostats specified by the operator.

4.5.2 Physical Criteria

4.5.2.1 The HAC shall include the following equipment as a minimum:

1) Dual identical 16 or 32 bit minicomputers. Each computer shall be backup to the other.

2) An operator's console for each computer.

3) A dedicated disk drive for each computer.

4) One magnetic tape drive.

5) A WWVB receiver/clock to maintain time base accuracy.

6) Two line printers.

7) Communications equipment to interface with the HFCs or HCs, MCS, BCS, and the receiver.

8) A collector field control console (preferably a color CRT).

Additional equipment and/or deviations from this list are acceptable, but must be justified.

4.5.2.2 The operator's console and collector field control console shall have backup spares readily available.

4.5.2.3 All control system components adjacent to a direct lightning strike shall be protected. For design purposes, the current in the lightning strike shall be 200,000 amperes.

4.5.2.4 Hardware service contracts for the HAC computer systems shall be acquired and maintained while the computers are in service.

5.0 SYSTEM DESIGN CRITERIA--BEAM CHARACTERIZATION SYSTEM

5.1 SYSTEM IDENTIFICATION

1) System name - Beam characterization system;

2) System code - CSC;

3) Purchase specification--62.4001.

5.2 FUNCTION

The function of the beam characterization system (BCS) is to measure heliostat tracking accuracy and alignment.

5.3 DESCRIPTION

The BCS shall consist of one or more sets of the following components: a target, an electronic imaging camera, an image processor, a desk top computer system (for interfacing with the HAC and data manipulation) located in the control house, and data transmission and power supply cabling. Additionally, at least one video monitor with switching capability to all BCS cameras shall be centrally located on the control panels in the control house. At least one video camera with pan, tilt, zoom and auto filter change capabilities shall be included in the BCS. The desktop computer system shall have disk storage and printer capability for data archiving and logging.

5.4 CODES AND STANDARDS

The BCS shall be designed and constructed in accordance with the codes and standards listed in Section 2.2 of this document.

5.5 SIZING CRITERIA

The BCS shall be designed so that every heliostat in the field shall, at all times, have a clear view of at least one target. Sufficient targets, cameras, and image processing equipment shall be available to allow annual verification of each heliostat's pointing accuracy and alignment. The verification process for each heliostat shall include at least three separate beam centroid measurements made at three different times of the day (a total of nine measurements for each heliostat). The BCS shall be capable of determining the location of the beam centroid to within 1.5 mrad of its true centroid.

5.5.1 Target

Each target shall be oriented in a fixed position to limit the maximum angle between the target plane's normal vector and the incident beam from any heliostat to 1.31 radians (75 deg). Each target shall be large enough to capture 90% of the energy in any heliostat beam that is centered on the target. Each target shall be painted with a durable flat white coating, and shall be reasonably flat and smooth. Discontinuities in the target surface or coating shall not be discernable to the camera. Black fiduciary markings of a size greater than the minimum resolution of the camera shall be located near the corners to aid in the precise determination of the geometrical relationship between the beam centroid and the target center.

5.5.2 Electronic Imaging Camera(s)

Each camera shall meet the survival and operational environmental criteria listed in Section 2.5 of this document. Each camera shall be capable of recording all reflected energy intensities that are greater than that of the isoflux contour containing 90% of the total power from any heliostat. Camera resolution shall be at least 700 TV lines (center) horizontal and 350 TV lines vertical (or equivalent). Geometric distortion shall be no greater than 2%. Each camera shall have an automatic sensitivity control to prevent damage to the camera from high light levels. Each camera shall be mounted in a fixed position on a stable foundation located where it will have a clear unobstructed view of its target at all times. The camera foundation(s) shall be designed to the same stability criteria as the heliostat foundations described in Section 3.5.6.2. The angle defined by the target normal vector and the camera lens when aimed at the target shall not exceed 0.44 rad (25 deg). Suitable lenses shall be defined that ensure that the camera field of view is limited to the target. Each camera shall have a shade to protect it from direct sunlight and stray heliostat beams.

5.5.3 Video Camera

There shall be at least one camera, located in the field and mounted above the uppermost limit of heliostat travel, that shall have pan, tilt, zoom, and automatic filter change capabilities. This camera shall be under control of the plant operator and shall be connected to the uninterruptible 120-Vac power supply. This camera shall be located in a position that allows a constant clear view of the tower and receiver and shall have at least a 4.7 rad (270 deg) field of view. The camera shall be furnished with protection from direct sunlight and stray heliostat beams. The camera shall meet the operational and survival criteria listed in Section 2.5 of this document. A failsafe mechanism shall be included to prevent camera damage caused by light level overloading. As this camera is intended to provide the operator with a view of the receiver, tower, and field, it need not have the same high resolution and stability features as the imaging cameras described above.

5.5.4 Image Processing System

Beam centroid locations will be determined using image processing equipment located in the control house. The following components are necessary:

1) Image analysis processor - Analysis of the image data provided by the field camera is carried out by microprogrammable firmware implemented in a dual-processor configuration. The processors are dedicated to perform the separate tasks of data acquisition and processing and control, measurement, and computation of the centroid location.

2) Video display monitor - Viewing of the image from any of the cameras will be through video display monitors. The monitor will display the analog or binary image, alphanumerics, or combinations as necessary.

3) ASCII keyboard controller - Communication with the processing system shall be through a full ASCII keyboard.

4) Manual video switches - Camera selection for the video monitor shall be accomplished using a manual switching device.

5) Camera controller - This equipment shall control camera power (on/off), automatic or manual light control, lens focus, iris and zoom, and pan/tilt functions.

6) Video cable equalizer - The video cable equalizer compensates for high frequency losses because of long video cable runs (up to 1830 m (6000 ft). One equalizer for each camera is necessary.

7) Microcomputer system - BCS interface with the heliostat array controller shall be accomplished using a software programmable microcomputer, disk drive, monitor, and printer.

With the exception of the microcomputer system described in Item 7, all of the BCS components located in the control house shall be suitable for rack-type mounting.

5.6 MATERIALS SELECTION

The BCS target(s) shall be constructed of light gage metal or equivalent and shall be painted with a flat-white, durable coating. All materials used in the BCS should resist environmental degradation while remaining cost effective.

6.0 SYSTEM DESIGN CRITERIA--HELIOSTAT CLEANING SYSTEM

6.1 SYSTEM IDENTIFICATION

1) System name - Heliostat cleaning system;

2) System code - CSB;

3) Purchase specification--62.4001.

6.2 FUNCTION

The function of the heliostat cleaning system (HCS) is to periodically remove accumulated dirt, water spots, and other foreign materials from the reflective surfaces of the heliostats.

6.3 DESCRIPTION

The HCS shall consist of one or more transporters, each equipped with a demineralized hot-water spray system, a rotary brush mechanical cleaning system, a water storage tank, and a water recovery system. The transporter shall be equipped with high-flotation, high traction tires to permit travel over soft soils and sand, an all-weather cab with air conditioning, and adequate lights for night work.

6.4 CODES AND STANDARDS

The HCS shall meet all codes and standards listed in Section 2.2 of this document.

6.5 SIZING CRITERIA

The HCS shall be sized to enable the maintenance of a 92% annual average reflectivity for the entire collector field. Both the demineralized water storage tank and the water recovery storage tank shall have sufficient capacity to allow at least four hours of continuous washing. Each vehicle shall be capable of one-man operation. Washing frequency shall be as needed, based on spot measurements of selected heliostats by maintenance personnel using portable reflectometers.

6.6 MATERIALS SELECTION

HCS materials shall be selected for durability, resistance to environmental degradation, and cost effectiveness. Additives to the demineralized wash water shall be limited to environmentally benign chemicals, such as a sheeting agent and/or a small amount of acetic acid for stubborn deposits.

7.0 SYSTEM DESIGN CRITERIA--MAINTENANCE EQUIPMENT

7.1 SYSTEM IDENTIFICATION

1) System name - Maintenance equipment;

2) System code - CSB;

3) Purchase specification--62.4001.

7.2 FUNCTION

The function of the maintenance equipment is to repair heliostats and control electronics and to repair other portions of the solar collector as required.

7.3 DESCRIPTION

7.3.1 Maintenance equipment shall include, as a minimum, the items in Table 7-1.

Table 7-1 Solar Collector Field Maintenance Equipment

Qty	Nomenclature	Usage	Availability
1	Maintenance Building	Parts storage, misc repair work	From heliostat manufacturing phase (formerly heliostat assembly bldg)
1	Drive mechanism assy fixture	Repair drive units	From installation
1	Drive assy checkout tooling (heliostat diagnostic tool)	Test drive assy. after repair/assy.	From installation
1	Riviting system with hydraulic pump	Fabricate rack assy	From installation
2	Portable oscilloscope	Repair electronic equipment	From installation
2	Impact wrench 1/2 in.-drive	Repair drives	From installation
2	Impact wrench 1 in.-drive	Repair drives	From installation
2	Torque wrench (15 to 100 ft-lb)	Repair drives	From installation

Table 7-1 Solar Collector Field Maintenance Equipment (Continued)

Qty	Nomenclature	Usage	Availability
2	Torque wrench (50 to 400 ft-lb)	Repair drives on heliostat	From installation
5	Fiber optics terminal tools	Repair transmission line	From installation
2	Heat gun	Repair cables	From installation
3	Multimeters	General electrical	From installation
1	Set misc hand tools	General usage	From installation
1	Air compressor	Operate rivit tool/ hand tools	From installation
1	Fork lift	General warehouse	From installation
2	HC/HF diagnostic tester	Repair HC/HFC and field diagnostic tool	From installation
2 set	Portable two-way radio	Comm. between control room & field	From installation
1	Fiber optics test tool	Verify fiber optics data link	From installation
1	Crane	Remove & replace reflective assy pedestal/foundation	From installation
1	Maintenance Truck	General collector field maintenance	From installation
2	Portable reflec-tometers	Measure heliostat reflectivity to determine need for and quality of washing operations	Deliverable item

Table 7-1 (concl)

Qty	Nomenclature	Usage	Availability
8	Diagnostic Tools	Trouble shoot heliostat, operate motors on and off heliostat; used to test and set encoders	Available from installation
2	Mobil Work Platform	Used to remove and replace gear motors, encoders, cabling, drives & mirrors	Available from installation
1 Set	Reflective Assy Sling	Remove & replace refl	Available from installation
70	Protective Covers	Cover mirror assy as required during maint	Available from installation
1	Transport Trailer	Required to transport reflective assy	Available from installation
4	Direct Drive Box	Drive gearmotors	Available from installation
12	Portable Floodlights (120-Vac)	Night repairwork	Deliverable item

7.3.2 Spare parts for the solar collector are listed in Table 7-2. The amounts specified are sufficient to support three or more years of normal operation.

Table 7-2 Spare Parts Inventory

No. Inst	Description	Quantity	Remarks
4,850	Pedestal Assy	2	Spared in Case of Physical Damage
4,850	Drive Mechanism Assy	5	Major Damage Supplier Reparable
4,850	Rack Components	10	Spared in Case of Physical Damage
63,050	Mirror Assembly	50	Spared in Case of Physical Damage
9,700	Encoders	100	Supplier Reparable
9,700	Gearmotors	100	Supplier Reparable
4,850	Cable Assy	50	Repaired at Site Repair Facility
4,850	HC	75	Repaired at Site Repair Facility
152	HFC	25	Repaired at Site Repair Facility
9,700	Couplers	100	Nonreparable - Off Shelf
19,400	Limit Switches	50	Nonreparable - Off Shelf

7.4 CODES AND STANDARDS

All maintenance equipment, facilities and procedures shall conform to the codes and standards listed in Section 2.2 of this specification.

7.5 SIZING CRITERIA

The solar collector system maintenance equipment shall be complete and sufficient to perform and detect all repairs. Critical items are described below.

7.5.1 Crane

The crane shall be capable of lifting the rack assemblies and pedestals.

7.5.2 Maintenance Truck

The maintenance truck shall be a four wheel drive vehicle with a winch. The cargo bed of the truck shall be large enough to carry 1.2 m (4 ft) mirror modules.

7.6 MATERIALS SELECTION

Not applicable

3.0 Receiver Specification

MCR-82-641

RECEIVER SPECIFICATION

PRELIMINARY DESIGN ENGINEERING SERVICES

FOR SOLAR REPOWERING OF THE

SAGUARO POWER PLANT

August 1983

Martin Marietta Corporation

Denver Division

Denver, Colorado 80201

Prepared for Arizona Public Service Company

Phoenix, Arizona

Under Subcontract No. RD82-6732

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SYSTEM DESIGN SPECIFICATION
FOR
RECEIVER

1.0 SYSTEM DESCRIPTION

1.1 SYSTEM IDENTIFICATION CODE

(1) Category Name	Solar Receiver
(2) Category Code	RS-
(3) System Name	Receiver
(4) System Code	RSA

1.2 FUNCTION

The function of the receiver is to intercept the solar energy reflected by the solar collector (CS), and to convert it into high-temperature sensible thermal energy using molten nitrate salt as the heat transfer fluid. Cold heat transfer fluid is provided by, and hot heat transfer fluid is returned to, the receiver Molten Salt Supply and Discharge System (RSC).

1.3 PROCESS DESCRIPTION

A simplified flow schematic of the receiver is shown on Figure 1-1. During normal operation, molten salt at 277°C (530°F) is pumped from the cold storage tank through horizontal and vertical piping, to the receiver inlet surge tank on the top of the tower. The cold salt pumps are used for this operation. The inlet surge tank feeds the two control circuits of the receiver, each consisting of several heat absorption panels in series, which heat the salt by the absorbed solar energy to 566°C (1050°F). The hot salt is discharged into the receiver outlet surge tank, from which it is fed by gravity, through the energy dissipating valves, into the hot salt storage tank of the ES.

The inlet surge tank is sized to provide emergency flow through the heat absorption panels during pump or power failure for sufficient time to permit heliostat defocusing and/or switch-over to backup power. The heat absorption panels are insulated and along with the structural steel form a cavity equipped with an aperture for transfer of the reflected solar energy from the solar collector. A thermally isolating aperture door is provided to minimize heat losses from the cavity during prolonged cloud transients or overnight standby. A recirculation pump (located on the top of the tower) is provided to maintain uniform temperature distribution through the heat absorption panels during overnight standby, and to maintain salt flow during pre-standby warmup of the panels and as a part of normal daily shutdown operations.

The salt outlet temperature is maintained within specified limits by controlling the salt flow rate to the heat absorption panels to match the variations in solar input.

An artist's rendering of the cavity receiver is shown on Figure 1-2.

1.4 INTERFACING SYSTEMS

Systems which have a significant interface with the receiver are listed on Table 1-1.

1.5 BOUNDARIES

The major boundaries of the receiver are shown on Figure 1-1. Additional boundaries not shown on this figure are TBD.

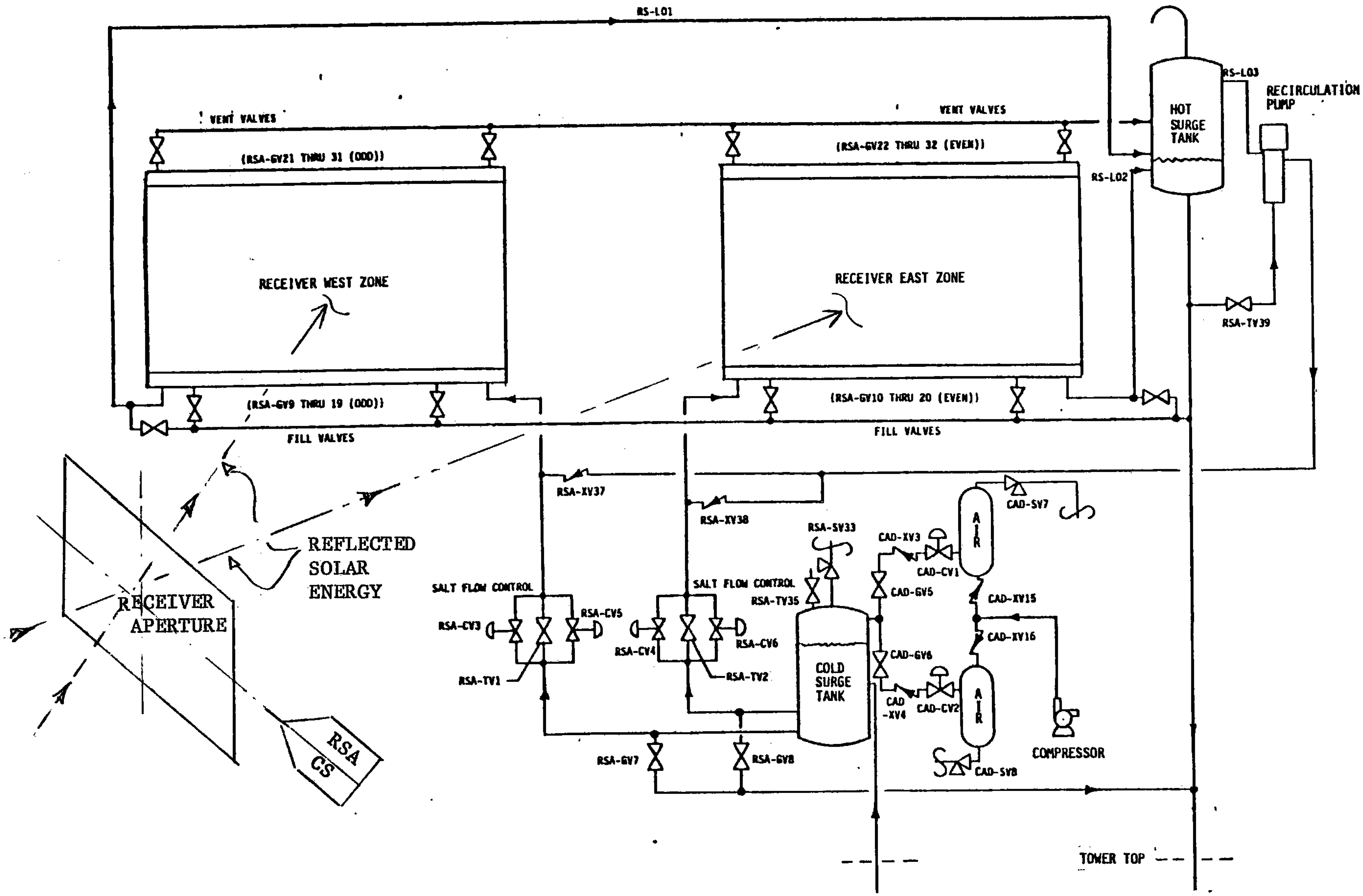


FIGURE 1-1 RECEIVER FLOW SCHEMATIC

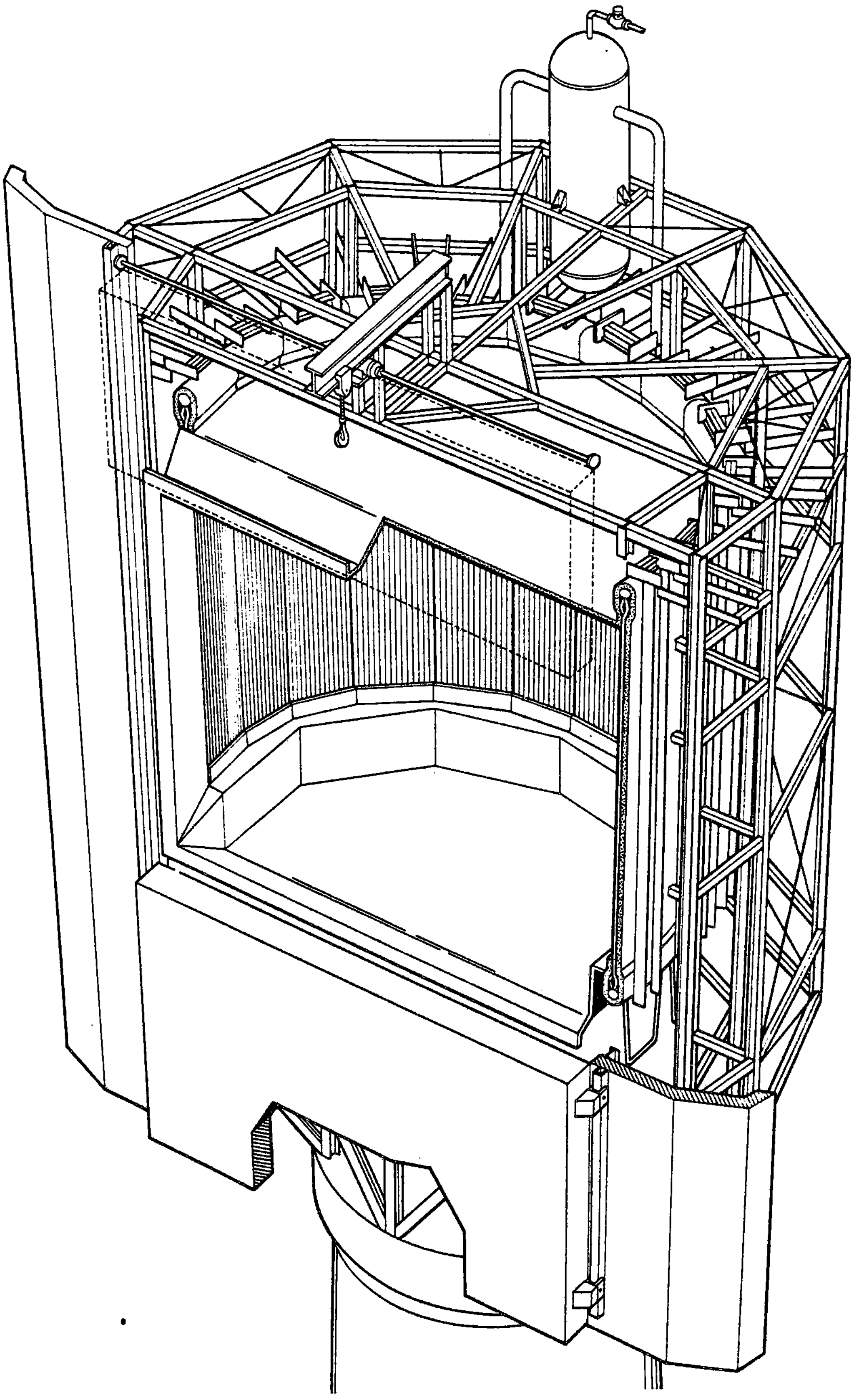


FIGURE 1-2 ARTIST'S RENDERING OF CAVITY RECEIVER

TABLE 1-1 INTERFACING SYSTEMS

System	System Code
Solar Collector	CS-
Tower	RSB
Master Control System	COG
Auxiliary Power Supply	APA-API
Plant Communication	CMA
Raceway	EEC
Solar Receiver Air	CAD
Grounding and Lightning Protection	EEB
Solar Receiver Tower Fire Protection	FPF
Solar Receiver Tower Lighting	LTJ
Receiver Molten Salt Supply and Discharge	RSC

1.6 DEFINITIONS OF TERMS AND ABBREVIATIONS

1.6.1 Definitions

Aim Point - The common centroid of flux patterns produced by several heliostat on a target plane; or the point of intersection of the centerlines of the beams produced by several heliostats.

Aim Point Strategy - The specified distribution of aim points on a target to achieve a desired flux pattern on the receiver absorbing surfaces.

Aperture - The opening through which the reflected solar energy from the collector field passes into the receiver cavity.

Canting - Adjustment of individual mirror facets to achieve a common focal point.

Cold Salt - Molten salt at a nominal temperature of 277°C (530°F).

Solar Collector - An array of individually controlled heliostats, including the wiring and controls, that redirects the available solar insolation onto the receiver.

Defocusing (of Heliostats) - The act of moving the aim points of heliostats from the target to the standby point.

Design Point - The time of day and year for which the system performance is specified, namely solar moon on Day 35.

Direct Insolation - The solar energy incident on a surface and that comes from within the solid angle subtended by the solar disk. It is to be distinguished from the diffuse or multidirectional component of solar radiation. Only the direct part of the insolation can be focused by an optical system.

Direct Normal Insolation - The direct insolation on a surface perpendicular to the sun's rays.

Diurnal - Pertaining to a daily cycle.

Distributed Digital Control - A process control system that uses digital electronics and where the computations are distributed between remote and central locations.

Downcomer - The pipe carrying the hot molten salt down the tower.

Fail-Over - Automatic or manual switch over from prime to backup system in case of failure of the former.

Flux (Radiant) - The time rate of flow of radiant energy.

Flux, Incident - Solar energy reflected by the heliostat field that is incident on a specified target.

Flux, Absorbed - Solar energy absorbed by molten salt.

Flux Density - The flux per unit of area.

Focal Height - The vertical distance between the plane of the heliostat hinge points and the center of the receiver aperture.

Focal Length of Heliostat - The distance along the centerline of the reflected beam, from the heliostat to the point where the reflected rays from various elements of the heliostat converge.

Focusing - (a) Providing a heliostat with a focal length by a combination of curvature and canting of the mirror facets comprising the heliostat.
(b) Concentrating the reflected beams of the heliostats in a collector field onto the receiver aperture in accordance with a specified aim point strategy.
(c) The act of moving the heliostat aim points from standby onto the receiver in accordance with a predetermined power "rampup" schedule.

Heliostats - A combination of mirrors, support structure, drive mechanism, and mounting foundation that tracks in two axes of motion to continuously reflect the sun's rays onto the receiver.

Hot Salt - Molten salt at a nominal temperature of 565°C (1050°F).

Peak Point - Time of day and year at which the collector field efficiency is a maximum.

Receiver Control Zone - An absorber panel flow circuit associated with a controller and a control valve assembly.

Reliability - The probability that an item will perform its required function under specified conditions for a specified time.

Repowering - The retrofitting of existing fossil-fueled electric utility or process heat power plants with solar energy collection systems in order to provide the capability to displace a portion or all of the fossil fuel used.

Riser - The pipe carrying the cold molten salt up the tower.

Sacrificial (Material or Structure) - Material or structure which is applied to protect the receiver structure, but which may be destroyed during an unplanned operation.

Slant Range - The distance from a heliostat to the center of aperture.

Slew Rate - Maximum angular speed of heliostat reflective surface (to be differentiated from "track rate" which refers to angular speed during tracking).

Solar Noon - The instant the sun reaches its zenith, at any specific location.

Solar Operation Factor (SOF) - Ratio of period of time in operation to the total time during which the direct normal insolation is above the threshold value.

$$SOF = \frac{\text{Number of Hours that Equipment is Ready to Operate when there is sufficient Insolation for Operations}}{\text{Number of Hours of Sufficient Insolation for Operation}}$$

Spillage (Radiation) - Radiation reflected from the collector system which misses the aperture of the receiver.

Standby Point (of Heliostat) - Off-target aim point of heliostats from which rapid focusing (or defocusing) onto the target can be achieved.

Stow - A position or act of reaching a position of storage of the heliostats.

Survival - State of no major structural damage. May require minor repairs of non-structural components before returning to operation.

Threshold Insolation - Minimum insolation required for operation.

Turndown Ratio - Ratio of maximum to minimum operating power.

1.6.2 Abbreviations

DDC - Distributed Digital Control

HC - Heliostat Controller

HFC - Heliostat Field Controller

RSA - Receiver

ESA - Thermal Energy Storage Hot Tank

ESB - Thermal Energy Storage Cold Tank

TBD - To Be Determined

2.0 SYSTEM DESIGN CRITERIA

2.1 SUPPORTIVE DOCUMENTATION

The supportive documentation for the system design criteria is contained in the following documents.

(1) Project Design Manual - Saguaro Solar Repowering, Volume I

2.2 CODES AND STANDARDS

The design and specification of all work shall be in accordance with all applicable laws and regulations of the federal government, the state of Arizona, and with the applicable local codes and ordinances. The significant codes and standards which apply to the receiver are as follows.

(1) Uniform Building Code, 1982 Edition by International Conference of Building Officials

(2) ASME Boiler and Pressure Vessel Codes Section VIII, Div. 1 (Pressure Vessels) and applicable Code Cases.

(3) IEEE - Institute of Electrical and Electronic Engineers, Codes as applicable.

(4) NFPA - National Fire Protection Association, National Fire Codes - 1975

(5) NESC - National Electrical Safety Code - 1981

(6) NEC - National Electrical Code - 1981

(7) Standards of ACI (American Concrete Institute)

(8) Standards of AISC (American Institute of Steel Construction)

(9) Standards of ASTM (American Society of Testing Materials)

(10) Standards of NEMA (National Electrical Manufacturer's Association)

(11) ANSI B31.1 - Power Piping

(12) ANSI A58.1 - Building Code Requirements for Minimum Design Loads in Buildings and Other Structures - 1982 Edition.

(13) ANSI B16.34 - Steel Valves, Flanges, an Buttwelding Ends.

(14) ANSI C37.20 Switchgear

(15) ANSI C57.12 Power Transformers

(16) Standards of AWS (American Welding Society).

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

(18) Nuclear Regulatory Commission Guides 1.60 and 1.61

2.3 REGULATORY REQUIREMENTS

The federal and state codes and standards requiring compliance under penalty of law are outlined in the Regulatory Requirements Manual.

2.4 QUALITY LEVEL CLASSIFICATION

TBD

2.5 NATURAL PHENOMENA

2.5.1 Plant Site - The Saguaro Station is located in southeastern Arizona on Interstate 10 approximately 143 kilometers (89 miles) southeast of Phoenix, Arizona, and 43 kilometers (27 miles) northwest of Tucson, Arizona. The nearest community to the Saguaro plant is Marana, Arizona, which is 15 kilometers (9.3 miles) to the southeast. The plant is located in Section 15 of Range 10 East, Township 10 South of Red Rock, Arizona Quadrangle. The plant location is at 32.5°N latitude, and 111° longitude (approximately).

2.5.2 Climate - The site has a southwestern desert climate with hot summers and cold winters.

2.5.3 Insolation - Direct normal at design point: 950 W/m^2 (Solar Noon)
- Maximum direct normal: 1045 W/m^2 (Solar Noon)
- Speed of Cloud Shadow: 13 m/s (29 mph) max.

2.5.4 Wind - Operational

- Wind speed at reference height of 10m (33 ft):

Speed, m/s	(mph)	Frequency, Percent
0 - 2	(0 - 4.5)	29
2 - 4	(4.5 - 9.0)	21
4 - 6	(9.0 - 13.5)	19
6 - 8	(13.5 - 18.0)	14
8 - 10	(18.0 - 22.5)	8
10 - 12	(22.5 - 27.0)	5
12 - 14	(27.0 - 31.5)	3
14 -	(31.5)	Less than 1

- For calculation of wind speed at other elevations, assume the following model:

$$V_H = V_1 (H/H_1)^c$$

where: V_H = wind velocity at height H
V_1 = wind velocity at reference height
H_1 = reference height (10 m or 30 ft)
$c = 0.15$

- Wind rise rate: 0.01 m/s^2 (1.3 mph/min) max.

2.5.5 Ambient Temperature - Operational:

-8.9 to +46.0 C (16 to 115°F)

2.5.6 Earthquake - Operational

- Maximum operational ground accelerations

  0.05 g (Peak Ground Acceleration, Average or Firm Conditions, UBC Risk Zone 2)

- Induced accelerations at the top of the tower shall be determined by appropriate dynamic analyses.

2.5.7 Survival Environments - The system shall be capable of surviving the environments specified below;

a. Wind

   - Maximum wind speed, including gusts: 35.5 m/s (75 mph)
   - Local wind vector variation: +10 degrees from the horizontal
   - Wind rise rate: TBD

b. Dust Devils - with wind speeds up to 17 m/s (38 mph)

c. Snow

   - Static snow loads: 250 Pa (5 lb/ft^2)
   - Snow deposition rate: 0.3m (1 ft) in 24 hours

d. Rain

   - Average Annual: 340 mm (13.4 in)
   - Maximum 24-hour Rate: 150 mm (6 in.)

e. Ice: Freezing rain and ice deposits in a layer 25 mm (1 n) thick

f. Earthquake: 0.10 (Peak Ground Acceleration, Average or Firm Conditions, UBC Risk Zone 2, 1982 Edition)

g. Hail

- Diameter: 25 mm (1 in.)
- Specific Gravity: 0.9
- Terminal Velocity: 23 m/s (75 fps)

h. Sandstorm Environment: The receiver shall survive after being exposed to flowing dust comparable to the conditions described by Method 510 of MIL-STD-810C.

2.5.8 Lightning Considerations - The receiver and its tower shall be fitted with lightning rods at their highest points. The receiver lightning rods shall be connected to earth through appropriate copper conductors, interconnecting copper cables, and driven ground rods. The horizontal piping shall be bonded to earth using ground straps and earth driven ground rods. The receiver lightning protection shall be provided by the grounding and lightning protection system (EEB).

2.6 INTERFACING SYSTEMS

Systems affecting the design of the receiver are as follows.

2.6.1 Solar Collector (CS)

The solar collector reflects solar radiation into the receiver through an aperture in a manner which satisfies receiver heat flux requirements per Sections 2.7, 2.9, and 3.5 of this specification. The aperture is a vertical, north facing square 18.3 m x 18.3 m (60 ft x 60 ft). The center of the aperture is 166.3 m (545' -8") above ground level. The collector field geometry, with approximate dimensions, is shown on Figure 2.6-1. The functional interface between the solar collector and the receiver shall meet the following requirements.

a. Thermal Rating at Design Point - The solar collector shall be capable of supplying the receiver absorbing surfaces with 209 MW_t (713 x 10^6 Btu/hr) at noon on day 35 assuming the following environmental conditions

   1) Isolation - 950 w/m^2 (301.3 Btu/hr-ft^2)
   2) Temperature - 38.9°C (102°F) (dry bulb)
   3) Wind Speed - 5.1 m/s (16.4 ft/s) at 10 m (30 ft) above ground
   4) Atmospheric Visibility - 25 km (15.5 miles)

b. Maximum Power Level - The maximum power level incident on the receiver absorbing surfaces shall not exceed 230 MW_t. The capability shall be provided to place individual heliostats in the standby position, if necessary, to prevent power levels to exceed this limit.

c. Flux Distributions - Redirected solar energy flux levels on the receiver absorbing surfaces shall be controllable, using suitable aiming and heliostat focusing strategies, such that the maximum absorber tube temperature does not exceed 649°C (1200°F). Maximum fluxes on absorber surfaces having a geometry as shown in Figure 2.6-2 shall meet the requirements of Section 3.5-6.

d. Standby Point coordinates. - The standby point shall be located in the aperture plane 120 m ± 10 m east of the aperture center, at an elevation of 170 m ± 10 m above ground level. This will permit access of personnel to the tower top with the heliostats at standby, and will insure that possible drifting of the standby point as a result of loss of power to the heliostat field will not result in overheating of the external structure of the receiver.

e. Defocusing - Normal Field Power. - The solar collector shall have the capability to defocus all heliostats from the receiver within 90 seconds following a rapid defocus command initiated by the Master Control System, or by manual override.

f. Defocusing following loss of field power. - In this situation, the normal collector field power supply is interrupted, causing the heliostats to cease normal operations. If the solar collector was functioning in the tracking mode prior to the power cutoff, severe damage could occur to the receiver as the collector field aim points drift due to the motion of the sun. To prevent this receiver damage, a backup power supply shall be available to provide electrical power to the solar collector. Further, the collector control system shall include at least one predefined defocusing strategy which allows all heliostat beams from the solar collector to be off the tower and/or receiver within 90 seconds after the initial loss of power occurrence.

g. Defocusing following partial loss of power due to fault in the system. - The power source to the collector field shall be configured such that partial loss of power due to failure of a feeder line, a transformer, or a circuit breaker shall not result in loss of control of more than one sixth of the heliostats comprising the field.

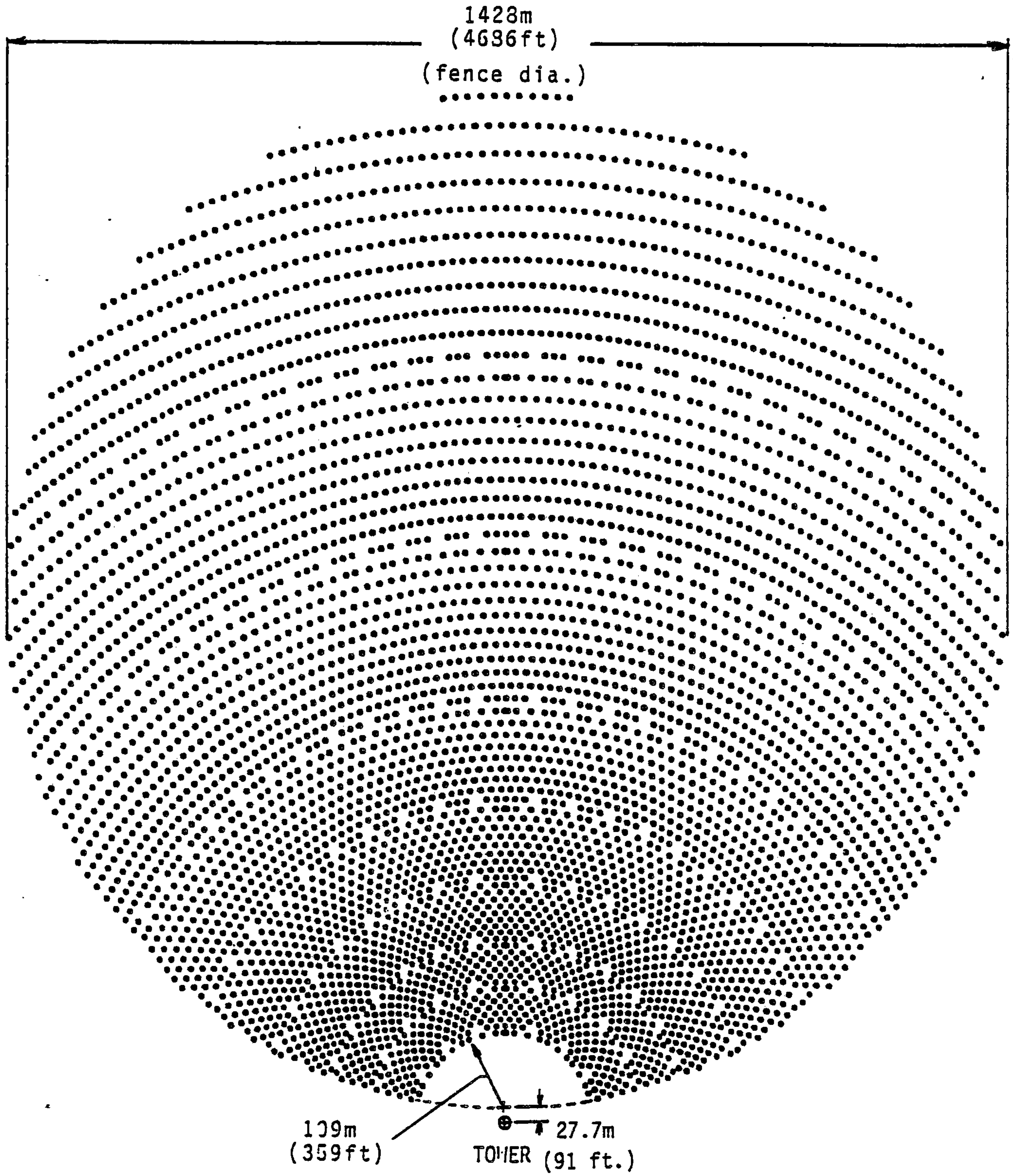


FIGURE 2.6-1 Solar Collector Field Geometry

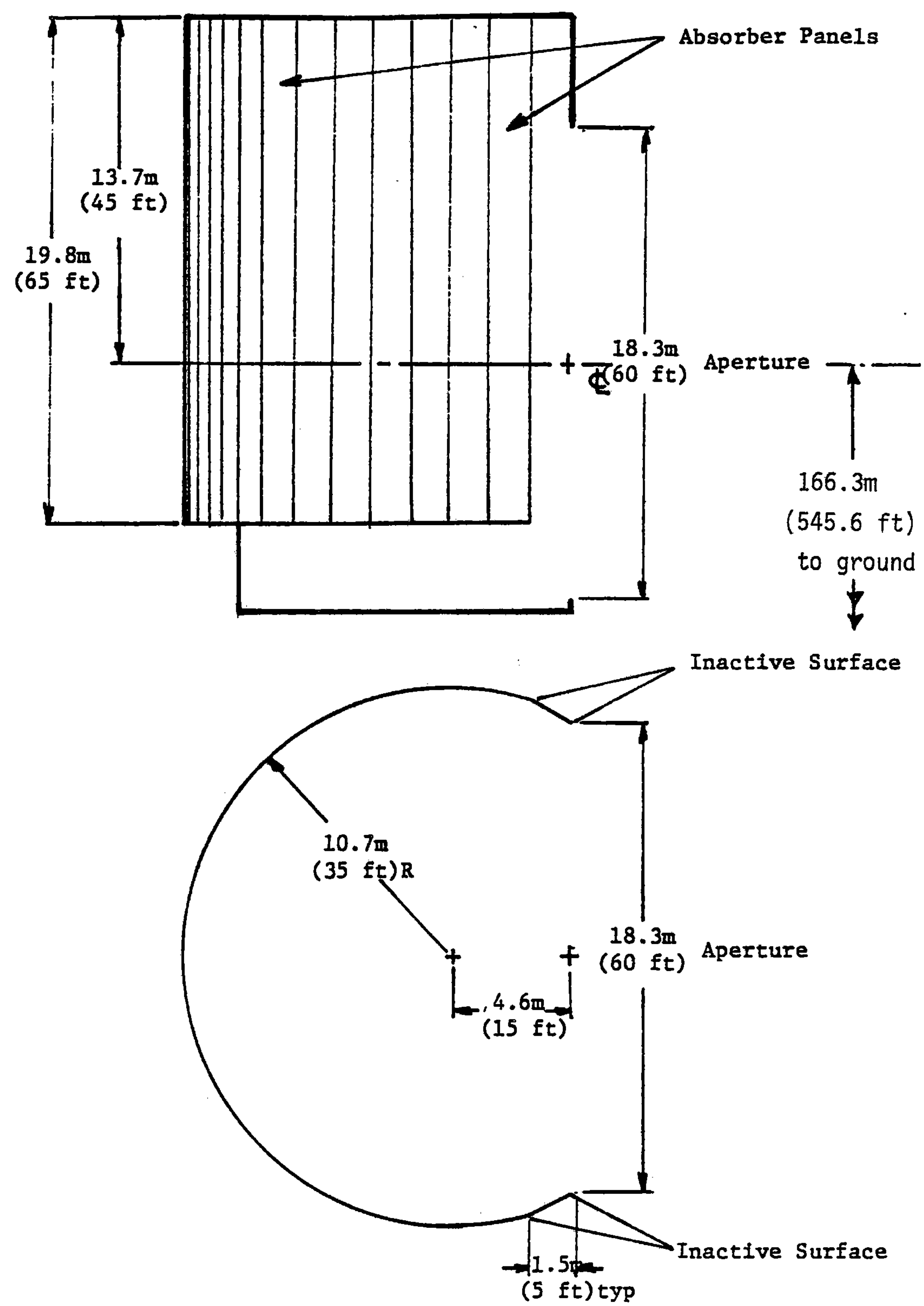


FIGURE 2.6-2 Receiver Radiation Geometry

g. Power Ramp-up. - The collector system shall be capable of refocusing the heliostats from standby to aim in a preprogrammed and continuous manner in 6 minutes.

h. Warmup Heliostats. - The capability shall be provided to preheat the receiver absorber panels with reflected solar energy without overheating, by the use of pre-selected groups of heliostats. Warmup must be possible for any insolation condition.

i. BCS Targets. - The receiver door shall be configured such as to permit installation of BCS targets on the door surfaces facing the collector field, per requirements of MCR-82-640.

2.6.2 Tower (RSB)

The tower provides structural support for the receiver and the boundaries for the receiver auxiliary systems (electrical, compressed air, cooling water).

The tower height shall be consistent with the focal height requirement of 162 m (532 ft) determined on the basis of radiation interface requirements.

2.6.3 Master Control System (COG)

The physical interface between the receiver control and instrumentation hardware and the master control system is provided by termination panels located within the tower.

The RSA/COG interface shall comply with the following functional requirements for receiver control:

a. Control salt outlet temperature within limits specified in 3.5.9, by controlling the salt flow rate to the heat absorption panels to match variations in solar input.

b. Monitor peak metal temperatures determined by a combination of direct measurements via radiometers, and indirect calculations from temperature measurements - and provide monitoring, warning, and alarm signals, as appropriate, to the master control system.

c. Protect the receiver from overtemperature by the incorporation of control override features that automatically increase the salt flow rates to values above those required by heat balance if safe local temperatures are exceeded.

d. Provide time-integrated absorbed energy and temperature data for performance evaluation and salt management control override decisions.

e. Provide thermal cycle count information on heat absorption panels for equipment life management decisions pertaining to intermittent cloud transient operations.

f. Monitor static or quasi-static salt temperatures during hot standby, and provide temperature warnings and alarms.

g. Provide remote and local override capability for all control functions.

h. Detect failure modes (e.g. loss of salt flow, loss of pump pressure, salt overtemperature, etc.), provide appropriate warning and alarm signals, and initiate safe shutdown in case of failures.

i. Provide receiver data processing, conversions to engineering units, and recording.

j. Provide control logic for the circulating pumps and all motor-operated valves.

2.6.4 Auxiliary Power Supply (APA-API)

The interfaces between the receiver and the auxiliary power supply consist of electrical wiring at the system boundary, including:

a. AC Power Supply -120/208V (APA)
b. AC Power Supply 480V (APB)
c. Essential Services AC (API)

2.6.5 Plant Communication (CMA)

The plant communications will be used to transmit verbal information between personnel at the receiver and other parts of the plant.

2.6.6 Raceway (EEC)

The raceway system shall support the power supply and control cables used by the RSA. The interface occurs were the cables are joined to the raceway.

2.6.7 Air Supply System (CAD)

The CAD supplies compressed air for pneumatic control and instrumentation devices, and for pressurization of the cold and hot surge tanks. It also provides blowdown air to supply 90 seconds of salt flow in case of power failure to the heliostat field.

2.6.8 Grounding and Lightning Protection (EEB)

Lightning protection for the receiver is provided by the EEB in accordance with Paragraph 2.5.8.

2.6.9 Solar Receiver Tower Fire Protection (FPF)

The receiver shall be protected against fire by the receiver area fire protection system. The FPF shall provide remote monitoring and activation capabilities.

2.6.10 Solar Receiver Tower Lighting (LTJ)

Adequate lighting for night-time maintenance shall be provided by the receiver area lighting system, in accordance with OSHA regulations.

2.6.11 Receiver Molten Salt Supply and Discharge (RSC)

The receiver interfaces with the vertical piping carrying the cold salt from the booster pumps to the cold surge tank, and the hot salt from the hot surge tank to the drag valves. The interfaces occur at the top of the tower. The vertical piping shall be designed to meet the flow, pressure, and temperature requirements of 3.5, and shall be supported and anchored in such a manner as to prevent undue loads on the receiver piping due to dead weight and/or thermal expansion.

2.7 OPERATING CONDITIONS

The receiver shall be capable of functioning in the following operating modes, within the constraints specified in 2.9.

2.7.1 Operating Modes - Normal

The normal operating modes involve combinations of 22 major operational sequences labeled A through V on Figure 2.7-1. The sequences pertaining to any given operational mode and their order of execution are indicated by the numbers in the matrix blocks. Some of the sequences are only used on an as required basis as shown on the figure.

a. Cold Startup
This operation brings the receiver from a dry and empty state at ambient temperatures to steady state operation through the eleven sequences (A through K) shown on Figure 2.7-1.

b. Diurnal Startup
This operation brings the receiver from hot standby to steady state operation through the eight sequences shown on Figure 2.7-1.

c. Sustained Operation
This mode includes all steady state operation specified in 3.5.12.

d. Operating Cloud Cover Transient
This transient entails operation during intermittent cloud passages between periods of steady state operation. Generally it involves repetitions of sequences L-M-N-G-O-I-J-K on Figure 2.7-1.

e. Hot Standby (Overnight or During Prolonged Cloud Passage)
The flexibility shall be provided to use alternate combinations of sequences P, Q, R, S, T, V (Figure 2.7-1), depending on the duration of cloud passages. The combinations shall include (in order of decreasing durations of the cloud passage):

- Sequence R-Q-R-S-T-V
- Sequence P-Q-R-S-T
- Sequence P-Q-R-S

f. Hot Startup Following Cloud Passage
This sequence is same as diurnal startup

g. Diurnal Shutdown and Overnight Hold
A controlled recirculation sequence is included at the start of shutdown in order to increase the thermal content of the receiver just prior to shutdown in preparation for overnight hold. For the appropriate sequence refer to MCR-82-844.

h. Prolonged Shutdown
The object of this operation is to drain the receiver and to allow it to cool down to ambient temperature.

NOTES: Numbers in the matrix blocks correspond to the approximate order in which the operational sequences are executed

(*) indicates use of sequence on an as needed basis

OPERATIONAL SEQUENCES	Cold Startup	Diurnal Startup	Sustained Operation (20 - 110 % Load)	Operating Cloud Cover Transient	Hot Standby (Overnight or Clouds)	Diurnal Shutdown & Overnight Hold	Prolonged Shutdown
				OPERATIONAL MODES & TRANSITIONS			
A. Trace heat RS to above salt freezing point	1						
B. Heliostats to standby point	2	1					
C. Open cavity door	3	2					
D. Preheat receiver panels w. "warmup" heliostats	4*						
E. Fill RS with salt from cold storage tank	5						
F. Establish flow for power rampup	6	3					
G. Divert sub-temperature receiver outlet salt to cold storage tank	7*	4*		4*			
H. Rampup power (bring heliostats on target)	8	5					
I. Establish design conditions (set point temps.)	9	6		6			
J. Discharge hot receiver salt into hot tank	10	7		7			
K. Steady sustained operation (clear sky or haze)	11	8	1	8			
L. Transient operation - Intermittent clouds, acceptable energy levels				1			
M. Establish minimum flow required for maintaining receiver outlet temperature				2			
N. Reduce number of heliostats on target for safe recovery from cloud transient				3*			
O. Return to full heliostat power w. temp. control				5			
P. Remove heliostat from target to standby point					1	2	1
Q. Close cavity doors					2	3	2
R. RS to hot standby configuration (booster and circulation pumps, valves, trace heaters)					3	4	3
S. Controlled recirculation through panels					4	1,5	4
T. Intermittent charging of inlet tank from ESB					5*	6*	
U. Drain RS into ESC							5
V. Heliostats to stow position					6*	7	6

FIGURE 2.7-1 Operational Sequences - Normal Operation

2.7.2 Operating Modes - Emergency

The RS shall be capable of safe, automatically controlled shutdown (without operator attention) resulting from the following emergency conditions.

a. Molten salt pump trip
b. Heliostat field rapid defocus
c. Loss of electrical power to the heliostat field
d. Failure of any molten salt pipe in the receiver system
e. Failure of receiver panel tube
f. Loss of receiver, collector, or flow control
g. Loss of station electrical power
h. Failure or improper operation of isolation, relief, or control valves
i. Loss of pneumatics
j. Loss of cooling water supply

2.8 REDUNDANCY

Redundancy shall be provided in the design as appropriate for the purpose of reliability/maintenance, and to prevent prolonged shutdowns due to normal failure modes of the receiver. Redundant design shall include, but not be limited to, the following:

a. Flow control valves. - Two control valves in parallel shall be used for each control zone to prevent panel overheating due to valve sticking.

b. Cold Salt pumps. - Three half-capacity pump assemblies shall be provided.

c. Redundant microprocessors and memory units shall be provided in the receiver control system, with automatic fail-over capability.

d. Backup, remotely operated, shutoff valves shall be provided to prevent excessive leakage through check valves, energy dissipating valves, and control valves.

e. Two level control transmitters for cold surge tank and two level control transmitters for the hot surge tank.

f. Two air tanks in the air supply system.

2.9 FUNCTIONAL CONSTRAINTS

The operation of the receiver is subject to the following constraints:

a. Freezing of salt, including the formation of dispersed solid particles, shall be prevented by insuring that the fluid transport equipment in contact with the salt is preheated to at least 11C (20°F) above the incipient freezing point of the salt (246C or 475°F).

b. The amount of salt discharged into the hot storage tank at receiver outlet temperatures below those specified in 3.5 shall be minimized by the master control system, so that the salt bulk temperature in the hot storage tank during operation of the steam generator subsystem shall not be reduced below 549°C (1020°F).

c. Entrapment of air pockets in the heat absorbing panels of the receiver shall be prevented.

d. Metal temperatures in contact with molten salt shall not exceed 600C (1112°F) during steady-state operation.

e. Peak tube metal temperatures shall not exceed 649C (1200°F) during steady state operating conditions and shall not exceed 710°C (1310°F) during transient conditions.

f. For the purposes of life predictions 50,000 thermal cycles due to intermittent cloud transients shall constitute 30-year life.

g. Focusing and defocusing of heliostats shall be controlled to comply with the flux limitations on external structure as detailed in 3.5.13.

2.10 PHYSICAL CONSTRAINTS

a. Drainability

The receiver and its components, including all valves, pumps, lines, tubes, headers, and tanks, shall be completely drainable in order to prevent the formation of frozen pockets of salt within the system during cold standby conditions.

The drain paths shall be carefully laid out with due consideration to the time required for the boundary layer flow phase of the draining process. Drain lines shall have a minimum slope of 1 cm/m.

The drain paths shall be insulated, and provided with trace heating.

All valves shall be equipped with manual override capability, so that they can be opened in case of electrical power or control system failure.

Provisions shall be made for the detection and/or elimination of accumulation of frozen salt due to valve leakage downstream of the drain valves, so that the drain path may be kept free throughout the operation of the receiver.

b. Freeze and Thaw Considerations

The receiver shall be designed to handle salt in the liquid form only. Local thawing shall not be relied on as an expedient means of correcting a freeze-up situation. If thawing becomes necessary, careful consideration shall be given to the fact that the melting of the salt mixture results in a significant increase in salt specific volume, thus creating a potential for failure of closed containers.

Heat tracing shall be provided as required to prevent freezing of salt within fluid transport equipment during fill, drain, and standby operations.

2.11 PROCESS CONTROL

The operation of the receiver will be controlled by the master control system through the system interfaces as described in 2.6.3. The capability will be provided for both fully automatic and manual control for all operating modes described in 2.7.1 and 2.7.2.

2.12 TESTING

Testing and certification of the receiver components and subsystems shall be accomplished in accordance with ASME and other applicable code requirements.

2.13 SAFETY

The receiver shall be designed to minimize safety hazards to operating and service personnel, the public, and equipment. Electrical components shall be insulated and grounded. All components with elevated temperatures shall be insulated against contact with, or exposure to, personnel. Any moving elements shall be shielded to avoid entanglements, and safety override controls/interlocks shall be provided for servicing.

Provisions shall be made to prevent uncontrolled access of personnel to the tower top and to the vicinity of the tower base during solar operations.

The requirements of the Occupational Safety and Health Administration and of the National Fire Protection Association shall be fully satisfied.

3.0 COMPONENT DESIGN CRITERIA - RECEIVER

3.1 COMPONENT IDENTIFICATION

(1) Component Name	Receiver
(2) System Code	RSA
(3) Purchase Specification	62.4201

3.2 FUNCTION

The function of the receiver is to intercept the solar energy reflected by the solar collector and to convert it into high-temperature sensible thermal energy using molten nitrate salt as the heat transfer fluid.

3.3 DESCRIPTION

The receiver comprises all equipment of the receiver subsystem that is mounted on the top of the tower, including: shop-fabricated modular absorbing panels, non-absorbing cavity enclosure, interconnecting piping, structural supports, aperture frame and door, door supports and actuation mechanism, salt inlet surge tank, salt outlet surge tank, insulation and sheathing, radiation shielding of external structures and components, access provisions, hoisting provisions, receiver circulation pumps, and accessories.

3.4 CODES AND STANDARDS

The receiver will be designed and built in accordance with the codes and standards listed in 2.2.

3.5 SIZING CRITERIA

3.5.1 Thermal Rating - The receiver shall be designed for 190 MWt output overall thermal rating at the design point with margin to accept power levels up to 209 MWt without heliostat defocus.

3.5.2 Insolation Rating - The design point thermal rating of 3.5.1 is based on 950 W/m^2 direct normal insolation. The receiver shall be capable of accepting all reflected energy without heliostat defocus for insolation levels up to 1045 W/m^2, at design salt temperatures per 3.5.9.

3.5.3 Efficiency - The thermal efficiency of the receiver (defined as the ratio of thermal output to the calculated solar energy passing through the receiver aperture) shall be equal to or greater than 90 percent at the design point, under the environmental conditions specified in 2.6.1a.

3.5.4 Heat Losses During Hot Standby and Overnight Shutdown - Thermal losses during hot standby shall not exceed 1 MWt.

3.5.5 Radiation Geometry - The geometrical configuration of the receiver cavity shall conform to the following requirements:

a. Maximum absorbed fluxes on the absorbing surfaces defined by Figure 2.6-2 shall not exceed those specified on Figure 3.5-1.

b. Incident fluxes on non-absorbing surfaces inside the cavity shall not exceed TBD kW/m^2 (TBD Btu/ft^2 - hr).

c. The calculated aperture efficiency (defined as the ratio of reflected solar energy that passes through the aperture to the total energy incident on the aperture plane) shall be equal to or exceed 97 percent.

3.5.6 Incident Flux Distributions - The thermal design of the receiver shall be based on the following incident flux distributions associated with the receiver radiation geometry shown on Figure 2.6-2:

a. Absorbing Surfaces - Design Point: Figure 3.5-2.
b. Absorbing Surfaces - Morning Startup: Figure 3.5-3
c. Absorbing Surfaces - Evening Shutdown: Figure 3.5-4
d. Absorbing Surfaces - Operational Cloud Cover Transients: Figures 3.5-5a through 3.5-5e
e. External Non-Absorbing Surfaces - Steady State Operation: Figure 3.5-6
f. Internal Non-Absorbing Surfaces - Steady State Operation: Figure 3.5-7
g. Flux Transients Following Loss of Power to the Collector Field: Figures 3.5-8a, b and c.

Flux distributions associated with maximum power rating per 2.6.1 b, 3.5.1, and 3.5.2 shall be obtained by the use of a multiplying factor of 1.1 applied to 3.5.6 a, d, e, f, and g.

3.5.7 Operating Life - The receiver components shall be designed for a 30 year operating life.

3.5.8 Heat Transfer Fluid - The heat transfer fluid shall be molten salt consisting of 60% sodium nitrate ($NaNO_3$) and 40% potassium nitrate (KNO_3) by weight, with thermo-physical properties as defined in the Project Design Manual.

3.5.9 Molten Salt Temperatures - The receiver shall be capable of sustained operation within the temperature ranges and conditions specified below:

a. Steady-state Operation:
Inlet Temperature = $277\,^{+67}_{-28}$C ($530\,^{+120}_{-50}$°F)

Outlet Temperature = 566 ± 11C (1050 ± 20°F) when not on salt flow limit, except that the 30 minute average shall be 566 ± 1C (1050 ± 2°F);
When on salt flow limits, the temperature shall not exceed 582C (1080°F) for periods greater than 10 minutes.

b. Operating Cloud Cover Transients: Cloud cover can cause the inlet or outlet salt temperature to go beyond the range specified for steady state operation. For this condition the operator can continue to operate or go to hot standby. If the salt temperature falls to 277C (530°F) the system will automatically go to hot standby.

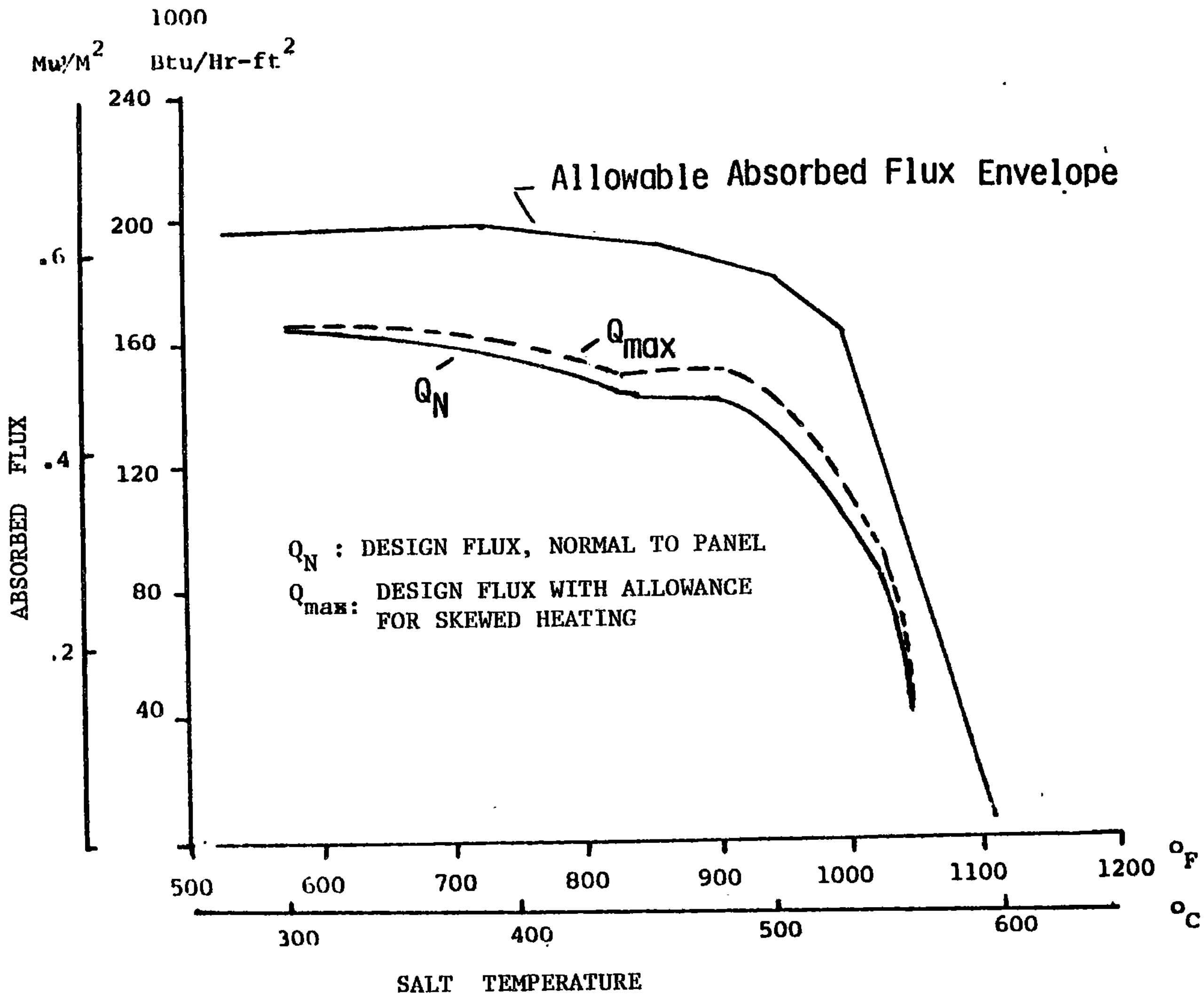


FIGURE 3.5-1 Allowable Flux Vs Salt Temperature

PASS No:

1	2	3	4	5	6	7	8	9	10	11	12
63	69	82	76	63	66	54	60	69	60	47	19
205	177	205	199	170	167	148	148	170	148	95	41
397	350	382	378	337	344	300	268	278	237	155	66
495	460	483	476	448	460	423	353	325	265	170	76
524	492	495	495	473	476	457	388	319	237	148	60
533	517	501	489	467	451	423	375	306	211	123	54
552	536	517	498	467	435	404	366	315	230	132	57
561	549	530	501	464	416	378	344	296	224	136	60
552	542	524	495	454	397	347	306	255	192	114	47
495	489	473	448	410	356	293	243	196	142	82	35
372	366	356	341	312	271	221	167	123	82	44	6
227	224	218	208	192	167	132	95	60	35	14	0
98	95	91	88	82	73	57	38	21	9	3	0

Active Length = 19.8 m (65 ft)

1.52m (TYP) (5.0ft)

0.76m (2.5ft)

Inlet

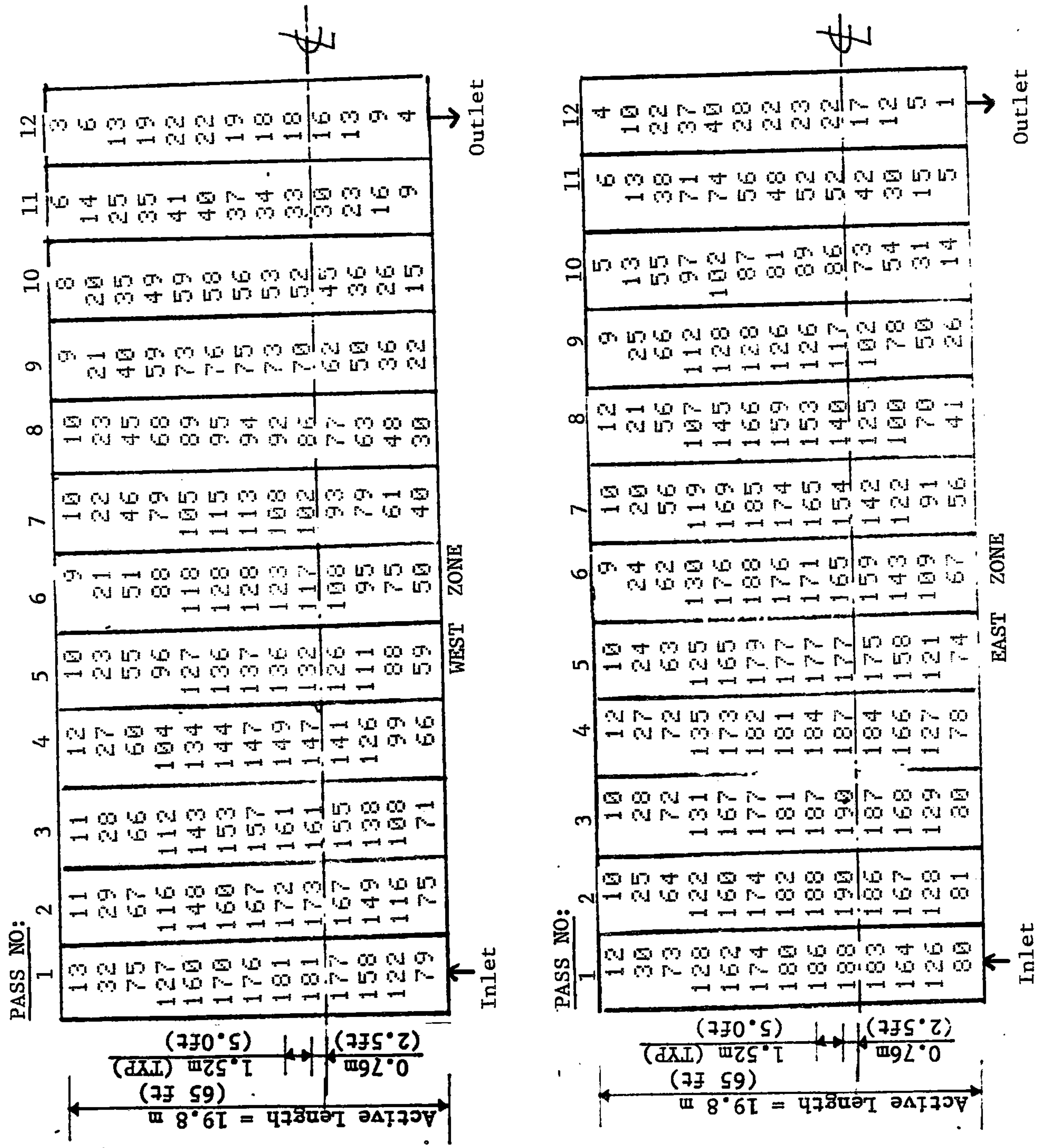
Outlet

℄ Heat Absorption Surface

NOTE: Fluxes are in KW/m^2
West Zone Shown, East Zone Opposite

East Zone | West Zone

FIGURE 3.5-2 Incident Fluxes - Absorbing Surfaces @ Design Point (Day 35, Solar Noon)



NOTE: Fluxes are in KW/m^2

FIGURE 3.5-3 Incident Fluxes - Absorbing Surfaces - Design Conditions for Morning Startup

PASS NO:

EAST ZONE (Active Length = 19.8 m (65 ft); 1.52m (TYP) (5.0ft); 0.76m (2.5ft); Inlet at pass 1, Outlet at pass 12; centerline ℄ between rows 9 and 10)

1	2	3	4	5	6	7	8	9	10	11	12
13	11	11	12	10	9	10	10	9	8	6	3
32	29	28	27	23	21	22	23	21	20	14	6
75	67	66	60	55	51	46	45	40	35	25	13
127	116	112	104	96	88	79	68	59	49	35	19
160	148	143	134	127	118	105	89	73	59	41	22
170	160	153	144	136	128	115	95	76	58	40	22
176	167	157	147	137	128	113	94	75	56	37	19
181	172	161	149	136	123	108	92	73	53	34	18
181	173	161	147	132	117	102	86	70	52	33	18
177	167	155	141	126	108	93	77	62	45	30	16
158	149	138	126	111	95	79	63	50	36	23	13
122	116	108	99	88	75	61	48	36	26	16	9
79	75	71	66	59	50	40	30	22	15	9	4

WEST ZONE (Active Length = 19.8 m (65 ft); 1.52m (TYP) (5.0ft); 0.76m (2.5ft); Inlet at pass 1, Outlet at pass 12; centerline ℄ between rows 9 and 10)

1	2	3	4	5	6	7	8	9	10	11	12
12	10	10	12	10	9	10	12	9	5	6	4
30	25	28	27	24	24	20	21	25	13	13	10
73	64	72	72	63	62	56	56	66	55	38	22
128	122	131	135	125	130	119	107	112	97	71	37
162	160	167	173	165	176	169	145	128	102	74	40
174	174	177	182	179	188	185	166	128	87	56	28
180	182	181	181	177	176	174	159	126	81	48	22
186	188	187	184	177	171	165	153	126	89	52	23
188	190	190	187	177	165	154	140	117	86	52	22
183	186	187	184	175	159	142	125	102	73	42	17
164	167	168	166	158	143	122	100	78	54	30	12
126	128	129	127	121	109	91	70	50	31	15	5
80	81	80	78	74	67	56	41	26	14	5	1

NOTE: Fluxes are in KW/m^2

FIGURE 3.5-4 Incident Fluxes - Absorbing Surfaces - Design Conditions for Evening Shutdown

25 PER CENT COVER FROM EAST SIDE OF THE FIELD

88	88	98	123	66	54	73	73	76	79	66	22
233	211	262	287	192	167	186	202	189	183	136	50
388	356	407	432	347	328	322	328	303	262	186	79
476	451	470	479	445	438	410	372	337	271	183	79
505	498	498	489	486	483	448	375	315	240	151	63
505	508	501	492	476	467	435	375	309	221	129	50
511	517	511	495	473	448	413	378	322	230	132	57
514	530	524	501	473	429	391	350	303	227	136	60
505	520	517	495	460	410	360	315	262	192	114	50
451	467	464	445	413	363	303	252	202	145	85	38
341	378	363	341	315	278	224	177	129	88	47	19
208	218	218	208	196	170	139	98	63	38	16	3
91	95	95	91	85	76	60	41	22	9	2	0

50 PER CENT COVER FROM EAST SIDE OF THE FIELD

85	98	91	117	66	54	73	73	76	79	66	22
196	227	243	268	189	167	186	202	189	183	136	50
290	356	385	407	341	328	322	328	303	262	186	79
322	416	448	460	442	438	410	372	337	271	183	79
331	432	473	476	483	483	448	375	315	240	151	63
328	426	470	476	470	464	435	378	309	221	129	50
334	423	470	476	464	445	413	378	322	230	132	57
341	429	473	479	464	426	391	350	303	227	136	60
337	419	460	473	451	407	360	315	262	192	114	50
300	372	413	423	404	360	303	252	202	145	85	38
227	284	315	325	309	274	224	177	129	88	47	19
139	177	196	202	192	170	136	98	63	38	16	3
63	79	85	88	85	76	60	41	22	9	2	0

75 PER CENT COVER FROM EAST SIDE OF THE FIELD

0	0	0	0	0	6	3	9	13	16	9	2
0	1	3	9	16	19	35	54	73	79	54	19
6	13	28	44	63	85	110	132	145	142	101	41
16	32	54	88	132	180	214	218	202	173	114	47
32	57	95	145	214	281	319	303	252	183	110	41
50	85	136	205	278	347	375	347	290	205	114	41
69	117	183	255	322	375	388	366	315	230	132	54
85	145	218	290	350	372	372	344	303	227	136	60
91	155	230	303	353	360	344	309	262	192	114	50
82	142	211	278	319	319	290	249	202	145	85	38
63	107	164	214	246	243	214	173	129	88	47	19
38	66	101	136	158	158	132	98	63	38	16	3
16	32	47	63	76	73	60	41	22	9	2	0

FIGURE 3.5-5 Incident Fluxes - Absorbing Surfaces - Operational Cloud Cover Transient

1.52 m (5 ft) TYP

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
.032	.032	0	0	0	0	0	0
.063	.063	.032	0	0	0	0	0
.063	.063	.063	.063	.032	0	0	0
.063	.063	.095	.126	.126	.252	1.89	3.47

1.52 m (5 ft) TYP

Door Edge

APERTURE OPENING = 18.29 m (60 ft)

℄ DOOR

1.39	5.05	7.57	6.31	2.49	5.05	10.4	15.8
2.49	4.42	4.10	1.39	.252	.158	.063	0
2.33	2.46	1.10	.158	.063	0	0	0
1.04	.536	0	0	0	0	0	0
.284	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

NOTES: Fluxes are in KW/m^2 incident on the North-facing Outer Surface of the Door

FIGURE 3.5-6 Incident Fluxes - External Non-Absorbing Surfaces - Steady State Operation - Day 35 Solar Noon

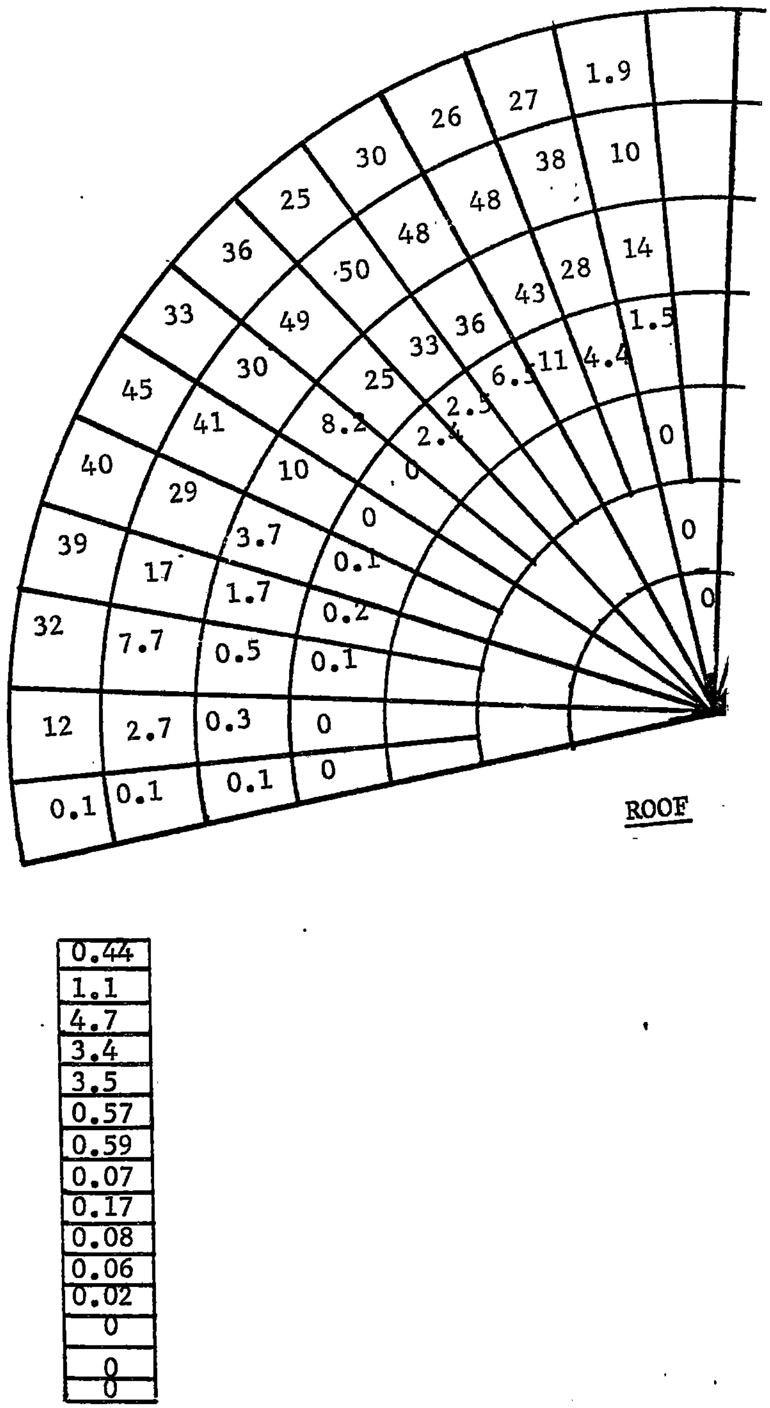


FIGURE 3.5-7 Incident Fluxes - Internal Non-Absorbing Surfaces - Steady State Operation, Day 35 Solar Noon

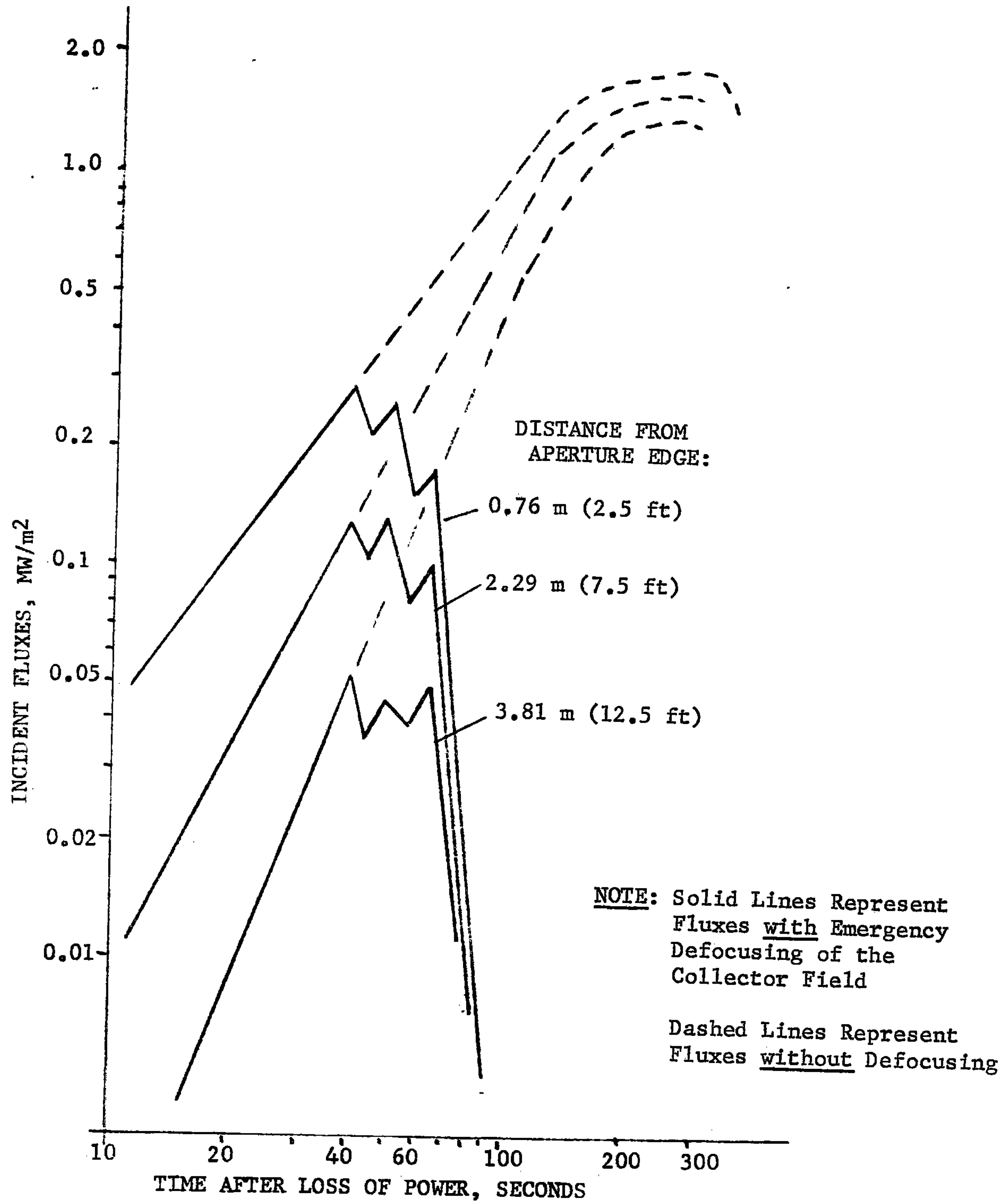


FIGURE 3.5-8 Flux Transients Following Loss of Power to the Collector Field (Page 1 of 2)-External Fluxes for Design Point, Day 35 Solar Noon

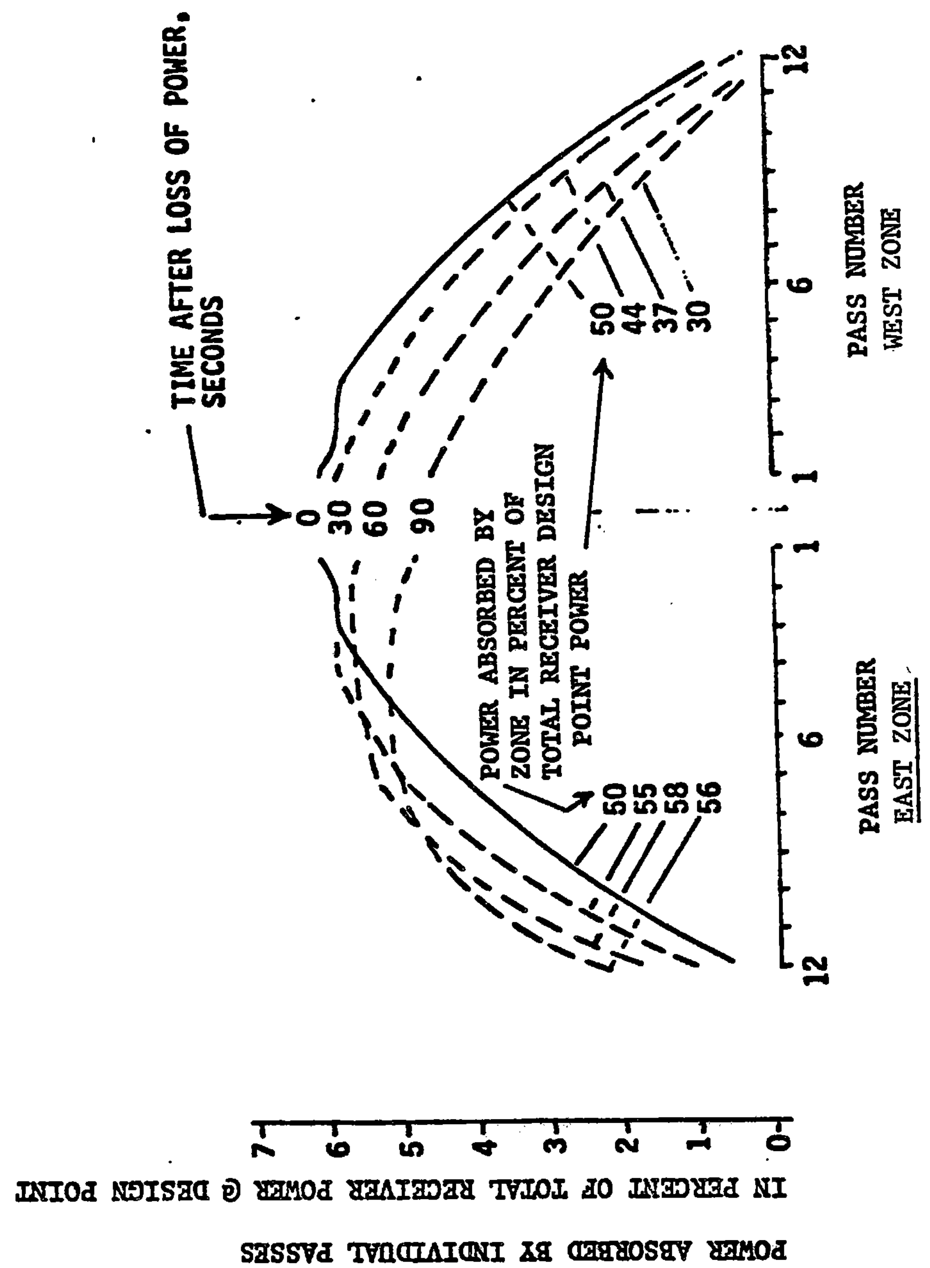


FIGURE 3.5-8 Flux Transients Following Loss of Power to the Collector Field (Page 2 of 2) Internal Fluxes for Design Point, Day 35 Solar Noon

c. Hot Standby - During hot standby, salt temperatures in the receiver shall be maintained above 246C (475°F).

3.5.10 Molten Salt Compatibility Requirements
The requirements specified in 2.9a and d, and 2.10a and b shall be met.

3.5.11 Turndown Ratio

a. Steady State and Operating Cloud Cover Transients - The receiver shall be capable of meeting the temperature requirements specified under 3.5.9a and b at part load conditions ranging from 20% to 110% of the rating specified under 3.5.1.

b. Minimum Absorbed Thermal Power - The receiver shall be capable of sustained operation (with salt flow) at minimum absorbed power of 10% of the rating specified under 3.5.1 with inlet salt temperatures as specified under 3.5.9a and outlet temperatures not exceeding those under 3.5.9b.

For design purposes the flux distributions per Figure 3.5.6 a, d, e, f and g shall be used, in conjunction with multiplying factors of 0.2, 1.1., and 0.1 for the 20%, 110% and 10% power levels, respectively.

3.5.12 Operating Modes - The receiver shall be capable of functioning in the operating modes specified under 2.7.

3.5.13 Induced Radiation Environments - The receiver shall be capable of surviving the following solar flux levels on its external surfaces:

a. Spillage, with intensities up to levels not exceeding TBD kW/m^2 (TBD Btu/ft^2-hr) on the aperture frame.

b. Flux patterns generated along the paths of heliostat images between the standby point and aim points during power ramp-up, shutdown, rapid defocus, and other focusing and defocusing operations, for the combinations of intensity and exposure times represented by the curve on Figure 3.5-9.

c. Fluxes due to stray heliostats (due to possible pointing errors or heliostat pointing system malfunctions) up to levels not exceeding TBD kW/m^2 Btu/ft^2-hr).

d. Fluxes resulting from loss of electrical power to the heliostat field and subsequent drifting of the aim points due to the motion of the sun, as defined in Figures 3.5-8a and b.

e. Fluxes resulting from loss of power due to fault in the system, leaving one sixth of the heliostats "frozen" in their position, as defined in Figure 3.5-8c.

The receiver shall be capable of surviving conditions a, b, and c of this paragraph (3.5.13) without damage. Sacrificial material may be used, as required, on the external surfaces, to provide thermal protection during d to minimize damage.

The receiver inlet tank shall be sized to provide emergency flow of salt during d for sufficient time to prevent overheating of the heat absorption panels.

Sufficient salt flow through the receiver shall be maintained during e to prevent overheating of the heat absorption panels.

3.5.14 Cycles for Cycling Operation

Cyclic Operation	Cyclic Life
Cold Startup and Prolonged Shutdown	1,000
Diurnal Startup and Shutdown	9,000
Operating Cloud Transients and Hot Standby and Recovery	50,000

3.6 MATERIALS SELECTION

a.	Heat Absorption Panels:	Alloy 800
b.	Panel Headers and Connecting Piping:	304 SS
c.	Inlet Tank	Carbon Steel
d.	Outlet Tank	304 SS

3.7 TESTING

Testing and certification of the receiver pressure components shall conform to ASME Code requirements.

3.8 RECEIVER CONTROL AND INSTRUMENTATION

Provisions for receiver control and instrumentation shall be in accordance with Appendix A of MCR-82-644.

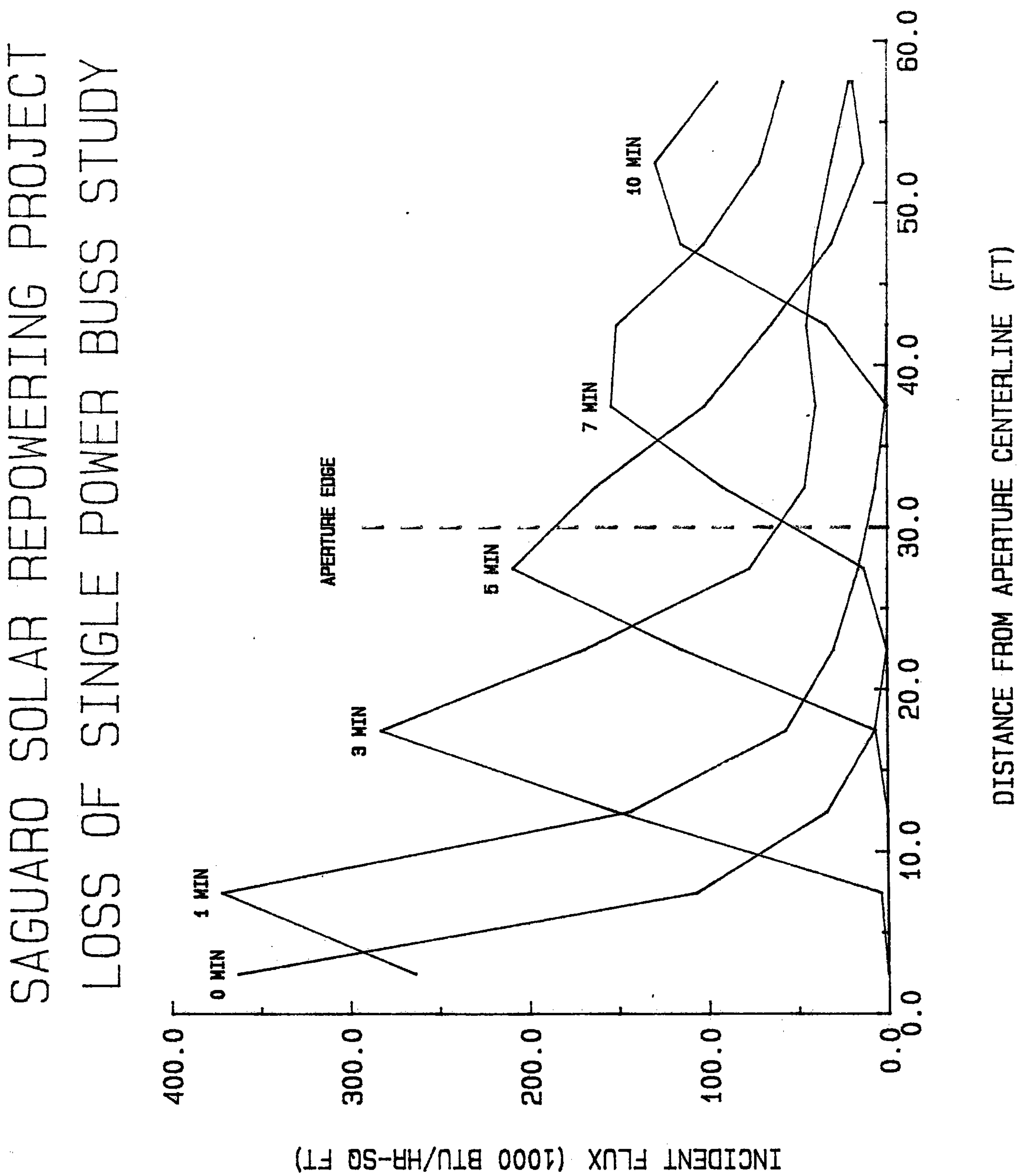


FIGURE 3.5-8c Flux Transients Following Loss of Power Due to Fault in the System

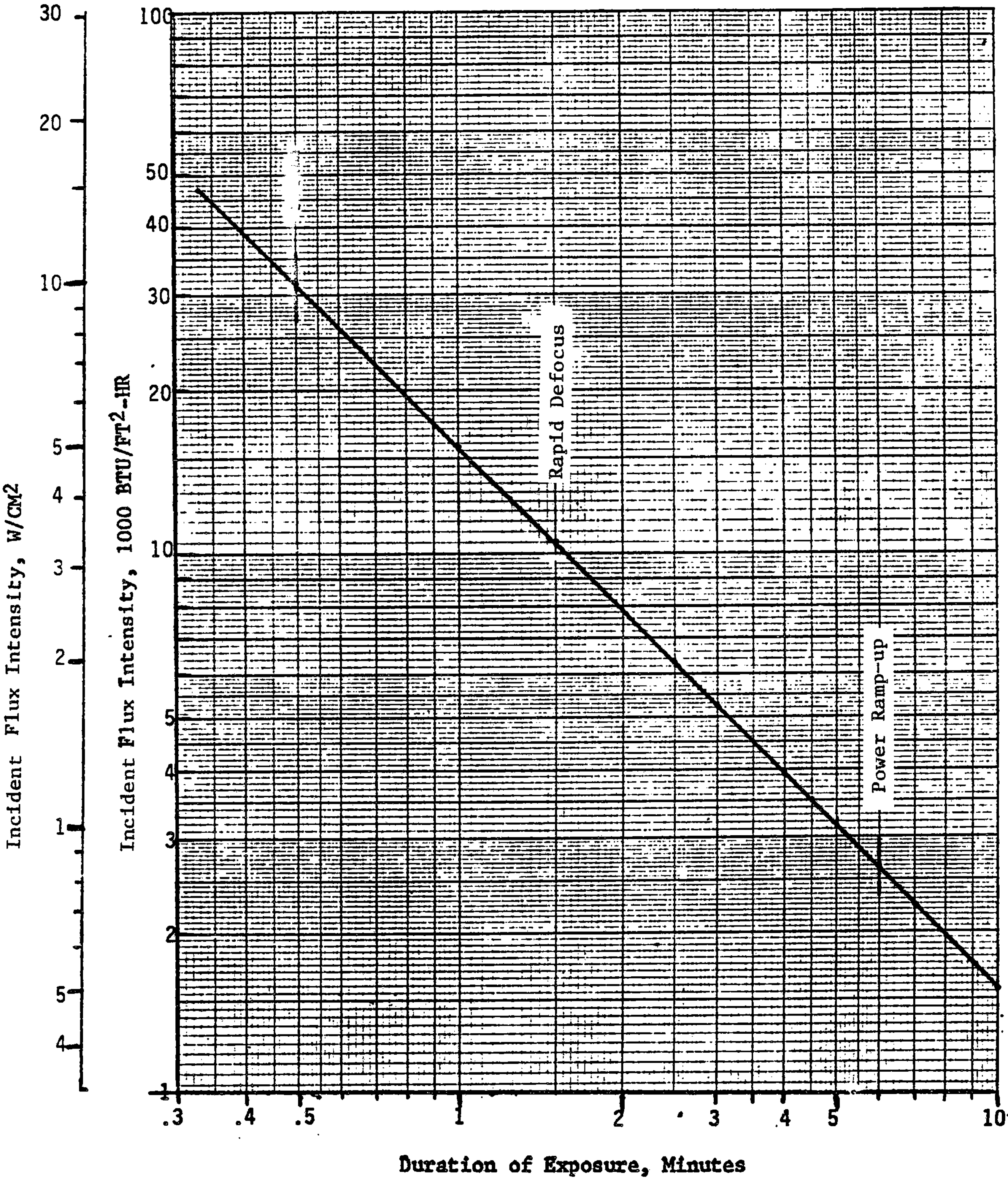


FIGURE 3.5-9 Intensity/Duration Curve For Induced Fluxes During Heliostat Transitions Between Standby Point and Target for Design Point, Day 35 Solar Noon

4.0 COMPONENT DESIGN CRITERIA - RECEIVER CONTROL VALVES

4.1 COMPONENT IDENTIFICATION

(1)	Component Name	Receiver Control Valves
(2)	System Code	RSA
(3)	Purchase Specification	62.4201

4.2 FUNCTION

The function of the receiver flow control valves is to control salt flow to the receiver heat absorption panels in order to maintain salt outlet temperatures within specified limits.

4.3 DESCRIPTION

The receiver control valves shall be equal percentage type with no less than 50:1 rangeability.

4.4 CODES AND STANDARDS

The valves shall be built in accordance with the codes and standards listed in 2.2.

4.5 SIZING CRITERIA

The valve operators shall be capable of stroking the speed no slower than 10 per cent per second at any point in the valve stroke. The two valves operating in parallel shall have flow capacity of 1.15 x maximum salt flow (corresponding to maximum absorbed power) when both valves are fully open.

4.0 Thermal Energy Storage Specification

MCR-82-642

ENERGY STORAGE SPECIFICATION

August 1983
Revision 4

Martin Marietta Corporation
Denver Division
Denver, Colorado 80201

Prepared for Arizona Public Service Company
Phoenix, Arizona
Under Subcontract No. RD82-6732

1.0 SYSTEM DESCRIPTION

1.1 CATEGORY IDENTIFICATION

1) Category Name: Thermal Energy Storage
2) Category Code: ES

1.2 FUNCTION

The thermal energy storage provides the ability to store thermal energy in order to decouple the periods of solar power generation from periods of available insulation.

1.3 PROCESS DESCRIPTION

A simplified flow diagram of the thermal energy storage system is shown in Figure 1-1. Hot salt is produced in the receiver and is stored in the hot salt storage tank. When electric power is to be generated, hot salt is pumped from the hot salt storage tank to the solar steam generator (SBB). The sensible heat in the hot salt is used to produce the steam required to operate the turbine. The cold salt from the steam generator is returned to the cold salt storage tank where it is stored for future use. The receiver is supplied with cold salt from the cold salt storage tank. The storage tanks are well insulated to minimize the heat loss from the system.

The drain sump is designed to store the salt contained in the steam generator heat exchangers in an emergency situation. It shall be located near the SBB to facilitate draining them during emergency conditions. The drain sump shall also be used as a blending/mixing tank during the initial charging of the system with salt. Hot salt shall be mixed with prilled or unmelted salt and the energy stored in the hot salt melts the prilled salt. The resulting molten salt is stored in the cold salt storage tank.

The salt heater shall provide thermal energy to melt prilled salt and to heat molten salt. The heater shall be used to melt at least the initial 20% of the salt inventory. The prilled salt is loaded into the salt heater. The fossil burner slowly melts the initial batch of prilled salt. Additional prilled salt is added, and an equal amount of molten salt is pumped to the cold salt storage tank. Agitators are used to assure complete mixing and to promote convective heat transfer. The process is repeated until there is sufficient molten salt to operate the receiver and the two storage tanks.

The salt heater is used to supply thermal energy to the storage tanks during extended shutdowns. Molten salt is pumped from either storage tank and heated with the fossil burner. The heated salt can be returned to either tank, depending on the salt temperature limitations.

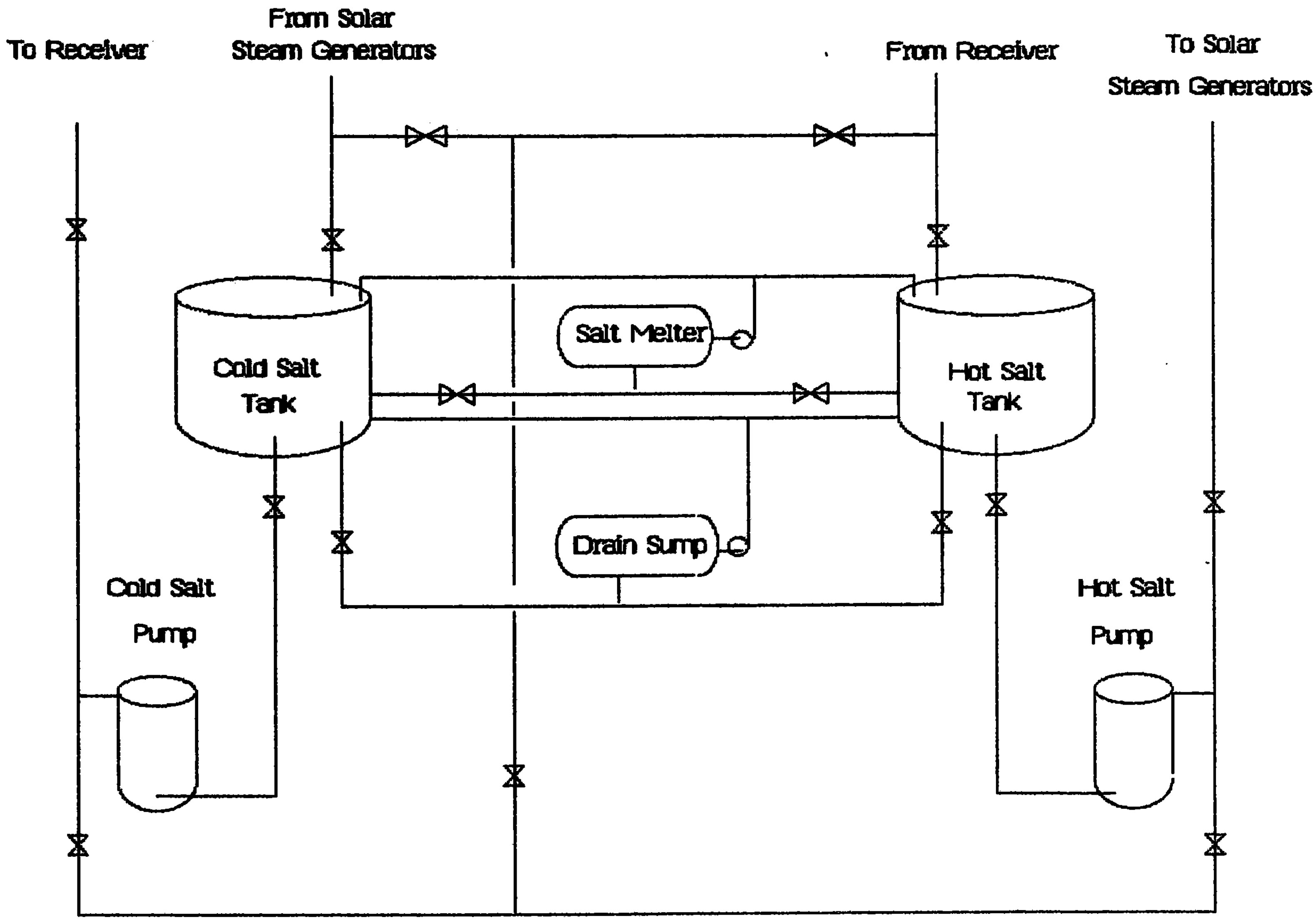


Figure 4-1 Simplified Schematic of the Thermal Energy Storage System

The salt reprocessor is intended to purify contaminated salt. The rate of contamination build up is dependent on the effectiveness of the ullage gas control system. It has been estimated that it shall be at least 5 years before the salt is contaminated to the point which it requires reprocessing. The connections for the reprocessor piping shall be installed during the plant construction period. The salt purity shall be monitored, and when it requires reprocessing, the salt reprocessor shall be installed.

1.4 INTERFACING SYSTEMS

Systems which have a significant interface with the Thermal Energy Storage are listed on Table 1-1.

Table 1-1 Interfacing Systems

System	System Code
AC Power Supply-120/208V	APA
AC Power Supply-480V	APB
Instrument Air	CAB
Intra-plant Communication	CMA
Master Control System	COG
Salt Storage Tank Foundation Cooling	ECC
Grounding and Lightning Protection	EEB
Raceway	EEC
Salt Freeze Protection	EEE
Thermal Energy Storage Area Fire Protection	FPI
Salt Heater Fuel Gas Supply	FGC
Energy Storage Area Lighting	LTM
Receiver Molten Salt Supply and Discharge	RSC
Salt Sampling and Analysis	SAG
Solar Steam Generator Vents and Drains	SBB
Solar Steam Generator Molten Salt Supply and Discharge	SBC

1.5 BOUNDARIES

The major boundaries for the Thermal Energy Storage System are listed below. The minor boundaries are described in Section 2.6, Interfacing Systems.

1) The boundaries between the hot salt storage tank and the receiver system occurs at the tank piping connection of these lines:.

   a. Receiver fill line

   b. Cold salt pump line

2) The boundaries between the hot salt storage tank and the solar steam generator occurs at the tank piping connection of these lines:

   a. Hot salt pump suction line

   b. Hot salt pump recirculation line

3) The boundaries between the cold salt storage tank and the receiver system occurs at the piping connection of these lines.

   a. Cold salt pump recirculation

   b. Receiver return line

   c. Attemperator pump recirculation

   d. Cold salt pump suction

   e. Attemperator pump suction

4) The boundary between the cold salt storage tank and the solar steam generator occurs at the tank piping connection of the cold salt storage tank fill line.

5) The boundaries between the drain sump and the solar steam generator occur at the following locations.

   a) At the valves of the salt drains of the SBB heat exchanger components (preheater, evaporator, and superheater).
   b) Down stream of the block valve on the drain branch of the SBB hot supply line.
   c) Downstream of the block valve on the drain branch of the SBB cold supply line.
   d) Downstream of the block valve on the drain branch of the SBB return line.

1.6 DEFINITIONS OF TERMS AND ABBREVIATIONS

1.6.1 Definitions of Terms

Availability - Is the hours that the subsystem is in service or available for service divided by the total number of hours whether or not the subsystem is required to operate, expressed as a percentage.

Cold Salt - This is molten salt which has a temperature of 276.7°C (530°F), nominal.

Containment Volume - The volume in which it is possible to store molten salt in the prescribed manner.

Cover Gas - The gas contained within the ullage space of the tanks.

Extended Shutdown - Describes a period during which the plant is not operational for more than several days. This implies that salt is not being heated up to 565.6°C (1050°F) in the receiver and the steam generators are not in use. Depending on the levels of salt in the two storage tanks and the duration of the outage, thermal energy from the heater may be required to prevent freezing of the salt.

Hot Salt - This is molten salt which has a temperature of 565.6°C (1050°F), nominal.

Molten Salt - A mixture of 60% $NaNO_3$ and 40% KNO_3 by weight which is in its liquid phase.

Prilled Salt - This is solid salt at ambient temperatures which has been processed in such a manner as to have the consistency of ordinary sand. Also referred to as dry salt.

Receiver Salt - The salt which is required to fill the receiver, its piping and associated components during normal operation.

Residual Heel - This term is used to describe the residual salt left in a tank when it is "emptied" during normal operation. The heel helps maintain the temperature of the tank during the daily cycles.

Solar Steam Generator Salt - The salt which is required to fill the Solar Steam Generator, its piping and associated components during normal operation.

Ullage Space - The volume contained within the storage tank above the salt.

Working Capacity - The salt required to store the thermal energy to meet the capacity of the thermal energy storage system.

2.0 SYSTEM DESIGN CRITERIA

2.1 SUPPORTIVE DOCUMENTATION

The supportive documentation for the system design criteria is as follows:

1) Saguaro Solar Repowering Preliminary Design Subsystem Interface Definition Document, MCR-82-639 MMC, 10/22/82.
2) Saguaro Solar Repowering System Codes, MMC, 12/13/82.

2.2 CODES AND STANDARDS

The significant codes and standards which apply to the thermal energy storage system are as follows:

1) API standard 650, "Welded Steel Tanks for Oil Storage".
2) ANSI Code for Pressure Piping, B31.1, Power Piping.
3) ASME Boiler and Pressure Vessel Code - Sections II and VII.

2.3 REGULATORY REQUIREMENTS

The thermal energy storage system shall comply with all applicable state laws, local ordinances and requirements of the federal Occupational Safety and Health Standards. All applicable regulatory requirements defined in the Regulatory Requirements Manual (File TBD) shall also be followed.

2.4 QUALITY LEVEL CLASSIFICATION

TBD

2.5 NATURAL PHENOMENA

2.5.1 Environmental Conditions

The Saguaro station is located 46 km (27 mi) north of Tucson, Arizona on Interstate 10. The nearest community to the Saguaro plant is Marana, Arizona which is 15 miles southeast. The plant is located in Section 15 of Range 10 east, Township 10 south of the Red Rock, Arizona quadrangle.

Design Conditions (24 hr average)

Dry bulb temperature	21°C (70°F)
Ground temperature	10°C (50°F)
Wind speed (10 m above ground)	2.2 m/s (5 mph)

Soil Bearing Strength

The Saguaro station has an allowable soil bearing pressure of 191.5 kPa (4000 psf) at a depth of 3 ft below grade in insite material (preliminary).

Wind

The thermal energy storage system shall be designed to survive a 33.5 m/s (75 mph) wind, measured 10 m (30 ft) above the ground.

The plant shall be designed to operate in winds up to 15.6 m/s (35 mph).

Ambient Temperature

The thermal energy storage system shall be designed to operate within an ambient dry bulb temperature range of -7°C (16°F) to 46°C (115°F).

Snow, Rain and Ice

The thermal energy storage system shall be designed to survive a static snow load of 250 Pa (5 lb/ft^2) and a snow deposition rate of 0.3 m (1 ft) in 24 hours.

The thermal energy storage system shall survive the following rainfall conditions:

Average annual - 340 mm (13.4 in)
Maximum 24-hr rate - 150 mm (6 in)

The thermal energy storage system shall survive freezing rain and ice deposits in a layer 25 mm (1 in) thick.

Earthquake

The Saguaro site is in a UBC Zone II seismic area with a ground acceleration of 0.1 g.

2.6 INTERFACING SYSTEMS

2.6.1 AC Power Supply-120/208V and 480V (APA-B)

The AC power supply is used for instrumentation, valve motors, pumps and other electrical requirements.

2.6.2 Instrument Air (CAB)

The instrument air is used to operate pneumatic valves and other control devices. The interface shall be the air connection on these devices.

2.6.3 Intra-plant Communications (CMA)

The intra-plant communications system shall be used to communicate verbal information from the thermal energy storage system to other parts of the plant.

2.6.4 Master Control System (COG)

The thermal energy storage control system (ESG) shall be capable of accepting and acting on commands from the master control system. The data required by the master control system shall be either provided directly or through the thermal energy storage control system.

2.6.5 Salt Storage Tank Foundation Cooling (ECC)

The foundations of the storage tanks and drain sump shall be cooled by the salt storage tank foundation cooling system. The interface occurs between the cooling pipes and the foundations.

2.6.6 Grounding and Lightning Protection (EEB)

The thermal energy storage system shall be grounded and protected against lightning by the grounding and lightning protection system. The interface occurs at the grounding connections of those components which require this protection. The interface occurs where the lightning rods are connected to the thermal energy storage system components.

2.6.7 Raceway (EEC)

The raceway system supports the power supply and control cables used by the thermal energy storage system. The interface occurs where the cables are joined to the raceway.

2.6.8 Salt Freeze Protection (EEE)

The drain sump, piping and valves of the thermal energy storage system shall be protected against salt freezing within them by the salt freeze protection system. The individual component requirements are detailed in the sizing criteria subsections. The pipe lines and valves shall be trace heated to 260°C (500°F) to prevent freezing.

2.6.9 Thermal Energy Storage Area Fire Protection (FPI)

The thermal energy storage system shall be protected against a fire by thermal energy storage area fire protection system. The system should be able to be activated either from within the thermal energy storage system area or remotely; i.e., control house.

2.6.10 Salt Heater Fuel Gas Supply (FGC)

The salt heater fuel gas supply system shall provide the necessary fuel to operate the salt heater. The interface shall occur upstream of the fuel flow rate control valve of the salt heater. The salt heater is designed to operate on natural gas.

2.6.12 Energy Storage Area Lighting (LTM)

Adequate lighting for night time operation and maintenance of the thermal energy storage system shall be provided by the energy storage area lighting system.

2.6.13 Receiver Molten Salt Supply and Discharge

The thermal energy storage system shall supply cold salt to the receiver system at the cold salt pump. The receiver shall supply hot salt to the thermal energy storage system. The points of interface are described in Section 1.5, Boundaries.

2.6.14 Salt Sampling and Analysis (SAG)

Provisions shall be provided to enable salt samples to be taken. The locations of these sampling ports are.

1) Auxiliary drain of hot salt storage tank
2) Hot salt pump suction line
3) Auxiliary drain of cold salt storage tank
4) Cold salt pump suction line
5) Salt heater drain
6) Drain sump drain.

The sampling ports shall be 0.025m (1 in.) lines with manually operated valves. The outlet shall be located such that personnel can safely take samples. The samples shall be contained within insulated vessels and be of such volume that all analyses can be performed. The analyses should include measurement of salt composition, carbonate content, hydroxide content, and chromium content. Initially the salt analyses should be performed weekly. Depending on the trends of the contamination buildup, the period between sampling may be extended.

2.6.15 Solar Steam Generator Vents and Drains (SSB)

The SBB drains shall conduct unwanted salt to the thermal energy storage system drain sump. The points where the interfaces occur are described in Section 1.5, Boundaries.

2.6.16 Solar Steam Generator Molten Salt Supply and Discharge (SBC)

The thermal energy storage system shall supply hot salt to the SBB and accept cold salt from it. The points of interface are described in Section 1.5, Boundaries.

2.7 OPERATING CONDITIONS

2.7.1 Operating Temperatures

The storage tanks and associated equipment shall be designed for the following temperatures.

<u>Hot Tank</u>

Operator Point	565.6°C (1050°F)
Maximum Bulk Salt Temperature	571.1°C (1060°F)
Minimum	260.0°C (500°F)
Maximum Inlet Fluid	593.3°C (1100°F)

Cold Salt Storage Tank

Operating Point	276.7°C (530°F)
Maximum Bulk Salt	343.3°C (650°F)
Minimum	243.3°C (470°F)

Drain Sump

Operating Point	565.6°C (1050°F)
Maximum Bult Salt	571.1°C (1060°F)
Minimum	243.3°C (470°F)
Maximum Inlet Fluid	593.3°C (1100°F)

2.7.2 Operating Pressures

Wall/Floor Corner Joint
The main storage tanks shall be designed to withstand a operating pressure of 165.5 kPa (24 psig) at the wall/floor corner joint.

Cover Gas
The main storage tanks shall be designed for a maximum pressure difference between the external ambient air and the internal cover gap of 0.69Pa (0.1 psig). The roof shall be designed for the following loads.

1) Dead weight of roof material
2) Dead weight of roof insulation
3) Live load of 0.7kPa (15 psf)
4) Vacuum load 0.69 kPa (0.1 psig)
5) Piping load

2.7.3 Allowable Heat Loss

The thermal energy storage system shall be designed not to exceed the following heat loss rates for the environmental condition prescribed as the design day (Sec 2.5.1) and the foundation cooling requirements (Sec 3.5.11 and 4.5.11).

Hot Tank

Full (salt at 565.6°C)	200 kWt
Empty (heel only, salt at 565.6°C)	195 kWt

Cold Salt Storage Tank

Full (salt at 276.6°C)	75 kWt
Empty (heel only, salt at 276.7°C)	73 KWt

Drain Sump

Full (salt at 565.6°C)	1 kWt

2.7.4 Charge/Discharge Rates

The thermal energy storage system shall be designed to operate with following charge/discharge rates.

Charge - Thermal Rate	
Design Point	190 MWt
Maximum	209 MWt
Minimum	47.5 MWt
Discharge - Thermal Rate	
Design Point/Maximum	172 MWt
Reduced Load	86 MWt
Minimum	8.6 MWt
Charge - Salt Flow Rates	
Design Point	429 kg/sec (3.406×10^6 lb/hr)
Maximum	472 kg/sec (3.746×10^6 lb/hr)
Minimum	107 kg/sec (0.952×10^6 lb/hr)
Discharge - Salt Flow Rates	
Design Point/Maximum	388.5 kg/sec (3.08×10^6 lb/hr)
Reduced Power	194.3 kg/sec (1.542×10^6 lb/hr)
Minimum	19.4 kg/sec (0.154×10^6 lb/hr)

2.8 REDUNDANCY

The use of redundant components has been limited to those items whose failure could cause a catastrophic failure. The main storage tanks are contained within berms, so that if the tanks were to develop a leak, all of the salt of the plant could be contained. Salt from either the receiver or the SBB can be placed in either the hot or cold salt storage tanks, should the fill line of the opposite tank become plugged. In order to protect the carbon steel shell of the cold salt storage tank, should the hot salt storage tank fill line become plugged, cold salt would be mixed with the hot salt before being drained into the cold salt storage tank. The vent system has rupture disks to relieve the pressure should the vent become plugged.

2.9 FUNCTION CONSTRAINTS

2.9.1 Initial Preheat

Before molten salt can be allowed to enter any of the storage tanks or support equipment, it is necessary to preheat the component. The surfaces to be in contact with the molten salt should be within 25°C (45°F) of the incoming fluids temperature.

2.9.2 Freeze Protection

It is necessary to prevent the molten salt from freezing within the components of the system.

2.9.3 Material Temperature Limits

All of the equipment of the thermal energy storage system shall be designed to operate within specific temperature ranges, specified in the component sizing criteria sections.

2.9.4 Drainability

All components of the system shall be designed to be drainable. This constraint is necessary to prevent residual salt from freezing during periods of nonoperation and making subsequent startup more difficult.

2.10 PHYSICAL CONSTRAINTS

The thermal energy storage system shall be designed to meet the constraints of the site. The environmental conditions are specified in Section 2.5, Natural Phenomena.

2.11 PROCESS CONTROL

The thermal energy storage system shall have sufficient process control to effectively interface with the receiver and solar steam generator. This involves the sensing of key parameters and the control of the valves of the storage subsystem. Further details of these requirements are presented in the Master Control System Division Specification.

The main storage tank must be protected against the possibility of either over or under pressurization. An alarm shall be hooked into the control room and used to warn against potential difficulties. The operator shall have the ability to open the exhaust check valve of the venting system. This would be done if there was reason to believe that there was a malfunction of the inlet to the vent system. The blowers to the inlet system shall be controlled by either the differential pressure sensors of the two tanks or the pump suction or drain line valves. This shall insure that the fan shall be operating whenever makeup air is required.

The salt heater and drain sump shall be controlled from the site and the control room. The loading of prilled salt shall be controlled locally, but the other equipment shall be designed to be controlled locally or remotely. The other items include the heater burner, the agitators, the pumps and the valves.

2.12 TESTING

The testing of the thermal energy storage system shall be in accordance with the recommendations of the API Code 650. In addition to these procedures, extensive testing, both of the raw materials and erected components, shall be done to limit the possibilities of leaks in the storage tanks.

2.13 SAFETY

The thermal energy storage system shall be designed to minimize safety hazards to operating and service personnel, the public, and equipment. Electrical components shall be insulated and grounded. All components with elevated temperatures shall be insulated against contact with or exposure to personnel. Any moving elements shall be shielded to avoid entanglements, and safety override controls/interlocks shall be provided for servicing. The requirements of the Occupational Safety and Health Administration, and the National Fire Protection Association shall be fully satisfied.

3.0 COMPONENT DESIGN CRITERIA--HOT SALT STORAGE TANK

3.1 COMPONENT IDENTIFICATION

1) Component Name - Hot Salt Storage Tank
2) System Code - ESA
3) Purchase Specification - 62.3601

3.2 FUNCTION

The function of the hot salt storage tank is to store the hot salt at 565.6°C (1050°F).

3.3 DESCRIPTION

The hot salt storage tank shall be an insulated right circular vertical cylindrical storage tank. It shall be designed to hold molten salt at 565.5°C (1050°F), nominal. The tank shall have internal and external insulation. The materials shall be sized such that the allowable heat loss requirement (Section 3.5.3) is satisfied and the structural shell is kept below a temperature of 287.8°C (550°F). The internal insulation is protected from the molten salt with a liner made from Incoly 800.

3.4 CODES AND STANDARDS

The hot salt storage tank shall be designed and constructed using the ASME Boiler and Pressure Code Section II, the API Standard 650 for welded steel tank for oil storage, and the ANSI Code for Power Piping-B31.1. These standards will be used as guidelines only, as there are no standards directly applicable for storage tanks operating at 565.6°C (1050°F), nominal.

3.5 SIZING CRITERIA

The design requirements for the hot salt storage tank are presented in the following subsections.

3.5.1 Storage Capacity

Working Capacity - The thermal energy storage system as a unit shall be designed to have a working thermal energy capacity of 688 MWht, based upon the normal operating temperatures (Sec 2.7.1) and the salt properties (Section 9.0).

Containment Volume - The hot salt storage tank shall be designed such that the entire salt inventory can be stored at a temperature of 315.6°C (600°F). The salt inventory includes the salt required for the working capacity, both of the residual salt heels, the receiver salt and the SBB salt. The salt inventory is specified in Section 9.5.

A working volume of 3740 m^3 (132,100 ft^3) is needed to satisfy this requirement. The following dimensions are for the inside of the hot storage tank and are based upon a soil bearing strength of 191.5 KPa (4000 psf). The optimum inside diameter shall be 23.3m (75.3 ft) with an inside height of 9.1m (30 ft).

3.5.2 Operating Temperatures and Pressures

The hot salt storage tank and associated equipment shall be designed for the following temperatures.

Operating Point	565.6°C (1050°F)
Maximum Bulk Salt	571°C (1060°F)
Minimum	260.0°C (500°F)
Maximum Inlet Fluid	593.3°C (1100°F)

The wall/floor corner joint of the storage tank shall be designed to withstand an operating pressure of 165.5 kPa (24 psig). The maximum allowable internal cover gas pressure shall be 0.69 kPa (0.1 psig). The roof shall be designed to support the following loads:

1) Dead weight of the roof material
2) Dead weight of the roof insulation
3) A live load of 0.7 kPa (15 psf)
4) Pipe support loads
5) Vacuum load 0.69 kPa (0.1 psig)

3.5.3 Allowable Heat Loss

The hot salt storage tank shall be designed not to exceed the following heat loss rates for the environmental conditions prescribe as the design conditions (Sec 2.5) and the foundation requirements (Sec 3.5.11).

Full (salt at 565.6°C)	201 kWt
Empty (heel only, salt at 565.6°C)	195 kWt

3.5.4 Charge/Discharge Rates

The thermal energy storage system shall be designed to operate with following charge/discharge rates.

Charge - Thermal Rate (Flow in)

Design Point	190 MWt
Maximum	209 MWt
Minimum	47.5 MWt

Discharge - Thermal Rate (Flow out)

Design Point/Maximum	172 MWt
Reduced Load	86 MWt
Minimum	8.6 MWt

Charge - Salt Flow Rates (Flow in)

Design Point	429 kg/sec (3.406×10^6 lb/hr)
Maximum	472 kg/sec (3.746×10^6 lb/hr)
Minimum	107 kg/sec (0.852×10^6 lb/hr)

Discharge - Salt Flow Rates (Flow out)

Design Point/Maximum	388.5 kg/sec (3.084×10^6 lb/hr)
Reduced Power	194.3 kg/sec (1.542×10^6 lb/hr)
Minimum	19.4 kg sec (0.154×10^6 lb/hr)

3.5.5 Operating Life

The hot salt storage tank shall be designed for a 30 year operating life and a 98% availability. The hot salt storage tank shall be designed to meet the following criteria.

Pressure Cycling (Corner Joint of Shell)	6.9 kPa (1.0 psig) to 165.5 kPa (24 psig) daily for 30 years (10,950 cycles).
Thermal Cycling	426.7°C (800°F) to 565.6°C (1050°F) Daily for 30 Years (10,950 cycles)
	Ambient to 565.6°C (1050°F) Two times a year for 30 years (60 cycles)

3.5.6 Storage Media/Heat Transfer Fluid

The storage media/heat transfer fluid shall be molten salt consisting of 60% $NaNO_3$ and 40% KNO_3 by weight. The salt specification and material properties are defined in Section 12.0.

3.5.7 Residual Salt Heel

There shall be a 0.4m (1.33 ft) salt heel in the hot salt storage tank. The weight of salt required for this purpose should be based upon the design operating temperature.

3.5.8 Ullage Space

The tank shall be designed to provide at least 0.4m (1.33 ft) above the maximum salt level for ullage space.

3.5.9 Tank Fill Lines

The tank fill lines shall be designed to assure that the horizontal salt lines remain full. This shall be accomplished by routing the lines through the top of the tank. A vacuum breaker shall be provided to enable the fill lines to drain. Flow diffusers or other flow spreaders should be specified to insure the flow does not impinge on the tank walls. The following fill lines shall be included:

Purpose	Size
Receiver Outlet	0.304 m (12 in.)
Pump Recirculation	0.204 m (8 in.)
Cold Salt Pump	0.203 m (8 in.)
Vent	0.304 m (12 in.)
Drain Sump Pump	0.076 m (3 in.)
Salt Heater	0.076 m (3 in.)

3.5.10 Tank Drain and Pump Suction Lines

The hot salt storage tank drainlines shall be mounted on the side of the tank. The pump suction lines shall be design to prevent air from being drawn in to the line when the salt is at the residual heel level, and shall not draw salt from the bottom of the tank. The residual salt could contain precipitated impurities and other foreign substances which should not be introduced to the balance of the plant. The tank shall be equipped with anti-vortex devices for the pumping suction lines. The hot storage tank shall have the following drain and pump suction lines:

Purpose	Size
Pump Suction	0.508 m (20 in.)
Drain	0.152 m (6 in.)
Salt Heater	0.102 m (4 in.)

3.5.11 Tank Foundations

Design Requirements - The tank foundations shall be designed to the soil bearing conditions specified in Section 2.5.1.

Foundation Cooling - The foundation shall be water cooled and limit the structural slab temperature to 82°C (180°F), based on the design conditions (Section 2.5.1).

3.5.12 Berms

A berm shall be built around the storage tank and be sized to contain the total salt inventory.

3.5.13 Manholes

The hot salt storage tank shall be equipped with manholes so that the tank interior is accessible for inspection and maintenance.

3.5.14 External Sheathing

The storage tank shall have external sheathing to protect the insulation from the weather. The sheathing shall be designed to the design conditions specified in Section 2.5.1.

3.6 MATERIALS SELECTION

Recommended Metals Which have Contact With Molten Salt (except valves):

Material	Temperature Range
Carbon Steel SA516 GR 70 - plate	Less than 343°C (650°F)
Nickel Alloy (Incoloy 800) - hot salt tank liner	Greater than 343°C (650°F)
Stainless Steel 304 all other applications	Greater than 343°C (650°F)

The internal insulation for the bottom and sides of the tank shall be JM C22Z insulating brick.

4.0 COMPONENT DESIGN CRITERIA-COLD SALT STORAGE TANK

4.1 COMPONENT IDENTIFICATION

1) Component Name - Cold Salt Storage Tank
2) System Code - ESB
3) Purchase Specification - 62.3601

4.2 FUNCTION

The function of the cold salt storage tank is to store the cold salt at 276.7° (530°F), nominal.

4.3 DESCRIPTION

The cold salt storage tank shall be an externally insulated right circular vertical cylindrical tank. A water cooled foundation shall support the tank and be designed to maintain the ground temperature below 82.0°C (180°F). Berms shall be built around the tank to contain the salt should a leak develop.

4.4 CODES AND STANDARDS

The cold salt storage tank shall be designed and constructed in accordance with the American Petroleum Institute Standard 650 for welded steel tanks for oil storage and the ANSI B31.1, Power Piping.

4.5 SIZING CRITERIA

The design requirements for the cold salt storage tank are presented in the following subsections.

4.5.1 Storage Capacity

Working Capacity - The thermal energy storage system shall be designed to have a working thermal energy capacity of 688 MWt, based upon the normal operating temperatures (Sec 2.7.1) and the salt properties (Section 9.0).

Containment Volume - The cold salt storage tank shall be designed such that the entire salt inventory can be stored at a temperature of 315.6°C (600°F). The salt inventory includes the salt required for the working capacity, both of the residual salt heels and the receiver salt and the Solar Steam Generator salt. The amount of salt to meet these requirements is stated in Section 9.5.

A working volume of 3740 m^3 (132,100 ft^3) is needed to satisfy this requirement. The following dimensions are for the inside of the cold storage tank and are based upon the preliminary soil bearing strength. The optimum diameter shall be 23.3m (76.5 ft) and the shell height shall be 9.1m (30 ft).

4.5.2 Operating Temperatures and Pressures

The cold salt storage tank and associated equipment shall be designed for the following temperatures:

Design Point	276.7°C (530°F)
Maximum Bulk Salt	343.3°C (650°F)
Minimum	243.3°C (470°F)
Maximum Inlet Fluid	343.3°C (650°F)

The wall/floor corner joint of the storage tank shall be designed to withstand an operating pressure of 165.5 kPa (24 psig). The maximum allowable internal cover gas pressure shall be 0.69 kPa (0.1 psig). The roof shall be designed to support the following loads:

1) Dead weight of the roof material
2) Dead weight of the roof insulation
3) A live load of 0.7 kPa (15 psf)
4) Pipe support loads
5) Vacuum load 0.69 kPa (0.1 psi)

4.5.3 Allowable Heat Loss

The cold salt storage tank shall be designed not to exceed the following heat loss rates for the design condition (Section 2.5.1).

Full (salt at 276.6°C)	77 MWt
Empty (heel only, salt at 276.7°C)	75 MWt

4.5.4 Charge/Discharge Rates

The cold salt storage tank shall be designed to operate with following charge/discharge rates.

Charge - Thermal Rate (Flow out)

Design Point	190 MWt
Maximum	209 MWt
Minimum	47.5 MWt

Discharge - Thermal Rate (Flow in)

Design Point/Maximum	172 MWt
Reduced Load	86 MWt
Minimum	8.6 MWt

Charge - Salt Flow Rates (Flow out)

Design Point	429 kg/sec (3.406×10^6 lb/hr)
Maximum	472 kg/sec (3.746×10^6 lb/hr)
Minimum	107 kg/sec (0.852×10^6 lb/hr)

Discharge - Salt Flow Rates (Flow in)

Design Point/Maximum	388.5 kg/sec (3.084×10^6 lb/hr)
Reduced Power	194.3 kg/sec (1.542×10^6 lb/hr)
Minimum	19.4 kg sec (0.154×10^6 lb/hr)

4.5.5 Operating Life

The cold salt storage tank shall be designed for a 30 year operating life and a 98% availability. The cold salt storage tank shall be designed to meet the following criteria.

Pressure Cycling (Shell corner joint)	6.9 kPa (1.0 psig) to 165.5 kPa (24 psig) daily for 30 years (10,950 cycles).
Thermal Cycling	260°C (500°F) to 315.6°C (600°F) Daily for 30 Years (10,950 cycles)
	Ambient to 315.6°C (600°F) Two times a year for 30 years (60 cycles)

4.5.6 Storage Media/Heat Transfer Fluid

The storage media/heat transfer fluid shall be molten salt consisting of 60% $NaNO_3$ and 40% KNO_3 by weight. The salt specification and material properties are in the Section 12.0.

4.5.7 Residual Salt Heel

There shall be a 0.4m (1.33 ft) salt heel in the cold salt storage tank.

4.5.8 Ullage Space

The tank shall be designed to provide at least 0.4m (1.33 ft) for ullage space.

4.5.9 Tank Fill Lines

The tank fill lines shall be designed to assure that the horizontal salt lines remain full. This shall be accomplished by routing the lines through the top of the tank. A vacuum breaker shall be provided to enable the fill lines to drain. Flow diffusers or other flow spreaders shall be provided to insure the flow does not impinge on the tank walls. The following fill lines shall be included:

Purpose	Size
SGS Outlet	0.456 m (14 in.)
Pump Recirculation	0.203 m (8 in.)
Receiver Return Line	0.304 m (12 in.)
Vent	0.304 m (12 in.)
Drain Sump Pump	0.076 m (3 in.)
Salt Heater/Reprocessor	0.076 m (3 in.)
Attemperator Pump Recirculation	0.063 m (2.5 in.)

4.5.10 Tank Drain and Pump Section Lines

The drain and pump suction lines of the cold storage tank shall be mounted on the side of the tank. The pump suction lines shall be design to prevent air from being drawn in to the line when the salt is at the residual heel level and shall not draw salt from the bottom of the tank. The residual salt could contain precipitated impurities and other foreign substances which should not be introduced to the balance of the plant. The tank shall be equipped with anti-vortex devices for the pump suction lines. The cold salt storage tank shall have the following drain and pump suction lines:

Purpose	Size
Pump Suction-Primary	0.508 (20 in.)
Attemperator Pump Suction	0.203 (8 in.)
Drain	0.152 (6 in.)
Salt Heater	0.102 (4 in.)

The cold storage tank shall be equipped with an auxiliary drain. It should be designed to facilitate complete draining of the tank. The auxiliary drain and line shall have a diameter of 0.15m (6 in).

4.5.11 Tank Foundations

Design Requirements - The tank foundations shall be designed to the soil bearing conditions specified in Section 2.5.1.

Foundation Cooling - The foundation shall be water cooled and limit the structural slab temperature to 82°C (180°F), based on the design conditions (Section 2.5.1).

4.5.12 Berms

A berm shall be built around the cold storage tank and be sized to contain the total salt inventory.

4.5.13 Manholes

The cold salt storage tank shall be equipped with manholes so that the tank interior is accessible for inspection and maintenance.

4.5.14 External Sheathing

The storage tanks shall have external sheathing to protect the insulation from the weather. The sheathing should be designed to the conditions specified in Section 2.5.1.

4.6 MATERIALS SELECTION

Recommended Materials Which have contact with molten salt (except valves):

Material	Temperature Range
Carbon Steel SA516 GR 70 - plate	Less than 343°C (650°F)
Stainless Steel 304 all other applications	Greater than 343°C (650°F)

5.0 COMPONENT DESIGN CRITERIA--MOLTEN SALT DRAINAGE SUMP

5.1 COMPONENT IDENTIFICATION

1) Component Name - Molten Salt Drainage Sump
2) System Code - ESC
3) Purchase Specification - 62.3601

5.2 FUNCTION

The function of the drainage sump is to accept the salt from within the solar steam generator heat exchanger during an emergency. The sump shall also be used to melt prilled salt during the initial startup of the plant. This function shall be accomplished by blending prilled salt with hot salt from the receiver.

5.3 DESCRIPTION

The drainage sump shall be an externally insulated stainless steel tank located below ground level. An agitator and prilled salt loading chute shall be included to facilitate the loading and melting of the prilled salt. A pump shall be used to drain the sump.

5.4 CODES AND STANDARDS

The drainage sump shall be designed and constructed using the ASME Boiler and Pressure Code and the ANSI Code for Power Piping-B31.1. The drain sump shall be designed as a pressure vessel operating at 565.6°C (1050°F).

5.5 SIZING CRITERIA

The design requirements for the drainage sump are presented in the following subsections.

5.5.1 Storage Capacity

The drainage sump shall be capable of storing 63,500 kg (140,000 lb) of hot salt. This shall permit the heat exchangers and interconnecting piping to be completing drained into the sump. This results in a minimum working volume of 37 m^3 (1300 ft^3).

5.5.2 Operating Temperatures

The drainage sump and associated equipment shall be designed for the following temperatures:

Design Point	593.3°C (1100°F)
Maximum Bulk Salt	571 C° (1060°F)
Minimum	260 C° (500°F)
Maximum Inlet Fluid	593.3°C (1100°F)

Under normal operating conditions the sump shall be maintained at a temperature between 371.1°C (700°F) and 426.7°C (800°F). Hot salt shall be bled into the sump for this purpose.

5.5.3 Allowable Heat Loss

The drainage sump shall be designed to have an allowable heat loss of 1 KWt when it is full. The environmental requirements are those prescribed for the design conditions (Section 2.5.1).

5.5.4 Operating Life

The drainage sump shall be designed for a 30 year operating life and a 98% availability. The sump shall meet the following criteria:

Thermal Cycling	371.1°C (700°F) to 565.6°C (1050°F) Once a month for 30 years (360 cycles)

5.5.5 Storage Media/Heat Transfer Fluid

The storage media/heat transfer fluid shall be molten salt consisting of 60% $NaNO_3$ and 40% KNO_3 by weight. The salt specification and material properties are in Section 12.0.

5.5.6 Fill Lines

The fill lines to the drainage sump shall have the following diameters:

SBB Drain lines (3)	0.305 m (12 in)
SBB Return line	0.102 m (4 in)
SBB Hot supply line	0.102 m (4 in)
SBB Cold supply line	0.076 m (3 in)

5.5.7 Drain Line

The sump drain line shall be capable of carrying 63,500 kg/hr (140,000 lb/hr).

5.5.8 Drain Sump Pump

The sump pump shall be capable of draining the full sump in a one hour period. This shall require a flow rate of 63,500 kg/hr (140,000 lb/hr).

5.5.9 Trace Heating

Trace heating shall be provided which is able to heat the empty sump up to a temperature of 260°C (500°F) in a two day period.

5.5.10 Agitator

The drainage sump shall be equipped with an agitator to ensure that the prilled salt is thoroughly mixed in the hot salt during the melting process.

5.5.11 Prilled Salt Load Chute

The drainage sump shall be equipped with a loading chute to facilitate the melting of prilled salt. The chute shall be designed to handle 8.2 kg/sec (63,000 lb/hr) of prilled salt.

5.5.12 Sump Foundation

The sump foundation shall be designed to the soil bearing conditions specified in Section 2.5.1.

5.5.13 Salt Spillage

The sump shall be located below grade level. The concrete retaining wall will contain any salt spillage.

5.5.14 Manhole

The sump shall be equipped with a manhole to provide access for maintenance and inspections.

5.5.15 External Sheathing

The sump shall have external sheathing to protect the insulation from the weather. The sheathing should be designed to the environmental conditions specified in Section 2.5.1.

5.6 MATERIALS SELECTION

Recommended metals which have contact with molten salt (except valves):

Material	Temperature Range
Carbon Steel SA516 GR 70 - plate	Less than 343°C (650°F)
Stainless Steel 304 - all other applications	Greater than 343°C (650°F)

6.0 COMPONENT DESIGN CRITERIA--SALT PREPARATION (HEATER)

6.1 COMPONENT IDENTIFICATION

1) Component Name - Molten Salt Fossil Heater
2) System Code - ESD
3) Purchase Specification - 62.4401

6.2 FUNCTION

The salt heater shall be used to melt prilled salt and to supply thermal energy to the system during extended shutdowns.

6.3 DESCRIPTION

The salt heater shall be a fossil-fired heater capable of melting prilled salt and heating molten salt to 565.6°C (1050°F).

6.4 CODES AND STANDARDS

The salt heater shall be designed to meet the requirements of the ANSI Power Piping Code (B31.1), the National Environmental Policy Act (NEPA 10CFR1021) and the National Fire Protection Code.

6.5 SIZING CRITERIA

6.5.1 Thermal Rating

The salt heater shall have a design thermal rating of 1.5 MWt (5 x 10^6 BTU/hr)

6.5.2 Fuel Supply

The heater shall be designed to operate on natural gas.

6.5.3 Salt Heater Pump

The salt heater pump shall be capable of a normal flow rate of 9.5 kg/sec (75,000 lb/hr).

6.5.4 Prilled Salt Loading Chute

The salt heater shall be equipped with a load chute which is capable of delivering 1.6 kg/sec (12,900 lb/hr).

6.5.5 Salt Agitators

The salt heater shall be equipped with two agitator to mix the prilled and molten salt, and to promote forced convection heat transfer.

6.6 MATERIALS SELECTION

Material	Temperature Range
Stainless Steel 304	565.6°C (1050°F)

7.0 COMPONENT DESIGN CRITERIA--MOLTEN SALT STORAGE TANK VENTING

7.1 COMPONENT IDENTIFICATION

1) Component Name - Molten Salt Storage Tank Venting
2) System Code - ESE
3) Purchase Specification - 62.3601

7.2 FUNCTION

The venting system shall allow the cover gas to be exchanged between the hot and cold storage tanks during either charging or discharging. Excess or makeup gas shall be exchanged with the atmosphere through the venting system. The venting system shall protect against over- or under-pressurization. The make up air shall be passed through a molecular sieve to remove excess water vapor and carbon diocede.

7.3 DESCRIPTION

The venting system shall be a duct connecting the hot and cold storage tanks. There shall be a vent or discharge port as well as a makeup port. The discharge port shall be check valve allowing flow out of the system only. The excess air will be passed through a recuperative heat exchanger. The energy gained will be used to purify the sieve. The makeup air shall be passed through a molecular sieve. Small fans shall be used to blow the air through this sieve due to the low pressure drop requirements of the system. Two full flow fans shall be used to provide redundancy. The venting system shall be equipped with rupture disks, one each at the two storage tanks. The rupture disks shall be on separate penetration from the vent system.

7.4 CODES AND STANDARDS

The venting system shall be designed to meet the requirements of the Occupational Safety and Hazard Act (OSHA) and the National Environmental Policy Act (NEPA 10CFR1021).

7.5 SIZING CRITERIA

The venting system shall be sized to accommodate a maximum air flow rate of 0.28% m^3/sec (600 ft^3/min). The maximum makeup air flow rate shall be 0.093 m^3/sec (200 ft^3/min). The system shall be designed for a maximum pressure drop of 0.35 kPa (0.05 psig). Based upon these requirements a duct diameter of 0.304 m (12 in) has be established for design purposes. The rupture disks should be designed to burst for pressure differences between the tank and the atmosphere of 0.70 kPa (0.10 psig).

7.6 MATERIAL SELECTION

The venting system shall be fabricated from 304 stainless steel.

8.0 COMPONENT DESIGN CRITERIA--MOLTEN SALT REPROCESSING

8.1 COMPONENT IDENTIFICATION

1) System Name - Molten Salt Reprocessing
2) System Code - ESF
3) Purchase Specification - 62.4402

8.2 FUNCTION

The salt reprocessor shall not be installed at the time the plant is built. Should a problem with the salt purity develop, the salt reprocessor shall be installed.

The molten salt reprocessor shall be used to remove contaminants which build up in the salt. The salt reprocessor shall operate independently of the main salt pumps. The reprocessor shall be installed when there is sufficient contaminant to warrant the expenditure.

8.3 DESCRIPTION

The salt reprocessor shall be a chemical reactor in which gaseous nitrogen dioxide is bubbled through the molten salt. The carbonate and hydroxide ions react with the nitrogen dioxide to form nitrate ions and carbon dioxide or water, respectively. A scrubber is used to absorb any unreacted nitrogen dioxide.

8.4 CODES AND STANDARDS

The salt reprocessing system shall be designed to meet the requirements of the Occupational Safety and Hazards Act (OSHA) and the National Environmental Policy Act (NEPA 10 CFR1021). The reactor shall be design to the requirements detailed in the ASME Boiler and Pressure Vessel Code Section VII.

8.5 SIZING CRITERIA

The salt reprocessor shall be of sufficient size to readily purify the salt inventory in a 6 month period. The necessary flow rate shall be determined by the size of the reactor vessel and the residence time required for the chemical reaction.

8.6 MATERIALS SELECTION

Material	Temperature Range
Carbon Steel SA516 GR 70 - plate	Less than 343°C (650°F)
Stainless Steel 304 - all other applications	Greater than 343°C (650°F)

9.0 COMPONENT DESIGN CRITERIA--ENERGY STORAGE SALT

9.1 COMPONENT IDENTIFICATION

1) System Name - Energy Storage Salt
2) System Code - ESH
3) Purchase Specification - 65.1001

9.2 FUNCTION

The salt acts as the heat transfer fluid and storage media for the solar portion of the plant.

9.3 DESCRIPTION

The salt shall consist of 60% $NaNO_3$ and 40% KNO_3 by weight.

9.3.1 Salt Purity

The salt shall meet the following purity requirements at the time it is introduced into the system.

Specifications

Component	Minimum, %	Maximum, %
$NaNO_3$	59	61
KNO_3	39	41
NaCl		0.30
Na_2SO_4		0.30
SiO_2		0.02
Al_2O_3		0.025
Fe_2O_3		0.025
Insolubles		0.06
Na_2CO_3		0.15
CaO		0.00045
MgO		0.00045

9.3.2 Salt Properties

The salt shall be used in the liquid or molten state. It shall operate over the temperature range of 277°C (530°F) to 566°C (1050°F). The properties of the molten salt are presented in Table 9.1.

Table 9.1 Molten Salt Properties

Composition: 60% $NaNO_3$, 40% KNO_3 by weight

Heat Capacity

C_p = 1532 watt sec/kg - °C
C_p = 0.366 Btu/lb °F

Density f(T)

$p = 2102.6 - 0.6684T$ kg/m^3 for T in °C
$p = 132.0 - 0.02318T$ lb/ft^3 for T in °F

Viscosity f(T)

$= 1.885 \times 10^{-2} - 9.610 \times 10^{-5}T + 1.799 \times 10^{-7} T^2 - 1.155 \times 10^{-10} T^3$ Pa sec, T in °C

$= 49.89 - 0.1379T + 1.389 \times 10^{-4} T^2 - 4.790 \times 10^{-8} T^3$ lb/fr hr, T in °F

Thermal Conductivity

$K = 0.06705 (T+273.15)^{0.326}$ watts/m-°C, T in °C
$K = 0.0320 (T+459.67)^{0.326}$ Btu/hr-ft-°F, T in °F

Melting/Freezing Temperature Range

221 to 245°C
429 to 473°F

Heat and Fusion

$H_f = 1.089 \times 10^5$ watt sec/kg
$H_f = 46.8$ x Btu/lb

9.4 CODES AND STANDARDS

The handling of the prilled salt shall meet the requirements of the Occupational Safety and Hazards Act (OSHA).

9.5 SIZING CRITERIA

The molten salt inventory of the plant is 7,079,591 kg (15,607,565 lb). This is made up from the following requirements:

COMPONENT	SALT WEIGHT	
Working Capacity	5,592,800 kg	(12,330,000 lb)
Hot Salt Storage Tank Heel	285,700 kg	(629,800 lb)
Cold Salt Storage Tank	313,500 kg	(691,200 lb)
Piping	716,793 kg	(1,580,231 lb)
Receiver	137,692 kg	(303,554 lb)
Evaporator	14,527 kg	(32,027 lb)
Preheater	14,464 kg	(31,887 lb)
Superheater	4,022 kg	(8,866 lb)
Total	7,079,591 kg	(15,607,565 lb)

In addition to the salt in the system, 3% of the total inventory is stored for makeup.

10.0 COMPONENT DESIGN CRITERIA--SALT DRY STORAGE AND HANDLING

10.1 COMPONENT IDENTIFICATION

1) System Name - Salt Dry Storage and Handling
2) System Code - BME
3) Purchase Specification - 65.1001

10.2 FUNCTION

The dry storage capability shall be used to store makeup salt for the system. Suitable handling equipment shall be available to transport the salt from the storage area to either the salt heater or the drain sump.

10.3 DESCRIPTION

The dry storage area shall be able to contain 210,000 kg (462,000 lb) of prilled salt. The prilled salt has a density of 1201 kg/m^3 (75 lb/ft^3). The handling equipment shall consist of:

1) Forklift or front end loader
2) Loading chute
3) Portable screw auger

10.4 CODES AND STANDARDS

The requirements of the National Environment Policy Act (NEPA 10CFR1021) shall be met.

10.5 SIZING CRITERIA

The handling equipment shall be sized to load salt into either the salt heater or drain sump at a maximum rate of 8.2 kg/sec (63,000 lb/hr).

10.6 MATERIALS SELECTION

The prilled salt handling equipment requires no special material over that of plain carbon steel, normally used in the manufacture of the necessary equipment.

11.0 COMPONENT DESIGN CRITERIA--MOLTEN SALT PIPING, VALVES AND INSULATION

11.1 COMPONENT IDENTIFICATION

1) Component Name - Molten Salt Piping, Valves, and Insulation
2) Component Code - ESA, ESB, ESC, ESD
3) Purchase Specification - 62.7201,2; 2408,9; 3802-3810; 72.0201;0403

11.2 FUNCTION

The piping will provide flow paths between components of the previously noted systems and to other interfacing systems. The valves will isolate the flow paths as necessary to control the flow of molten salt. The insulation will limit the heat losses from the piping and valves to maintain system efficiency and prevent freezing of the salt.

11.3 DESCRIPTION

All piping, valves, and insulation associated with the storage tank instrumentation, the molten salt drainage system, and the salt makeup system will be included.

11.4 CODES AND STANDARDS

The piping will be designed in accordance with the requirements of the ANSI Power Piping Code B31.1. The valves will be in accordance with the requirements of ANSI B16.34.

11.5 SIZING CRITERIA

The piping and valves will be sized to provide reasonable velocities and prevent freezing of the molten salt. Pipe wall thickness and valve pressure class will be selected based on system design pressure and temperature plus a suitable margin. All salt piping will have a nominal diameter not smaller than 25mm (1"). Piping wall thickness for 51mm (2") and smaller pipe will be in accordance with the following.

Carbon steel pipe	-	Sch 80 minimum
Stainless steel pipe	-	Sch 40S minimum

Insulation thickness will be in accordance with the following.

Operating Temperarture	Pipe Size	Insulation Thickness
427°C (801°F) to	38 mm (1.5") and smaller	102 mm (4")
556°C (1050°F)	51 mm (2") - 102 mm (4")	102 mm (4")
	127 mm (5") - 203 mm (8")	127 mm (5")
	254 mm (10") and larger	229 mm (9")

Operating Temperarture	Pipe Size	Insulation Thickness
261°C (501°F) to 427°C (800°F)	38 mm (1.5") and smaller	76 mm (3")
	51 mm (2") - 102 mm (4")	89 mm (3.5")
	127 mm (5") - 254 mm (10")	102 mm (4")
	305 mm (12") and larger	229 mm (9")
149°C (301°F) 261°C (500°F)	51 mm (2") and smaller	76 mm (3")
	64 mm (2.5") and larger	89 mm (3.5")
66°C (150°F) to 148°C (300°F)	254 mm (10") and smaller	38 mm (1.5")
	305 mm (12") and larger	64 mm (2.5")

11.6 MATERIALS SELECTION

Salt piping with design temperatures of 468°C (875°F) and above shall be type 304 stainless steel. Salt piping with design temperatures between 353°C (650°F) and 468°C (875°F) shall be ASTM A335 Grade P22 alloy steel. Salt piping with design temperatures below 343°C (650°F) shall be ASTM A106 Gr B carbon steel.

Salt valves in piping with design temperatures of 468°C (875°F) and above shall be stainless steel. Salt valves in piping with design temperatures between 343°C (650°F) and 468°C (875°F) shall be alloy steel. Salt valves in piping with design temperatures below 343°C (650°F) shall be carbon steel.

Insulation will be calcium silicate with aluminum jacketing.

12.0 COMPONENT DESIGN CRITERIA--ENERGY STORAGE INSTRUMENTATION

12.1 COMPONENT IDENTIFICATION

1) Component Name - Energy Storage Instrumentation
2) Component Code - ESA, ESB, ESC, ESD, ESE
3) Procurement Specification - 62.3601; 64.0601,2; 1001-1006; 1202,3; 1205; 72.0201

12.2 FUNCTION

To monitor the critical variables in the thermal energy storage system.

12.3 DESCRIPTION

The thermal energy storage system shall be fitted with all instrumentation and backup systems necessary to monitor the temperature of the tanks contents, monitor the tanks shell temperatures, monitor internal liner leakage and monitor tanks ullage space pressures. Appropriate alarms shall be included as noted.

12.3.1 Level Sensors

Two independent air bubbler level sensor systems with automatic density compensation shall be provided to monitor the two main tanks during filling and draining operations. Both systems shall utilize the same set of two open ended stainless steel pipes penetrating the top of the tank and running to the tank bottom. One pipe shall stop 0.1m (4") from the liner level, and the other tube shall stop 0.3m (12") from the liner level. Suitable electronic and mechanical equipment, located in a weathertight enclosure located on the tank roof, shall be provided to determine salt density and tank level by measuring the air pressure required to displace the salt in the tubes. The drain sump and salt heaters shall be equipped with similar level gages.

12.3.2 Temperature Monitors

The temperature of the shells of the two main storage tents shall be monitored with 50 thermocouples each. They shall be distributed through out the sides, roof and floor of the tank.

To monitor the temperature of the salt stored in the tanks, two temperature rakes, each consisting of ten thermocouples positioned at 1 meter intervals and contained in a 25 mm (1") diameter stainless steel tube, shall be provided.

The tubes shall be inserted in a fixed perforated stainless steel pipe, supported by structure welded to the tank fill piping. The tubes shall extend from just above the liner at the tank bottom to above the suspended deck level, and a stuffing box with wire seals shall be provided at the suspended deck penetration. Design shall be such that the tubes can be withdrawn and replaced without shut down and cool down of the storage tank. The tube shall be perforated as required to allow access to the thermocouples for installation. Leads shall be grouped together and run through a common nozzle at the tank roof.

The drain tank and salt heater shall be equipped with 15 thermocouples each. Five of the thermocouples shall be used to monitor the salt temperature. The remaining 10 shall be used to monitor the tank structure. The heater shall have an additional 10 thermocouples to measure the temperature of the burner tube.

12.3.3 Leak Detectors

The liner of the hot salt storage tank shall be equipped with leak detectors. The leakage shall be deflected by the thin stainless foil placed between the liner and the insulating fire brick, and run down the wall to the tank bottom. At the tank bottom, collection trays pressed into the foil in recesses in the brick shall be fitted with conductance probes. Twenty leak detection sensors shall be fitted in the tank bottom, with leads grouped together and run through a thermocouples lead nozzle in the tank roof to a weathertight junction box at the tank roof.

12.3.4 Pressure Monitoring

The Hot Storage Tank is configured such that three separate spaces are present: the tank, the tank attic , and the insulation space between the liner and the steel shell. The attic and insulation spaces are made common by means of internal piping connections.

The tank ullage pressure is monitored by means of a pressure transducer located on the external portion of the 10" vent piping. A local reading pressure gage is also included at this location.

The tank attic pressure is monitored by means of a pressure transducer and local reading pressure gage located at the tank roof. The two transducers are connected to a differential pressure controller, with adjustable set points to alarm on insulation space high pressure, tank high pressure, tank high differential pressure, and insulation space low differential pressure (tank vacuum).

The cold salt storage tank shall be equipped with differential pressure sensors. Adjustable set points are used to alarm of high or low differential pressures.

5.0 Solar Steam Generator Specification

MCR-82-643

SOLAR STEAM GENERATOR SPECIFICATION

PRELIMINARY DESIGN ENGINEERING SERVICES
FOR SOLAR REPOWERING OF THE
SAGUARO POWER PLANT

Revision 2
August 1983

Martin Marietta Corporation
Denver Division
Denver, Colorado 80201

Prepared for Arizona Public Service Company
Phoenix, Arizona
Under Subcontract No. RD82-6732

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SOLAR STEAM GENERATOR SPECIFICATION

1.0 SYSTEM DESCRIPTION

1.1 SYSTEM IDENTIFICATION

1) Category Name — Solar Steam Generation
2) Category Code — SB-

1.2 FUNCTION

The function of the Solar Steam Generator is to transfer energy from molten nitrate salt to water/steam for subsequent use in a turbine-generator for the purpose of electrical power generation.

1.3 PROCESS DESCRIPTION

The Solar Steam Generator uses molten salt (60% $NaNO_3$, 40% KNO_3 by weight) as a heat transfer fluid and storage medium. The Solar Steam Generator is a forced recirculation system employing a separate preheater, evaporator, superheater, and steam drum. Separate superheater, and evaporator components are mandated by the recirculating system. A separate preheater results in a more economic utilization of the total heat transfer surface. The heat exchangers are horizontally oriented with both salt and water nozzles arranged to facilitate venting and draining.

At design conditions, hot salt at 566°C (1050°F) will be pumped from the hot salt storage tank to the superheater where saturated steam is heated to 541°C (1006°F) (see Figure 1-1). The steam temperature will be controlled by mixing cold salt with the hot salt at the inlet of the superheater. The temperature of the salt entering the superheater is 560 ± 3°C (1040 ± 5°F) after attemperation.

Salt then leaves the superheater, mixes with more cold salt (277°C, 530°F) and enters the evaporator. The addition of the cold salt ensures maintaining the evaporator salt inlet temperature below the maximum use temperature of the evaporator material (468°C, 875°F) during both steady-state and transient operation. The line from the salt attemperation pump to the superheater inlet also is used to reduce temperature gradients during plant startup. Steam generated in the evaporator enters the steam drum where separation takes place. Saturated dry steam goes to the superheater while saturated water, mixed with subcooled water from the preheater, is recirculated to the evaporator inlet. A circulation ratio of 1.5 is sufficient to prevent DNB. As the two evaporator recirculation pumps operate at constant speed, the water flow through the evaporator is nearly independent of steam generator duty or feedwater flow. A 1% blowdown from the steam drum has been assumed for design purposes.

Salt leaves the evaporator and enters the preheater at 331°C (627°F). Boiler feedwater is heated to 313°C (596°F) and piped to the steam drum. Feedwater comes from the high pressure feedwater heater at 197°C (387°F) and it is mixed with 317° (602°) water from the preheater recirculation pump. This increases the water temperature to 238°C (460°F) before entering the preheater thus preventing solidification of salt on the preheater tubes. This temperature is maintained as the power level is reduced by increasing the recirculation ratio to feedwater flow (30% power is the minimum operating level). This offsets the reduction in feedwater temperature from the feedwater heaters as load is reduced. In the event of an upset condition where feedwater temperature would fall, the control system could further increase the recirculated flow through the preheater to maintain approximately a 266°C (510°F) preheater salt outlet temperature.

The Solar Steam Generator consists of the following major components:

- Preheater;
- Evaporator;
- Steam drum;
- Evaporator water recirculating and preheater recirculating pumps, piping, and valves;
- Superheater;
- Hot salt pumps;
- Startup desuperheater;
- Salt, feedwater, and steam piping and valves;
- Cold salt attemperation pump;
- Thermal insulation and trace heating;
- Foundations, component structural supports, and access platforms;
- Controls and instrumentation.

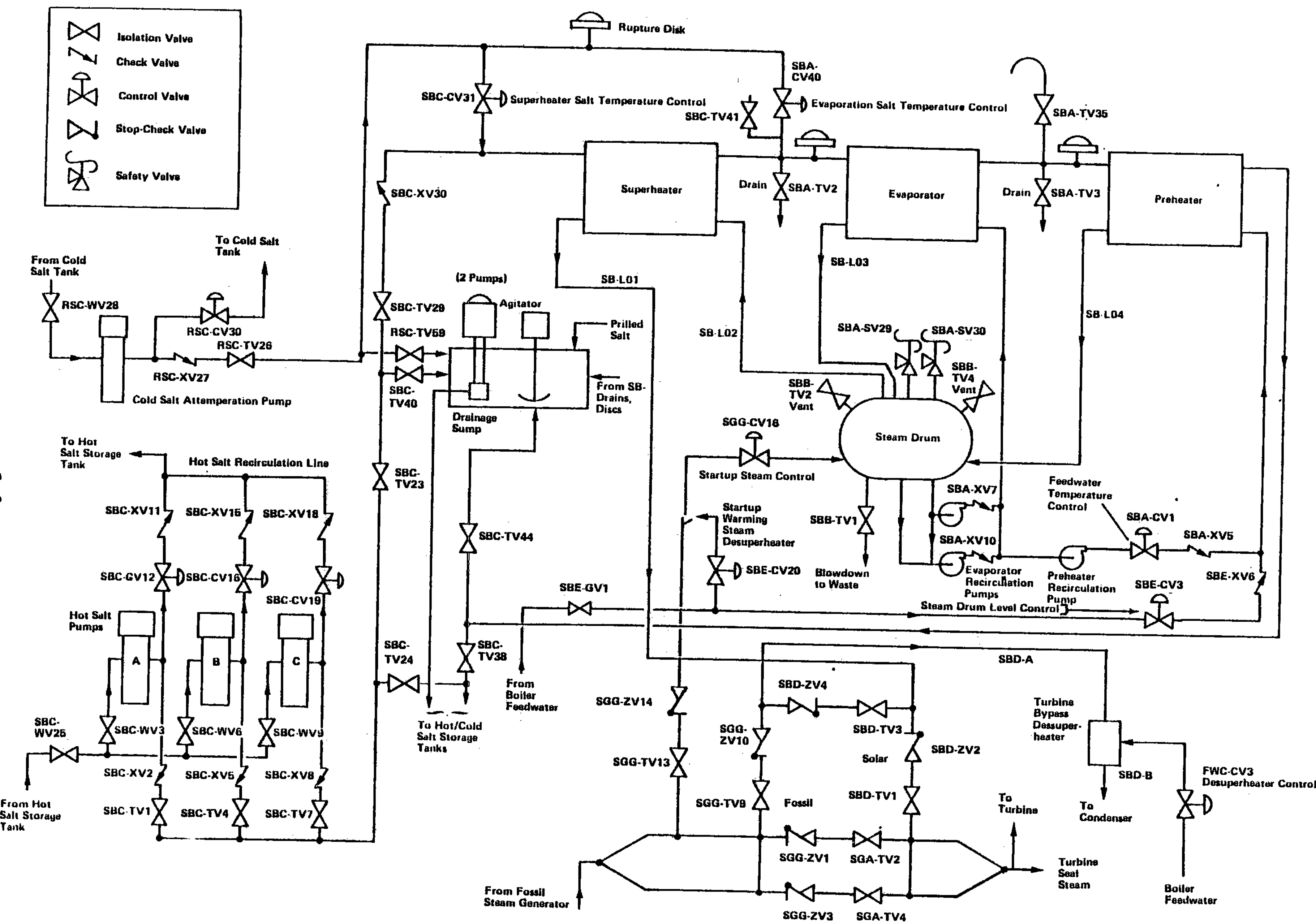

Figure 1-1 Solar Steam Generator Flow Schematic

1.4 INTERFACING SYSTEMS

Systems which have a significant interface with the Solar Steam Generator are listed on Table 1-1.

Table 1-1 Interfacing Systems

System	System Code
AC Power Supply (120V/208V)	APA
AC Power Supply (480V)	APB
AC Power Supply (2,400V)	APC
AC Power Supply (4160V)	APD
Essential Service AC (Inverter)	API
Instrument Air	CAB
Master Control System	COG
Condensing	HRA
Water Freeze Protection	EEA
Grounding and Lightning Protection	EEB
Raceway	EEC
Salt Freeze Protection	EEE
Boiler Feedwater	SBE
Solar Steam Cycle Chemical Feed	FWG
Solar Steam Generator Area Fire Protection	FPH
Fossil Fuel Boiler Main Steam	SGG
Solar Steam Generator Area Lighting	LTK
Receiver Molten Salt Supply and Discharge	RSC
Hot Salt Storage Tank	ESA
Cold Salt Storage Tank	ESB
Turbine Seals and Drains	TGC
Salt	ESH

1.5 BOUNDARIES

The system boundaries of the Solar Steam Generator can be determined from valve designations shown on Figure 1-1.

1.6 DEFINITION OF TERMS AND ABBREVIATIONS

1.6.1 Definition of Terms

<u>Desuperheater</u> - Apparatus for reducing the temperature of a superheated vapor to saturated conditions.

<u>Fouling</u> - The process of forming an encrusting layer which may be permeable or impermeable on the tube walls due to precipitation of dissolved and suspended solids from the fluids or due to the chemical reaction of the tube wall material with that of the fluids.

Turndown Ratio - The ratio of the total thermal power transmitted from the salt system to the steam water system at specified full load power to that transmitted at the lowest load at which the system operates under fully automatic control.

Operating - SOLAR STEAM GENERATOR producing steam.

Standby - Heat exchangers full on the water/steam side; cold salt circulation used to maintain temperature.

Empty - Both salt and water sides drained for extended shutdown.

1.6.2 Abbreviations

CR - Circulation Ratio;

DNB - Departure from Nucleate Boiling;

NDE - Non-Destructive Examination;

TBD - To Be Determined;

2.0 SYSTEM DESIGN CRITERIA

2.1 SUPPORTIVE DOCUMENTATION

The supportive documentation for the system criteria is as follows.

1) Sagauro Solar Repowering Preliminary Design Subsystem Interface Definition Document, MCR-82-639 MMC.
2) Sagauro Solar Repowering System Codes, MMC.

2.2 CODES AND STANDARDS

In addition to this specification, the equipment, materials, design, and construction of the Solar Steam Generator shall comply with all federal, state, local and user standards, regulations, codes, laws, and ordinances currently applicable at the power plant site. These shall include, but not be limited to, the government regulatory and non-government documents listed below. If there is an overlap in, or conflict between, the requirements or these documents and the applicable federal, state, county, or municipal codes, laws, or ordinances, the applicable requirement which is the most stringent shall take precedence.

2.2.1 Non-Government Documents

- Uniform Building Codes - 1982 Edition by International Conference of Building Officials
- ASME Boiler and Pressure Vessel Code
- Institute of Electrical and Electronic Engineers (IEEE) Standards as applicable
- National Fire Protection Association (NFPA) National Fire Design, Construction and Fabrication Standards
- Standards of ACI (American Concrete Institute)
- Standards of TEMA (Tubular Exchanger Association)
- Standards of ASTM (American Society of Testing Materials)
- Standards of NEMA (National Electrical Manufacturers Association)

- Standards of ICEA (Insulated Cable Engineers Association)
- Standards of AISC (American Institute of Steel Construction)
- ANSI B31.1 - Power Piping
- ANSI A58.1 - Building Code Requirements for Minimum Design Loads in Buildings and Other Structures -1982 Edition
- ANSI B16.34 - Steel Valves, Flanged and Buttwelding Ends.

2.3 REGULATORY REQUIREMENTS

2.3.1 Specifications

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

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

2.3.2 Standards

- Applicable Human Engineering Design Criteria

2.4 QUALITY LEVEL CLASSIFICATION - TBD

2.5 NATURAL PHENOMENA

Operating Requirements - The system shall be capable of operating in and surviving appropriate combinations of the following environments:

2.5.1 Design Point Conditions

6.77 kPa (2.0 in Hga) turbine back pressure

2.5.2 Design Point Environmental Conditions

Dry bulb temperature: 39°C (102°F)
Wet bulb temperature: 21°C (69°F)
Atmospheric pressure: 94.2 kPa (27.82 in. Hga)
Wind speed: 3.5 m/s (7.8 mph)
Wind direction: 135° (Southeast)

2.5.3 Receiver Tower Location: Longitude - 111°17'10.9"W, Latitude - 32°33'8.6"N, Base Elevation - 593 m (1945 ft) AMSL

2.5.4 Soil Bearing Strength: 191.6 kPa (4000 psf) (preliminary)

2.5.5 Annual Average Daily Direct Insolation: 6.90 kWh/m^2-day

2.5.6 Maximum Wind Speeds [at 10 m (33 ft) elevation]

Operational: 15.6 m/sec (35 mph)
Survival: 33.5 m/sec (75 mph)

2.5.7 Seismic Zone: UBC Risk Zone 2

2.5.8 Earthquake Ground Acceleration: 0.1 g

2.5.9 Temperature Extremes: -7 to 46°C (20 to 115°F)

2.5.10 Dust Devils

Dust devils with wind speeds up to 17 m/s (38 mph) shall be survived without damage to the plant.

2.5.11 Snow

The plant shall survive a static snow load of 250 Pa (5 lb/ft^2) and a snow deposition rate of 0.3 m (1 ft) in 24 hours.

2.5.12 Rain

The plant shall survive the following rainfall conditions:

Average Annual	-	340 mm (13.4 in.)
Maximum 24-hr rate	-	75 mm (3 in.)

2.5.13 Ice

The plant shall survive freezing rain and ice deposits in a layer 25 mm (1 in.) thick.

2.5.14 Sandstorm Environment

The plant shall survive after being exposed to flowing dust comparable to the conditions described by Method 510 of MIL-STD-810C.

2.5.15 Lightning Considerations

All electrical equipment enclosures, the energy storage tanks, horizontal piping and various points of the salt/steam heat exchanger subsystem shall be bonded to earth using ground straps and earth driven ground rods.

2.5.16 Water Quality Standards

The plant shall comply with the National Pollution Discharge Elimination Standards. The addition of the solar system should not affect that compliance.

2.6 INTERFACING SYSTEMS

The interface description and applicable criteria to be met at the interface boundary between the SOLAR STEAM GENERATOR and the systems are listed.

2.6.1 AC Power Supply (120/208/480V/2400V) (APA-C)

The AC Power Supply is used for instrumentation, valve motor operators, and smaller motors.

2.6.2 AC Power Supply (4160V) (APD)

The 4160 V power supply is used for the molten salt pumps and other large pumps.

2.6.3 Essential Service AC (Inverter) (API)

Valves and instrumentation of major importance are connected to the Essential Service AC power source for uninterrupted service.

2.6.4 Instrument Air (CAB)

The Solar Steam Generator shall interface with the Instrument Air System at the instrument air connections on all pneumatic control and instrumentation devices.

2.6.5 Master Control System (COG)

The Solar Steam Generator control system shall provide the capability to accept commands from and transmit data to the plant Master Control System. The COG will provide the capability for control of the total plant including emergency control.

2.6.6 Condensing (HRA)

Wet steam from the startup desuperheater is delivered to the condenser when the turbine by-pass is used during the Solar Steam Generator startup sequence. The steam is routed to a connection on condenser 1A.

2.6.7 Water Freeze Protection (EEA)

Water/steam piping shall be heat traced to avoid freezing during prolonged periods in the standby mode.

2.6.8 Grounding and Lightning Protection (EEB)

The Solar Steam Generator shall interface with the Grounding and Lightning Protection System at the grounding connections of pump motors and motor-operated valves.

2.6.9 Raceway (EEC)

The Raceway System supports the power supply and control cables.

2.6.10 Salt Freeze Protection (EEE)

Salt piping and salt sumps shall be heat traced to avoid freezing during prolonged periods in the standby mode.

2.6.11 Boiler Feed (FWA)

Feedwater for the Solar Steam Generator shall be taken from a tee connection in the existing 0.254m (10 in) main feedwater line between the high pressure feedwater heater and the S-65 flow meter.

Feedwater is bled off the high pressure side of the boiler feedwater pumps to be used in the startup desuperheater.

2.6.12 Solar Steam Generator Area Fire Protection (FPH)

Provision for fire protection of the Solar Steam Generator shall be provided.

2.6.13 Fossil Fuel Main Steam (SGG)

Superheated Solar Steam Generator steam will be introduced into the existing system via tee connections in the two existing 0.254m (10 in) main steam lines between the S-12 flow meters and the hogging ejector tap. Block valves shall be installed in each of the main steam lines and crossover piping between the two main steam lines that shall be provided upstream and downstream of the main steamline block valves.

2.6.14 Solar Steam Generator Area Lighting (LTK)

Lighting shall be provided according to OSHA regulations.

2.6.15 Receiver Molten Salt Supply and Discharge (RSC)

The Solar Steam Generator interface is upstream of control valve SBA-CV6 where the cold salt attemperation line is located.

2.6.16 Hot Salt Storage Tank (ESA)

The Solar Steam Generator interface with the hot salt tank is downstream of the hot recirculation control valves in the hot salt pump recirculation loop. A second interface occurs at the inlet of the drain sump.

2.6.17 Cold Salt Storage Tank (ESB)

The Solar Steam Generator interface with the cold salt tank is at the termination of the cold salt return line.

2.6.18 Turbine Seals and Drains (TGC)

Dry superheated steam is bleed off near the inlet of the turbine stop valve to be used for gland sealing.

2.6.19 Salt (ESH)

Molten salt circulates through the heat exchangers. Properties of molten salt are shown on Table 2-1

2.7 INTERFACE OPERATING CONDITIONS

2.7.1 Maximum Gross Electrical Power at 6.77 kPa (2.0 in. Hg a) Backpressure: 120.985 MWe

Turbine Cycle Conditions are:

Valves wide open
Throttle Steam flow 126 kg/sec (1.00×10^6 lb/hr)
Throttle pressure 10 MPa (1450 psig)
Throttle temperature 538°C (1000°F)

Design Repowering Level:	66.1 MWe (gross)
Turbine Cycle Conditions are:	Backpressure 6.77kPa (2.0 in Hg a) Throttle Steam Flow 65.0 kg/sec (515.8×10^3 lb/hr) Solar Steam Generator Outlet Steam Flow 65.7 kg/sec (521.0×10^3 lb/hr) Feedwater Flow 66.3 kg/sec (526.2 lb/hr) Throttle pressure 10 MPa (1450 psig) Throttle temperature 538° C (1000° F)

Table 2-1 Properties of Molten Salt

Composition: 60% $NaNO_3$, 40% KNO_3 by weight

Heat Capacity

C_p = 1532 watt sec/kg - °C
C_p = 0.366 Btu/lb °F

Density f(T)

$p = 2102.6 - 0.6684T$ kg/m^3 for T in °C
$p = 132.0 - 0.02318T$ lb/ft^3 for T in °F

Viscosity f(T)

$\mu = 1.886x10^{-2} - 9.610x10^{-5}T + 1.799x10^{-7} T^2 - 1.155x10^{-10} T^3$ Pa sec, T in °C

$\mu = 49.89 - 0.1379T + 1.389x10^{-4} T^2 - 4.790x10^{-8} T^3$ lb/ft hr, T in °F

Thermal Conductivity

$K = 0.06705 (T+273.15)^{0.326}$ watts/m-°C, T in °C

$K = 0.0320 (T+459.67)^{0.326}$ Btu/hr-ft-°F, T in °F

Melting/Freezing Temperature Range

221 to 245°C
(429 to 473°F)

Heat of Fusion

$\Delta H_f = 1.089x10^5$ watt sec/kg
ΔH_f = 46.8 Btu/lb

2.7.2 Turbine Throttle Steam

Nominal temperatures at 6.77 kPa (2.0 in. Hg a)

Gross Power Level MWe	Throttle Steam Temperature °C (°F)	
	Fossil Only	Solar Only
120	537.8 (1000)	-
100	* TBD	-
80	TBD	-
66	---	537.8 (1000)
60	TBD	537.8 (1000)
40	TBD	537.8 (1000)
30	TBD	537.8 (1000)

NOTE: For combined operation an approximate throttle steam temperature is the steam flow weighted average of the fossil and solar steam temperatures. A more exact calculation would use enthalpies rather than temperatures for the averaging.

Nominal throttle pressure: 10.0 MPa $\pm$ 138 kPa (1450 psig $\pm$ 20 psi)

2.7.3 Steam flowrates at 6.77 kPa (2.0 in Hg a) backpressure.

Gross Power Level MWe	Throttle Steam Flowrate - kg/s (1000s lb/hr)	
	Fossil Only	Solar Only
120	125.9 (1000.0)	---
100	TBD	---
80	TBD	---
66	---	65.0 (515.8)
60	TBD	TBD
40	TBD	TBD
30	TBD	31.7 (251.5)

NOTE: For combined operation the total throttle steam flowrate is equal to the sum of the flowrates from the fossil and solar steam generators.

* TBD's will be determined early in the Final Design Phase.

2.7.5 Feedwater Temperature at 6.77 kPa (2.0 in. Hg a) Backpressure.

Gross Power Level MWe	Feedwater Temperature °C (°F)	
	Fossil Only	Solar Only
120	233 (451)	---
100	TBD	---
80	TBD	---
66	---	197 (387)
60	TBD	TBD
40	TBD	TBD
30	TBD	163 (326)

NOTE: For combined operation, an approximate final feedwater temperature can be obtained by adding TBD to the fossil only feedwater temperature corresponding to the combined throttle steam flowrate. (See paragraph 2.7.8.) A detailed heat balance is required for an accurate determination of final feedwater temperature.

2.7.6 Gross Heat Rate at 6.77 kPa (2.0 in. Hg a) Backpressure.

Gross Power Level MWe	Gross Heat Rate MWe/MWt (Btu/kWh)	
	Fossil Only	Solar Only
120	0.385 (8868)	---
100	TBD	---
80	TBD	---
66	---	0.3826 (8921)
60	TBD	TBD
40	TBD	TBD
30	TBD	0.3402 (10031)

NOTE: For combined operation, an approximate gross heat rate can be obtained by starting with the fossil only gross heat rate corresponding to the combined throttle steam flowrate and then adding a temperature correction. The temperature correction is:

TBD

An approximate generator gross power can then be calculated from the enthalpies corresponding to the throttle steam and final feedwater approximate temperature and pressure conditions, the throttle steam flowrate and the approximate gross heat rate.

A more accurate determination of gross heat rate and generator gross power would require that a detailed heat balance be performed.

2.7.7 Allowable Pressure Variation

The steam pressure at the turbine main steam valve shall average not more than 1522 psi gage over any 12 month operating period. In maintaining this 12 month average, the pressure shall not exceed 1595 psi gage except during abnormal conditions when the pressure may swing momentarily to 1885 psi gage but the aggregate duration of such swings shall not exceed 12 hours per 12 month operating period.

2.7.8 Allowable Temperature Variations

The steam temperature at the turbine main steam valve shall average not more than 1000°F over any 12 month operating period. In maintaining this average, the temperature shall not exceed 1015°F except during abnormal conditions resulting in temperatures not in excess of 1025°F for operating periods not more than 400 hours per 12 month operating period nor 1050°F for swings of 15 minutes duration or less, aggregating not more than 80 hours per 12 month operating period.

2.7.9 Solar Steam Generator Water/Steam Pressure Drop Allocations (psia), 66.1 MWe

Unit	Salt	P (psi) Water/Steam
Preheater	12	5
Evaporator	29	10
Superheater	50	70
Interconnecting Piping		
SH to Evap.	12	—
Drum to SH	—	10
Evap. to PH	4	—
PH to Drum	—	7

1) Reference elevation may be taken as ground level at solar steam generator site.

2) 1 psi = 6.895 KPa.

3) Excluding static head effects.

2.7.10 Solar Steam Generator Interface Salt Flowrates

<u>Design Point Load</u> (new system, 172.5 MWt))

Hot Salt -	389.6 kg/s (3.093×10^6 lb/hr)
Superheater Cold Salt Attemperation -	11.85 kg/s (9.400×10^4 lb/hr)
Evaporator Cold Salt Attemperation -	53.58 kg/s (4.250×10^5 lb/hr)

<u>Reduced Load</u> (89.3 MWt power level)

Hot Salt	201.8 kg/s (1.601×10^6 lb/hr)
Superheater Cold Salt Attemperation	12.44 kg/s (9.87×10^4 lb/hr)
Evaporator Cold Salt Attemperation	151 kg/s (1.198×10^6 lb/hr)

<u>Salt Temperature Variation</u>

From storage to solar steam generator:	$566 \,^{+6}_{-17}$ °C ($1050 \,^{+10}_{-30}$ °F)
From solar steam generator to storage:	277 ± 11 °C (530 ± 20 °F)

2.7.11 Operating Life

The Solar Steam Generator components shall be designed for a 30 year operating life.

2.7.12 Water Quality

Preliminary water quality standards are identified in Table 2-2.

Table 2-2 Water Quality Standards

Boiler Water Chemistry:	pH--9.5-10.0 PO_4--4-6ppm Silica<2.0 ppm Chlorides--0 T.D.S.--Typically less than 50 ppm
Condensate/Feedwater:	pH--8.8-9.2 Cation Conductivity--0.5 micromhos Dissolved Oxygen--10 ppb N_2H_4--10-30 ppb at economizer inlet Fe & Cu<10ppb

2.7.13 Turndown Ratio

The steam generator subsystem shall be capable of operating in fully automatic control at part load conditions ranging from 30 to 110% of the rating specified under 3.1.1 during automatic control, and between 10 and 30% with manual control.

2.7.14 Operating Modes

The steam generator subsystem shall be capable of functioning in the following operating modes and transitions, within the constraints specified herein as applicable to specific modes:

Empty - Both salt and water side drained for extended shutdown.

Empty to Standby Transition

This operation entails filling of the salt and water sides of the heat exchangers with the respective heat transfer fluids, and establishing flow through the salt side from and to the cold salt tank. Constraints:

- Freezing of salt, including the formation of dispersed solid particles shall be prevented by insuring that the salt side surfaces of the heat exchangers are at least 20°C (36°F) above the freezing point 238°C (or 460°F) from start of salt fill throughout the operation;

- Entrapment of air pockets on the salt and water sides of the heat exchangers shall be prevented.

Standby - The Solar Steam Generator temperature is maintained above the freezing point of the salt by recirculating salt from and to the cold salt tank, in combination with heat tracing and insulation, as required. Constraints:

- Heat loss from the salt to the environment and to the water/steam side of the Solar Steam Generator by the combined mechanisms of conduction, convection, and radiation shall be minimized, and shall not exceed 0.1% of the rated capacity of the Solar Steam Generator.

Standby to Operating Transition: - This transient entails: (1) raising the water/steam side temperature and pressure of the evaporator to saturation levels; (2) raising the salt side temperatures of the evaporator and superheater to water side saturation levels or above; (3) establishing water/steam flow; (4) establishing hot salt flow (from the hot tank); (5) establishing controlled operation at design set-point conditions (with automatic control). Constraints:

- Salt temperatures in the evaporator and preheater shall not exceed the limits established to prevent material corrosion;

- A startup desuperheater shall be included in the system to cool the superheated steam leaving the Solar Steam Generator to lower temperature steam during this transient, before it is routed to the condenser;

- It shall be a design objective to minimize the quantity of hot salt required to accomplish this transient.

Operating - This mode includes all steady state operation at the conditions specified under 2.7. Normal operation shall be accomplished with either manual or automatic control.

Load Changes - The Solar Steam Generator shall be compatible with load changes of 10% of rated capacity per minute, between 30 and 110% of rating during automatic control and between 10 and 30% with manual control.

Operating to Standby Transition: - This operation requires the capability of controlled reduction of steam and salt flow from normal operating levels to zero, while maintaining steam drum temperatures and pressures at saturation levels. Constraints:

- Salt temperatures in the evaporator in preheater shall not exceed safe limits established to prevent material corrosion.

Standby to Empty Transition - This operation requires the capability of insulation of the Solar Steam Generator flow paths from the other subsystems of the power plant, and complete drainability of both water/steam and salt sides.

2.7.15 Shutdown from Emergency or Upset Conditions

The steam generator subsystem shall be capable of safe, controlled shutdown resulting from upset and emergency conditions due to any of the following:

Turbine trip;
Loss of feedwater flow;
Loss of salt flow;
Break of any water/steam/salt pipe;
Indication of water-to-salt leak;
Loss of pneumatics;
Control system failure;
Loss of all station power
(some emergency power required).
Emergency Drain

2.8 REDUNDANCY

Redundancy has been incorporated into the Solar Steam Generator in the following areas:

Hot Salt Pumps - Two out of three pumps can maintain full flow in the steam generator.

Cold Salt Attemperation Pump - In case of failure of the cold salt attemperation pump, the cold salt pumps can be used to supply cold salt to the Solar Steam Generator by opening control valve RSC-CV34.

Evaporator Recirculation Pumps - One out of two pumps can maintain partial flow in the evaporator.

2.9 FUNCTIONAL CONSTRAINTS

2.9.1 Thermal/Hydraulic Design

The components in the Solar Steam Generator shall be designed to satisfy the following thermal/hydraulic requirements:

Fluid Velocities - The mass velocities of the water, water/steam, or steam shall be maximized, within pressure drop constraints, to develop efficient heat transfer and minimize surface requirements. Salt side velocities shall also be maximized within limits necessary to preclude tube vibration.

DNB - The evaporator circulation ratio shall be established sufficiently high to preclude departure from nucleate boiling (DNB).

Mixing - The heat exchanger components shall be designed to promote mixing of the molten salt and inhibit any tendency of the salt to stratify.

Subcooling in the Evaporator Downcomer - Sufficient subcooling will be provided in the downcomer to prevent flashing during transient operation.

Fouling - Component design shall consider the fouling on the salt side to be negligible. Water side fouling resistances are:

Preheater - 0.00002m^{-o}C/watt (.0001hr^{-o}F-ft^2/Btu);

Evaporator - 0.00002m^{-o}C/watt (.0001hr^{-o}F-ft^2/Btu);

Superheater - 0.0000m^{-o}C/watt (.000hr^{-o}F-ft^2/Btu);

Temperature Control Design Margin - The design salt superheater inlet temperature is 560 ± 3°C (1040 ± 5°F). The anticipated inlet temperature for a new system is 557°C (1035°F). A mature system with the entire fouling margin consumed would have a salt inlet temperature of 563°C (1045°F).

Flow Induced Vibration - Flow induced vibration frequencies shall be safely below resonant frequencies at flow rates up to 110% of rated capacity.

2.9.2 Compatibility with Molten Salt Operation

Freeze and Thaw Considerations

- The Solar Steam Generator shall be designed to handle salt in the liquid phase only.

- The design and operation of the Solar Steam Generator shall be such as to prevent incipient or bulk freezing of the salt in any and all parts of the subsystem.

- Local thawing shall not be relied on as a practical means of correcting a freeze-up situation in the Solar Steam Generator components. The melting of the salt mixture results in a significant increase in salt specific volume, thus creating the potential for failure of closed containers.

- Should salt freeze-up occur, heat tracing shall be provided to thaw the salt, with isolation valves open to permit thermal expansion.

Heat Tracing - Heat tracing shall be provided to meet the requirements of Paragraph 2.7.

- The heat tracing subsystem shall use electric power as an energy source.

- The minimum preheat temperature for all trace heated surfaces of the Solar Steam Generator system which contact the molten salt is 260°C (500°F). The trace heating subsystem shall be designed to provide this minimum temperature prior to Solar Steam Generator system start-up.

- Provisions shall be made to disconnect the power to electrical trace heaters when (1) this heating is no longer needed due to established molten salt flow or (2) the trace heating subsystem would experience temperatures above its maximum operating limit if left on.

- Provisions shall be made to monitor the Solar Steam Generator component and piping metal temperatures adjacent to the trace heating subsystem heating elements.

2.10 PHYSICAL CONSTRAINTS

2.10.1 General Requirements

The following requirements shall be met in designing the steam generator components:

- Heating surfaces must be oriented to promote efficient heat transfer and hydraulic stability of the heating fluid and steam/water mixture;

- Materials must be selected to provide adequate strength and corrosion/erosion resistance in the operating environment;

- Uniform distribution of flow to all heating surfaces must be assured;

- Sufficient flexibility must be provided for the U-tubes to preclude high stresses resulting from differential thermal expansion;

- Tube supports must be arranged to prevent potential damage resulting from flow-induced and machinery-induced vibration;

- Quality weld configurations and weld inspection standards must be provided to assure pressure boundary integrity;

- Access must be provided for inspection and corrective maintenance;

- The vessel must be capable of being fully drained and vented.

2.10.2 Structural Design

The following structural design requirements shall apply:

Pressure Boundaries - Pressure boundaries will be designed to meet applicable codes.

Supports - Component supports and restraints shall be designed to account for deadweight, seismic loads, operating loads, live loads, wind loads, snow loads, and ice loads.

Differential Expansion - Sufficient flexibility for differential thermal expansion shall be provided between tubes in the tube bundle so that the nominal stress in the tube bends will be in the elastic range.

Pressure Relief - Provisions shall be made for salt side pressure relief in the event of a heat exchanger tube leak.

Test Conditions - The Solar Steam Generator components shall be pressure tested as defined by the ASME Code on both salt and water/steam sides.

2.10.3 Molten Salt Component Design/Selection

- Valves shall be of the drainable type.

- Salt pumps shall be of the multistage turbine, canned type.

- Flanges shall be of the raised faces flange or ring joint type where possible.

2.11 PROCESS CONTROL

Control of the steam generator components is accomplished by the Master Control System. The Master Control System will provide the capability for manual or automatic start-up , normal operation, and shutdown of the equipment, as well as collecting data. The Master Control System will also issue emergency shutdown commands whenever critical process parameters exceed allowable operating limits.

2.11.1 Temperature and Pressure Control

- The superheated steam temperature is controlled by attemperating the hot 566°C (1050°F) salt entering the superheater with cold 277°C (530°F) salt. The superheater salt attemperator valve controls the flow of cold salt for mixing. The temperature of the steam exiting the superheater is set at 541°C (1006°F) during steady state operation. The temperature of the salt entering the superheater is used as the feedback term to drive the valve.

- The variable speed pumps control the salt-flow to the evaporator and are therefore used to control the pressure of the supply steam.

- The evaporator salt attemperator valve controls the flow of cold salt for mixing with the salt from the superheater. The temperature of the salt entering the evaporator is used as the feedback term to drive the valve such that the salt into the evaporator does not exceed 452°C (845°F).

- The feedwater supply valve controls the flow of the water supply. A load-following feedforward term is used along with a feedback term correcting the fluid level in the drum;

- The preheater water recirculation valve is used to ensure that the temperature of the preheater water supply does not fall below a specified value 238°C (460°F) high enough to limit local salt temperatures within the tube bundle to a safe minimum above the salt freezing point. As with the evaporator salt attemperator, temperature feedback of the water entering the preheater is used to generate the error signal.

2.11.2 Requirements

- The control system shall control the salt and steam systems in a safe and reliable condition under all modes of operation. Components/circuits shall have high reliability with redundancy incorporated where necessary to provide safe and reliable operation.

- Manual operation of the Solar Steam Generator will be possible during all operational modes. All control panel parameter displays and alarms will be easily read with all manual controls arranged for ease of operation. The following capabilities shall be available to the operator:

  1. Capacity to change set points;
  2. Display of system parameters and alarms;
  3. Capability to accomplish start-stop and on-off functions.

- Automatic control shall be possible during all operational modes except start-up and shut-down. The control system shall provide overall subsystem control and integration in the automatic mode.

- During start-up, the Solar Steam Generator will be capable of a load increase of 2 to 3% of rated capacity per minute. When a preprogrammed sequence is followed, the control system will keep the operator apprised of the status of the start-up. The operator can interrupt the automated sequence at any point and complete the start-up manually. The system shall be capable of load changes between 30 and 110% of rated capacity automatically, and down to 10% with manual operation.

- The control system shall monitor critical equipment parameters and operating conditions of the Solar Steam Generator. Upon detection of an abnormal condition which would compromise the safety of personnel or integrity of equipment, the control system will trigger an emergency shutdown of the system.

2.12 TESTING

Pressure vessels shall be hydrostatically tested in accordance with ASME Code requirements.

2.13 SAFETY

The Solar Steam Generator shall be designed to minimize safety hazards to operating and service personnel, the public, and equipment. Electrical components shall be insulated and grounded. All components with elevated temperatures shall be insulated against contact with or exposure to personnel. Any moving elements shall be shielded to avoid entanglements, and safety override controls/interlocks shall be provided for servicing. The requirements of the Occupational Safety and Health Administration, and the National Fire Protection Association shall be fully satisfied.

3.0 COMPONENT DESIGN CRITERIA-SOLAR STEAM GENERATOR

3.1 COMPONENT IDENTIFICATION

1) Category Name	Solar Steam Generation
2) Category code	SB-
3) System Name	Solar Steam Generator
4) System Code	SBA
5) Purchase Specification	62.3401

3.2 FUNCTION

The solar steam generator receives feedwater of 216°C (420°F) and produces superheated steam at 541°C (1006°F).

3.3 DESCRIPTION

The Solar Steam Generator consists of the preheater, evaporator, superheater, steam drum, evaporator recirculation pumps, and preheater recirculation pump. All salt/steam heat exchangers use a horizontal U-tube/U-shell configuration. A forced recirculation cycle using two recirculation pumps is employed in the evaporator. The superheater steam outlet temperature is controlled by means of attemperation of the hot salt entering the superheater with cold salt.

3.4 CODES AND STANDARDS

3.4.1 Design Quality Assurance

The supplier shall establish and implement procedures required to assure that design, fabrication, inspection, and testing activities are planned and conducted in accordance with the requirements of applicable codes and this specification. Records shall be maintained in accordance with ASME code requirements.

3.4.2 ASME Code Classification and Stamping

The steam generator subsystem components shall be designed and fabricated to Section VIII Division 1 of the ASME Code. Supplemental requirements for creep fatigue analysis will be developed as necessary.

3.4.3 Certification

Marking and certification of pressure vessels shall conform with ASME Code requirements.

3.5 SIZING CRITERIA

3.5.1 Operating Conditions

Table 3-1 lists the design point operating conditions for the Solar Steam Generator components.

Table 3-1 Operating Conditions

Heat Exchanger Transfer Rates at Design Point:

Description	Rate, MWt
Superheater	50.5
Evaporator	84.4
Preheater	37.6
TOTAL	172.5

Molten Salt Temperatures:

Description	In	Out
Superheater	560 ± 3°C (1040±5°F)	475 ± 3°C(887±5°F)
Evaporator	452 (845)	331 (627)
Preheater	331 (627)	277 (530)

Water/Steam Temperatures:

Description	Temperature °C (°F) In	Out
Superheater	322 (611)	541 (1006)
Evaporator	317 (602)	522 (611)
Preheater	238 (460)	313 (596)

Molten Salt Flowrates:

Description	Flowrate kg/sec (lb/hr)
Superheater	401.5 (3.187×10^6)
Evaporator	455.0 (3.612)
Preheater	455.0 (3.612)

Water/Steam Flowrates:

Description	Flowrate kg/sec (lb/hr)
Superheater	65.7 (521,000)
Evaporator	99.6 (789,000)
Preheater	96.4 (764,000)

3.5.2 Design Temperatures and Pressures

Table 3-2 lists the design temperatures and pressures for the Solar Steam Generator components for both water/steam and molten salt sides of each unit.

Table 3-2 Design Pressures and Temperatures

Molten Salt Temperatures:

	°C	(°F)
Superheater	579	(1075)
Evaporator	482	(900)
Preheater	370	(700)

Water/Steam Temperatures:

	°C	(°F)
Superheater	579	(1075)
Evaporator	482	(900)
Preheater	370	(700)
Steam Drum	482	(900)

Molten Salt Pressures:

	kPa	(psia)
Superheater	1310	(190)
Evaporator	1310	(190)
Preheater	1310	(190)

Water/Steam Pressures:

	kPa	(psia)
Superheater	12411	(1800)
Evaporator	12411	(1800)
Preheater	12411	(1800)
Steam Drum	12411	(1800)

Seismic Loads - 0.1g in lateral direction (based on UBC Zone 2).

Piping Loads - Maximum loads to be based on geometry at nozzle terminal.

3.5.3 Water Recirculation Pumps

Evaporator Water Recirculation Pumps - The main evaporator water recirculation pumps shall be vertical wet motor pumps designed specifically for boiler circulating water service. The pumps circulate water from the steam drum through the evaporator and back to the drum. Two half capacity pumps shall be provided each with a total developed head sized to overcome the piping and evaporator friction and static losses plus a suitable design margin. Each pump shall have a capacity of 115.6 l/s (1750 gpm). Pump head shall be 15.24m (50 ft).

Preheater Recirculation Pump

The preheater recirculaiton pump shall be a vertical wet motor pump designed specifically for bolier circulating water service. The pump takes evaporator recirculation pump discharge and pumps it to a pressure adequate to be used for feedwater temperature control. The pump shall have a capacity of 49.56 l/s (750 gpm). Pump head shall be 6.10m (20 ft).

3.6 MATERIALS SELECTION

Materials shall be selected for manufacture of the Solar Steam Generator components that meet the strength requirements of ASME Section VIII Division 1 as well as offering the corrosion resistance necessary in the operating environment. Materials selected for the Solar Steam Generator components are identified in Table 3-3.

Table 3-3 Steam Generator Component Materials

COMPONENT	ENVIRONMENT	MAXIMUM OPERATING TEMPERATURE		MATERIALS
Preheater	Salt/Water	336°C	637°F	Carbon Steel;
Evaporator	Salt/Water-Steam	448	838	2 1/4 Cr-1 Mo
Superheater	Salt/Steam	566	1050	304 Stainless Steel
Steam Drum	Water-Steam	336	636	Carbon Steel

Based on these material selections, the following allowances shall be made for corrosion (Table 3-4).

Table 3-4 Corrosion Allowances

	Carbon Steel		2 1/4 Cr-1Mo		304 Stainless Steel	
Corrosion	mm	in	mm	in	mm	in
Salt Side	0.233	0.009	0.91	0.036	0.15	0.006
Water/Steam Side	0.28	0.011	0.41	0.016	0.10	0.004

3.6.1 Fabrication Process

The components of the steam generator subsystem shall be completely shop welded, assembled, stress relieved, pressure tested, and ASME Code stamped. Pressure testing may be performed as either a shop or field procedure but must precede Code stamping.

Heat Treatment - The need for heat treating after forming operations shall be evaluated and if necessary, temperature, hold times, and heat up and cooldown rates in heat treatment procedures specified.

Surface Finish - The finish of surfaces subject to non-destructive examination shall be in accordance with ASME Code requirements. Unless otherwise determined by the supplier, all other surfaces shall be acceptable in the "as-formed" condition. Gross surface irregularities in pressure boundary material, such as dents or gouges, shall be ground to a smooth contour and shall not violate minimum wall thickness requirements.

Welding - Welding materials used for fabricating shall comply with the requirements of the ASME Code Section VIII, Section IX and applicable welding procedures.

Cleanliness - Care shall be taken to prevent unnecessary contamination of surfaces by dirt producing operations such as machining and grinding. Surfaces to be welded shall be clean and free of scale, rust, oil, grease, and other foreign material. Equipment shall be suitable for installation at the user's site without additional cleaning.

Spare Parts/Tooling - A list of spare parts for operation shall be developed. The list of spare parts to be stocked at the site shall include those parts and tools likely to be damaged or expended during delivery and/or operation.

Shipping and Handling - Shipping rigs and/or containers shall be provided to secure and protect components during shipment to the user's site. Open nozzles shall be sealed with temporary plugs or caps.

3.6.2 Structural Components

The structure in which the system components are located shall be designed in accordance with the AISC Manual of Steel Construction (Eighth Edition) and ACI Standard 318-77 (Building Code Requirements for Reinforced Concrete); this structure will be designed to make cost effective use of space, considering component size and weight, as well as potential seismic and wind loads.

3.6.3 Solar Steam Generator Component Insulation

The Solar Steam Generator components shall have .229 m (.75ft) of insulation.

4.0 COMPONENT DESIGN CRITERIA - SOLAR STEAM GENERATOR VENTS AND DRAINS

4.1 COMPONENT IDENTIFICATION

1) Category Name	Solar Steam Generation
2) Category Code	SB-
3) System Name	Solar Steam Generator Vents and Drains
4) System Code	SSB
5) Purchase Specification	62.2202, 62.3401, 72.0201, and 72.0403

4.2 FUNCTION

The function of the solar steam generator vents and drains will be to relieve pressure or to remove the molten salt and water/steam from the Solar Steam Generator in a safe and orderly manner both in the normal transition from standby to empty mode and during an emergency condition. Water/steam drains are also used when filling the system during startup.

4.3 DESCRIPTION

The salt side of the Solar Steam Generator including heat exchangers, interconnecting piping, valves, and fittings shall be drainable. The Solar Steam Generator shall be designed such that the system will drain to the sump by gravity alone. Salt drain lines will be provided from the inter-connecting piping to the salt drain sump. Salt-side pressure relief is required to prevent over-pressurization in the event of a heat exchanger tube leak. Salt drain lines shall be provided from the hot salt delivery, cold salt attemperation, and cold salt return lines to the drain sump.

The water/steam lines shall also be drainable. Pressure relief valves shall be provided for the steam drum in the event of an over-pressure condition. The steam drum blowdown line shall be used to drain excess water off during start-up and to drain the steam drum in the transition to the empty mode.

4.4 CODES AND STANDARDS

The supplier shall establish and implement procedures required to assure that design, fabrication, inspection, and testing activities are planned and conducted in accordance with the requirements of applicable codes and this specification. Records shall be maintained in accordance with code requirements.

Gate and globe valves as applicable, shall meet with code requirements of ANSI B16.34.

4.5 SIZING CRITERIA

Burst disc drain lines from the steam generator components to the salt drain sump shall be adequate to quickly dispense a sudden charge of salt and steam. All other salt drain lines shall be sized according to capacity. The drain path shall be carefully laid out with due consideration to the boundary layer flow phase. Drain lines shall have a minimum slope of 1 cm/m. The drain path shall be insulated, and provided with trace heating that is not adversely affected by a subsystem or station power failure. Drain valves shall be equipped with manual override capability, so that they can be opened in case of power or control system failure.

4.6 MATERIALS SELECTION

Salt piping with design temperatures of 468°C (875°F) and above shall be type 304 stainless steel. Salt piping with design temperatures between 343°C (650°F) and 468°C (875°F) shall be ASTM A335 Grade P22 alloy steel. Salt piping with design temperatures below 343°C (650°F) shall be ASTM A106 Gr B carbon steel. Pipe wall thickness shall be selected based on design pressure plus a suitable margin. Salt valves in piping with design temperatures of 468°C (875°F) and above shall be stainless steel. Salt valves in piping with design temperatures between 343°F (650°F) and 468°C (875°F) shall be alloy steel. Salt valves in piping with design temperatures below 343°C (650°F) shall be carbon steel.

Material selection for water/steam applications will generally be based on the design temperature and service conditions in accordance with the following.

- Carbon steel piping materials will be used for design temperatures less than or equal to 399°C (750°F).

- 1-1/4 percent chromium alloy steel piping materials will be used for design temperatures greater than 399°C (750°F) and less than or equal to 510°C (950°F).

- 2-1/4 percent chromium alloy steel piping materials will be used for steam and water service with design temperatures greater than 510°C (950°F).

5.0 COMPONENT DESIGN CRITERIA - SOLAR STEAM GENERATOR MOLTEN SALT SUPPLY AND DISCHARGE

5.1 COMPONENT IDENTIFICATION

1)	Category Name	Solar Steam Generation
2)	Category Code	SB-
3)	System Name	Solar Steam Generator Molten Salt Supply and Discharge
4)	System Code	SBC
5)	Purchase Specification	62.2202, 62.2409, 62.2601, 62.2609, 62.3602, 62.3803, 62.3806, 62.3807, 62.3808, 62.3809, 64,0601, 64.0602, 64.1001, 64.1203, 72.0201, and 72.0403

5.2 FUNCTION

The function of the solar steam generator molten salt supply and discharge system is to deliver hot salt from the hot salt storage tank to the Solar Steam Generator and return the cold salt to the cold salt storage tank.

5.3 DESCRIPTION

Hot salt is drained from the hot salt tank by gravity to the hot salt pumps. In the hot salt sump, 2 out of 3 hot salt multistage turbine canned pumps draw a total of 389.6 kg/s ($3.093x10^6$ lb/hr) of hot salt and pump it to the superheater inlet. At the same time cold salt is pumped from the cold salt sump to the superheater and evaporator inlets by the cold salt attemperation pump. The cold salt is mixed with the hot salt to maintain a 560 ± 3°C (1040 ± 5°F) superheater inlet temperature and a 452°C (845°F) evaporator inlet temperature. After the salt exists the preheater, it is returned to the cold salt tank.

5.4 CODES AND STANDARDS

Piping shall be designed in accordance with the requirements of the Code for Pressure Piping ANSI B31.1 -- Power Piping. Gate and globe valves, as applicable shall meet the code requirement of ANSI B16.34.

5.5 SIZING CRITERIA

5.5.1 Hot Salt Pumps

Table 5-1 lists the operational requirements of the hot salt pumps.

Table 5-1 Hot Salt Pumps Requirements

Fluid	Molten Salt -	(60% $NaNO_3$ 40% KNO_3)
Operating Temperature	566°C	1050°F
Density	1726 kg/m^3	107.7 lb/ft^3
Viscosity	1.16 x 10^{-3}Pa sec	2.782 lb/ft hr
Design Point Flowrate	389.6 kg/sec	3.093 x 10^6 lb/hr
Reduced Load 89.3 Mwt power level)	201.8 kg/s	1.601 x 10^6 lb/hr
Discharge Pressure	1.85 MPa	267.5 psig
Suction Pressure	0 MPA	0 psig

5.5.2 Cold Salt Attemperation Pump

Table 5.2 lists the operational requirements of the cold salt attemperation pump.

Table 5-2 Cold Salt Attemperation Pump Requirements

Fluid	Molten Salt -	(60% $NaNO_3$ 40% KNO_3)
Operating Temperature	277°C	530°F
Density	1918 kg/m^3	119.7 lb/ft^3
Viscosity	3.59 x 10^{-3}Pa sec	8.69 lb/ft hr
Design Point Flowrate	65.43 kg/s	5.190x10^5 lb/hr
* Reduced Load 89.3 MWt power level)	163.5 kg/s	1.297x10^6 lb/hr
Discharge Pressure	2.08 MPA	300.9 psig
Suction Pressure	0 MPA	0 psig

* Maximum Flowrate

5.5.3 Salt Piping, Valves, Trace Heating, and Insulation

Pipe wall thickness shall be selected based on design pressure plus a suitable margin. Pipe size shall be selected based on providing reasonable fluid velocities and pressure loss.

Trace heaters shall be flexible type with Nichrome elements. Transitions should be located outside of the pipe insulation. Pipe insulation shall be calcium silicate with aluminum jacketing. Thickness of the pipe insulation shall be 0.229 m (9 in) for the main 0.356 m (14 in) hot and cold salt lines.

5.6 MATERIALS SELECTION

5.6.1 Molten Salt Pumps

Materials for the molten salt pumps are as follows:

Hot Salt Pumps - 304 Stainless Steel
Hot Salt Sump - 304 Stainless Steel

Cold Salt Attemperation Pump - Carbon Steel
Cold Salt Sump - Carbon Steel

5.6.2 Piping and Valves

Salt piping with design temperatures of 468°C (875°F) and above shall be type 304 stainless steel. Salt piping with design temperatures between 343°C (650°F) and 468°C (875°F) shall be ASTM A335 Grade P22 alloy steel. Salt piping with design temperatures below 343°C (650°F) shall be ASTM A106 Gr B carbon steel.

Valves shall meet the code requirements of ANSI B16.34. Salt valves in piping with design temperatures of 468°C (875°F) and above shall be stainless steel. Salt valves in piping with design temperatures between 343°C (650°F) and 468°C (875°F) shall be alloy steel. Salt valves in piping with design temperatures below 343°F (650°F) shall be carbon steel.

6.0 SYSTEM DESIGN CRITERIA - SOLAR MAIN STEAM

6.1 SYSTEM IDENTIFICATION

1)	Category Name	Solar Steam Generation
2)	Category Code	SB-
3)	System Name	Solar Main Steam
4)	System Code	SBD
5)	Purchase Specification	62.2201, 62.2202, 62.2401, 62.2408, 62.2409, 62.3806, 62.3807, 72.0201, 72.0403, 64.0601, 64.0602, and 64.1001

6.2 FUNCTION

The function of the Solar Main Steam System is to route superheated steam from the solar superheater to the specified interface with the existing Fossil Fuel Main Steam System, or alternately to the startup desuperheater during startup.

6.3 DESCRIPTION

Superheated steam from the solar superheater enters the solar main steam line at 541°C (1006°F) and is routed to the fossil main steam interface location at the two existing 0.254m (10 in.) main steam lines between the S-12 flow meters and the hogging ejector tap. The solar main steam line is connected to both fossil main steam lines as shown in Figure 1-1. Under normal operation valves SGG-TV9 and SBD-TV3 are closed and the fossil and solar steam are allowed to mix at this location (for combined operation) before entering the turbine. During startup block valves SGA-TV2, SGA-TV4 and SBD-TV1 are closed and steam is routed through valves SGG-TV9 and SBD-TV3 before entering the startup desuperheater. The valving is arranged so that either the solar steam generator or the fossil steam generator can use the startup desuperheater. The startup desuperheater line is sized to regulate steam pressure by choking the steam flow. Boiler feedwater is used for desuperheating the steam which is then routed to the condenser.

6.4 CODES AND STANDARDS

Piping shall be designed in accordance with the requirements of the Code for Pressure Piping ANSI B31.1 — Power Piping. Gate and globe valves as applicable, shall meet the code requirement of ANSI B16.34.

6.5 SIZING CRITERIA

6.5.1 Piping

Pipe wall thickness shall be selected based on design pressure plus a suitable margin. Pipe size shall be selected based on providing reasonable fluid velocities and pressure loss. When introducing solar steam to the fossil main steam line for combined operation, the solar-fossil steam temperature difference shall not exceed 29°C (85°F) to preclude excess stress.

6.5.2 Startup Desuperheater

The startup desuperheater shall be the spray type. The sizing criteria are shown on Table 6-1.

Table 6-1 Startup Desuperheater Sizing Criteria

Outlet steam pressure:	TBD
Outlet steam temperature:	TBD
Outlet steam flowrate:	TBD
Inlet steam pressure:	Variable
Inlet steam temperature:	Variable
Inlet steam flowrate:	Variable
Feedwater pressure:	14.03 MPa (2035 psia)
Feedwater temperature:	138°C (281°F)
Feedwater flowrate:	TBD
Turndown ratio:	TBD

6.6 MATERIALS SELECTION

Material selection for water/steam applications will generally be based on the design temperature and service conditions in accordance with the following.

- Carbon steel piping materials will be used for design temperatures less than or equal to 399°C (750°F).

- 1-1/4 percent chromium alloy steel piping materials will be used for design temperatures greater than 399°C (750°F) and less than or equal to 510°C (950°F).

- 2-1/4 percent chromium alloy steel piping materials will be used for steam and water service with design temperatures greater than 510°C (950°F).

Pipe insulation shall be calcium silicate with aluminum jacketing. Thickness of the pipe insulation shall be as indicated in Table 5-3.

7.0 COMPONENT DESIGN CRITERIA - SOLAR BOILER FEEDWATER

7.1 COMPONENT IDENTIFICATION

1)	Category Name	Solar Steam Generation
2)	Category Code	SB-
3)	System Name	Solar Boiler Feedwater
4)	System Code	SBE
5)	Purchase Specification	62.2201

7.2 FUNCTION

The function of the solar boiler feedwater system will be to transfer boiler feedwater from the specified interface with the existing boiler feed system to the inlet of the solar preheater.

7.3 DESCRIPTION

Feedwater for the Solar Steam Generator is taken from a tee connection in the existing 0.254 m (10 in.) main feedwater line between the high pressure feedwater heater and the S-65 flow meter. Before entering the preheater, saturated liquid from the steam drum is mixed with the feedwater to maintain a preheater inlet temperature of 238°C (460°F) under all load conditions.

7.4 CODES AND STANDARDS

Piping shall be designed in accordance with the requirements of the Code for Pressure Piping ANSI B31.1 -- Power Piping. Gate and globe valves as applicable, shall meet the code requirement of ANSI B16.34.

7.5 SIZING CRITERIA

Pipe wall thickness shall be selected based on design pressure plus a suitable margin. Pipe size shall be selected based on providing reasonable fluid velocities and pressure loss.

7.6 MATERIALS SELECTION

Material selection for water/steam applications will generally be based on the design temperature and service conditions in accordance with the following.

- Carbon steel piping materials will be used for design temperatures less than or equal to 399°C (750°F).
- 1-1/4 percent chromium alloy steel piping materials will be used for design temperatures greater than 399°C (750°F) and less than or equal to 510°C (950°F).
- 2-1/4 percent chromium alloy steel piping materials will be used for steam and water service with design temperatures greater than 510°C (950°F).

Pipe insulation shall be calcium silicate with aluminum jacketing.

8.0 COMPONENT DESIGN CRITERIA-SOLAR STEAM GENERATOR TEMPORARY BLOWOUT

8.1 COMPONENT IDENTIFICATION

1)	Category Name	Solar Steam Generation
2)	Category Code	SB-
3)	System Name	Solar Steam Generator Temporary Blowout
4)	System Code	SBF
5)	Purchase Specification	62.3806, 62.2408, 72.0201

8.2 FUNCTION

The Solar Temporary Blowout System will provide a temporary flow path for cleaning steam blowing to atmosphere through the solar main steam piping. The steam blow will serve to clear the superheater and solar main steam piping of mill scale, slag, weld beads, and other foreign material prior to its use for supplying steam to the turbine.

8.3 DESCRIPTION

Steam will flow from the solar steam generator through the superheater, the solar main steam piping, and the temporary piping to the atmosphere. The temporary piping will connect into the solar main steam line upstream of the isolation valves and as close to them as possible such that the maximum quantity of main steam piping will be cleaned.

The temporary piping will be provided with a shut-off valve that will be used to isolate the system and allow the steam pressure to build up. When the pressure reaches a predetermined value, the valve will be quickly opened and the steam discharged to atmosphere. When the steam pressure decays to another predetermined value, the valve is closed and the pressure allowed to build again. The cycle is repeated until the piping is clean as indicated by the cleanliness of the discharging steam.

8.4 CODES AND STANDARDS

Piping shall be designed in accordance with the requirements of the Code for Pressure Piping ANSI B31.1 — Power Piping. Gate and globe valves as applicable, shall meet the code requirement of ANSI B16.34.

8.5 SIZING CRITERIA

The Solar Steam Generator Temporary Blowout system will be sized to be compatible with the water/steam piping system and the flowrates used during blowout.

8.6 MATERIALS SELECTION

The Solar Steam Temporary Blowout System will utilize carbon steel pipe.

6.0 Master Control System Specification

MCR-82-644

MASTER CONTROL SYSTEM SPECIFICATION

PRELIMINARY DESIGN ENGINEERING SERVICES FOR SOLAR REPOWERING OF THE SAGUARO POWER PLANT

August 1983

Martin Marietta Corporation
Denver Division
Denver, Colorado 80201

Prepared for Arizona Public Service Company
Phoenix, Arizona
Under Subcontract No. RD82-6732

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SYSTEM DESIGN SPECIFICATION

FOR

MASTER CONTROL SYSTEM

1.0 SYSTEM DESCRIPTION

1.1 SYSTEM IDENTIFICATION CODE

1)	Category Name	Control
2)	Category Code	CO
3)	System Name	Master Control
4)	System Code	COG

1.2 FUNCTION

The main function of the Master Control System is to directly control the receiver, thermal energy storage, solar steam generator and to coordinate the control of the solar collector.

The MCS shall also coordinate the operation of the fossil and solar steam generators, and shall provide an operator interface and a data acquisition, data storage and retrieval and logging function for the solar portion of the plant.

1.3 PROCESS DESCRIPTION

A block diagram of the Master Control System is shown in Figure 1-1. The System Flow Diagram is shown in Figure 1-2

1.4 INTERFACING SYSTEMS

Systems that have a significant functional interface with the Master Control System are listed on Table 1-1. See paragraph 2.6 for a description of these interfaces.

Table 1-1 Master Control System Primary System Interfaces

System	System Code
1. Collector Control and Instrumentation	CSD
2. Fossil Fuel Steam Generator Control and Instrumentation	SGL
3. Turbine Instruments	TGF
4. Control and Multi-system Panels	COF
5. Grounding and Lightning Protection	EEB
6. Control House/Instrument Repair Space Conditioning	SCC
7. Solar Protection	COC
8. Solar Receiver	RS
9. Thermal Energy Storage	ES
10. Solar Steam Generation	SB
11. AC Power Supply--120/208V	APA
12. Essential Service AC	API

1.5 BOUNDARIES

The boundaries between the Master Control System and the solar receiver, thermal energy storage, and solar steam generator exist at the terminal blocks inside the Master Control System termination cabinets.

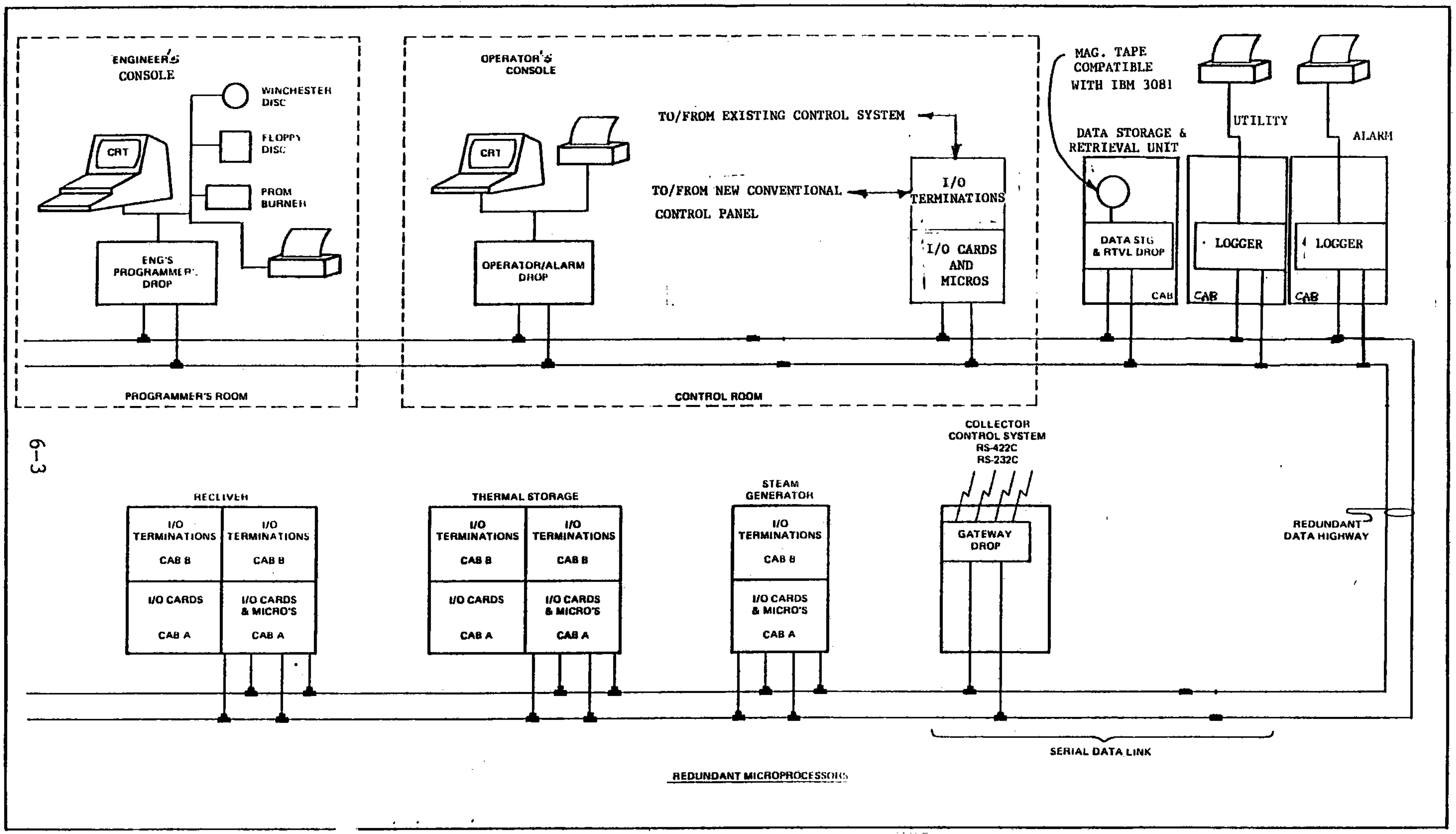


Figure 1-1 Master Control System Block Diagram

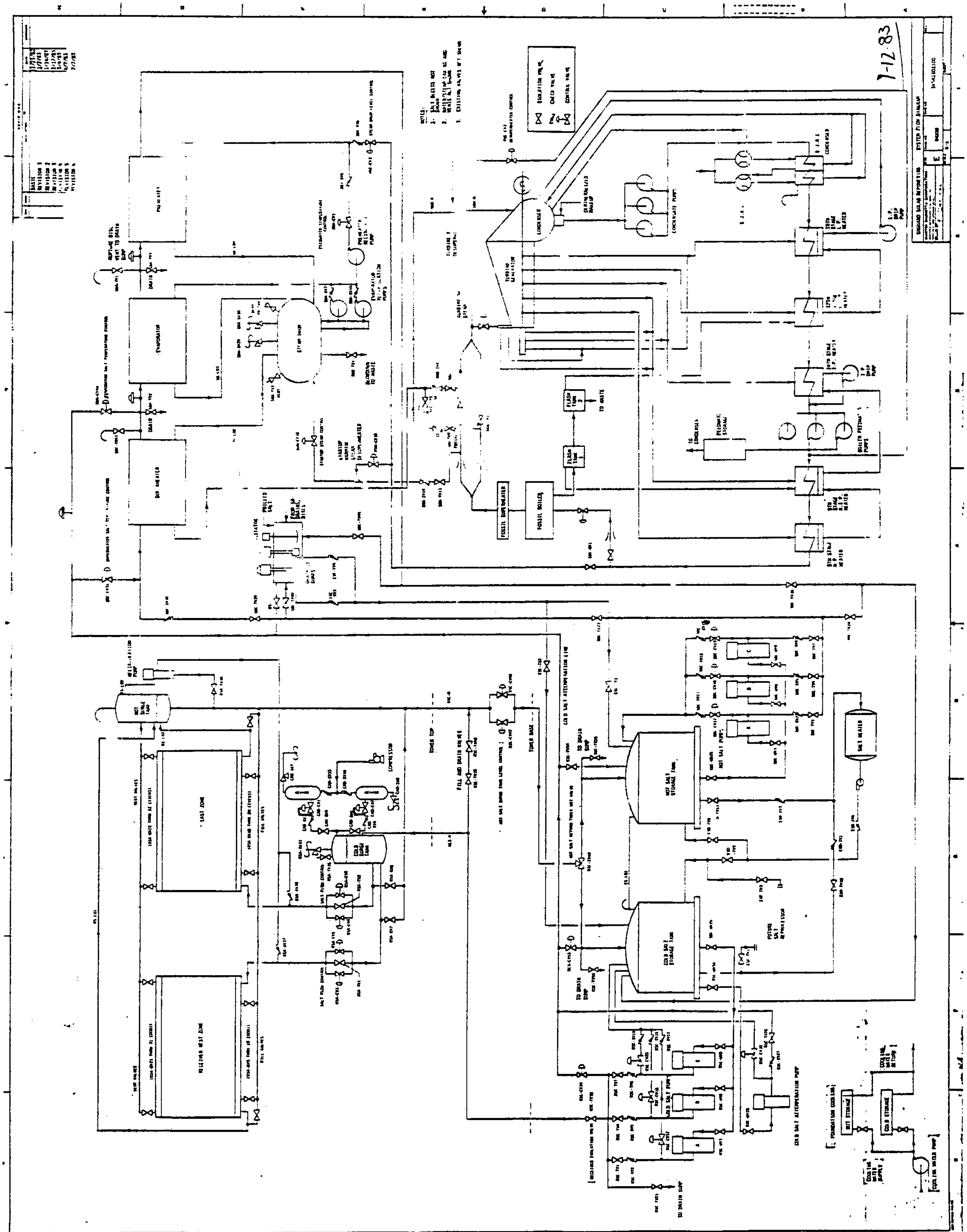


Figure 1-2 System Flow Diagram

2.0 SYSTEM DESIGN CRITERIA

2.1 SUPPORTIVE DOCUMENTATION

The supportive documentation for the system design criteria is contained in the following documents.

1) Saguaro Solar Repowering Preliminary Design Subsystem Interface Definition Document, MCR-82-639 MMC, 10/22/82.

2) Saguaro Solar Repowering System Codes, MMC 12/13/82.

2.2 CODES AND STANDARDS

The significant codes and standards which apply to the Master Control System are as follows.

ANSI	American National standards Institute, Inc.
ASME	American Society of Mechanical Engineers.
IEEE	The Institute of Electrical and Electronics Engineers, Inc.
IPCA	Insulated Power Cable Association.
ISA	Instrument Society of America.
NEMA	National Electrical Manufacturer's Association.
NESC	National Electrical Safety Code.
NFPA	National Fire Protection Association.
SAMA	Scientific Apparatus Makers Association.

2.3 REGULATORY REQUIREMENTS

The MCS shall comply with all applicable state laws, local ordinances and requirements of the federal Occupational Safety and Health Standards. All applicable regulatory requirements defined in the Regulatory Requirements Manual (File TBD) shall also be followed.

2.4 QUALITY LEVEL CLASSIFICATION

The quality level classification for the Master Control System and its components will be identified later.

2.5 NATURAL PHENOMENA

All field-mounted instruments and control devices will be designed to withstand ambient temperature extremes from 0°F to 120°F and relative humidities up to 100 percent throughout the temperature range.

All instruments and control devices installed in the control center building and other air-conditioned buildings will be designed for an operating condition of 75°F ambient temperature and 50 percent relative humidity. In case of an air conditioning failure, they shall withstand temperatures ranging from 50°F to 120°F for extended periods of time in a non-operating condition.

2.6 INTERFACING SYSTEMS

The interface between the systems listed in Section 1.4 and the Master Control System are as follows.

2.6.1 Collector Control and Instrumentation (CSD)

Communication between the Master Control System and the Collector Control and Instrumentation system will be through a data link. The Master Control System will send commands to and receive status information from the Collector Control and Instrumentation System.

2.6.2 Fossil Fuel Steam Generator Control and Instrumentation (SGL)

Interface with existing control system for control of fossil firing rate when the system is in one of the following modes:

a) Solar Only
b) Fossil & Solar Combination

Either the solar or fossil steam generator can be operated at constant output with the other system following load demand; the normal mode of operation will be with the solar system at constant output and the fossil system output varying with load demand.

2.6.3 Turbine Instruments (TGF)

Sensing of turbine system parameters (throttle pressure, turbine first stage pressure) for control of Hot Salt Flow of Solar System. The interface involves no control of the turbine.

2.6.4 Control and Multi-System Panels (COF)

Interface with existing and new control consoles for command input, status requests & alarm. See Appendix A for inputs & outputs in control room.

2.6.5 Grounding and Lightning Protection (EEB)

The Grounding and Lightning Protection System provides an independent electrical connection for the logic circuits of the Master Control System to the earth grounding grid network. A separate connection is required to ground the control system's cabinets to protect operations personnel and the electronic circuitry from high voltage transients.

2.6.6 Control House/Instrument Repair Space Conditioning (SCC)

The HVAC System has a functional interface with the Master Control System to maintain the environmental requirements necessary for the correct operation of the equipment. The environmental envelope for the control system equipment will be provided later.

2.6.7 Solar Protection System (COC)

This interface will consist of alarm inputs to the MCS, failure contact outputs and reset or enable outputs from the MCS, and outputs to selected valves which will go through the Solar Protection System for appropriate trips.

2.6.8 Solar Receiver, Solar Steam Generation and Thermal Energy Storage

The Master Control System interfaces with the solar receiver (RS), solar steam generation (SB) and thermal energy storage (ES) as follows:

1) The Master Control System receives analog signals from these systems, representative of process variable values.

2) The Master Control System generates control signals to position final elements in these systems, thus regulating process variables. These signals will be compatible with the final element or an interposing device.

3) The Master Control System receives contact status inputs from other systems. The Master Control System will provide the interrogation voltage for such contact inputs.

4) The Master Control System generates contact outputs to these other systems. The output will be a dry contact.

5) Signals required from one area to control devices in another area will be transmitted over the data highway.

See Appendices B, C, & D for inputs & outputs to these areas.

2.6.9 AC Power Supply--120/208V (APA)

The interface with the MCS and this system will be for lighting and convenience receptacles within the MCS cabinets.

2.6.10 Essential Service AC (API)

The MCS will have it s power supplied from this system.

The process control functions that the Master Control System performs for the receiver, solar steam generator and thermal storage system are defined in Section 2.10 & 2.11.

2.7 REDUNDANCY

It will be a design goal that no single failure in the Master Control System will result in an automatic shutdown of the plant or in the necessity for manual shutdown. Redundancy and automatic failover will be used in the Master Control System where appropriate to achieve this design goal.

2.7.1 Data Highway

Data highways between major elements of the system (process controllers, CRT terminals) will be dual redundant.

2.7.2 Power Supplies

Power supplies in the equipment racks containing the process controllers will be dual redundant.

2.7.3 Operator Interface

No single failure should result in the loss of operator capability to communicate with the Master Control System.

2.7.4 Input/Output

Redundancy will be used in the case of some of the sensors and the control valves in the controlled systems. These inputs and outputs shall be routed through separate I/O cards so that no single failure in the I/O equipment would disable more than one input or one output.

2.7.5 Microprocessors

Microprocessors which handle more than two control loops shall be dual redundant.

2.7.6 Power Sources

The Master Control System will be supplied from redundant power sources of the Essential Service AC (Inverter) System.

2.7.7 Hand/Auto Stations

Redundant H/A Stations will be provided at local system cabinets for critical loops.

2.8 FUNCTIONAL CONSTRAINTS

The function of the Master Control System is to provide overall control of the Receiver, Thermal Storage and Solar Steam Generator and coordination of the fossil and solar steam generators, and the solar collector system.

The Master Control System will control the solar systems in a stable manner and maintain the temperatures and pressures in these systems within the required tolerances.

The MCS will implement control of all pumps, motor operated valves, solenoid operated valves, and heat tracing circuits. Unless otherwise specified herein, this control will consist of start-stop (open-close) from the control panel and the keyboard. Pumps will also be controlled from local start-stop stations.

2.9 PHYSICAL CONSTRAINTS

The Master Control System will be designed as an electronic, distributed, direct-digital-control system in which all calculation will be performed digitally by several microprocessors (computers). Each microprocessor will be assigned (or dedicated) to a certain part of the automatic control program.

The Master Control System will be arranged to have termination cabinets physically separate from the system cabinets. Connection between the termination and system cabinets will be through prefabricated cables. It is preferred that all cable connections to and from the process equipment be located in the termination cabinets.

2.10 RECEIVER REQUIREMENTS

2.10.1 Receiver Operating Requirements

2.10.1.1 MCS System Capability - The Master Control System shall provide the capability to monitor and control the receiver during the operating modes and the start-up and shut-down sequences. The overall control configuration of the receiver is shown in Figure 2-1.

2.10.1.2 Receiver Modes - There are three operating modes as shown in Figure 2-2; empty, standby and operational. The empty mode is the initial condition of the receiver when it is fully drained of salt. The standby mode is the overnight condition in which the receiver is kept full of molten salt. In the operational mode, the heliostats are focused on the receiver to generate hot salt.

Figure 2-2 also illustrates the relationships between each of these modes. Included are four operational sequences: cold startup, shutdown, normal startup and drain. These sequences are sets of commands which will transition the receiver operation from one mode to another and will be performed automatically by the Master Control System. The operator must be able to interrupt any sequence and assume manual control during any mode of operation.

2.10.1.3 Receiver Operation Sequences - Figures 2-3 through 2-6 describe the receiver sequences. The lefthand column describes the instrumentation readings used at each step; the central section describes the decision or action to be made by the Master Control System, and the righthand column defines each stage in the sequence.

These automatic sequences related to the receiver shall be resident in the Master Control System. The sequence can be prematurely aborted, in which case the operator must have the capability to command the sequence to proceed or acknowledge the abort and assume control.

2.10.1.3.1 Cold Startup Sequence (Fig. 2-3) - This sequence assumes an empty condition prior to start. The receiver is prewarmed first with trace heaters and then with a limited number of heliostats. When it is confirmed that the receiver is warm enough, the salt lines to the receiver are filled (at a reduced rate of flow) and the receiver is gradually filled with salt. As the receiver is filled, air will be purged through the vent valves. When it has been confirmed that all this air has been purged, the salt flow will be increased to the maximum and all the heliostats will then be focused.

2.10.1.3.2 Receiver Shutdown Sequence (Fig. 2-4) - The normal shutdown sequence will maximize the heat content in the receiver panels by operating the recirculation pump and decreasing the flow from the cold salt pumps prior to defocusing the heliostats and closing the control valves, thereby returning the system to the standby condition. The capability must also be provided for an immediate defocus of the heliostats.

2.10.1.3.3 Normal Startup Sequence (Fig. 2-5) - This sequence assumes the receiver is in a standby condition prior to start. Salt flow is established through the receiver from the cold surge tank and the cold salt pumps, at which time the heliostats are focused and the system placed in an operational condition.

2.10.1.3.4 Drain Sequence (Fig. 2-6) - This sequence will have the capability to empty the receiver from either the operational condition or the standby condition.

From the operational condition, the heliostats will be defocused, flow shutoff, and appropriate valves are opened to drain the salt into either the Hot or Cold salt storage tank, as dictated by the temperature. The drain sequence from standby is the same, with the exception that the heliostats are already defocused, and the salt flow is already shut off.

2.10.2 Receiver Standby Control Functions

The Master Control System will be required to perform the following when the receiver is in the standby mode (see Figure 2-7).

2.10.2.1 Receiver Temperature [Fig. 2-7(a)] - When any of the thermocouples in the receiver (East and West Zone) indicate a temperature below an acceptable minimum (Temp TBD) the recirculation pump will be turned on. When all of the thermocouples indicate a temperature above this minimum, the recirculation pump will be turned off.

2.10.2.2 Cold Surge Tank Level [Fig. 2-7(b)] - When the level in the cold surge tank drops below an acceptable minimum (Level TBD) the cold salt pumps will be activated at a low flow rate until the level in the cold surge tank goes above this minimum level.

2.10.2.3 Hot Surge Tank Temperatures [Fig. 2-7(c)] - When the temperature in the hot surge tank falls below an acceptable minimum (Temp TBD) the flow control valves will be opened to allow 80% flow from the cold surge tank through the receiver until the hot surge tank temperature is above the minimum.

2.10.3 Receiver Operational Control Functions - The following paragraphs describe the main control functions for operation of the receiver.

Overall control configuration is shown in Figure 2-1.

2.10.3.1 Receiver Salt Flow Control - The MCS regulates the flow of salt through the receiver such that the deviation in the output temperature of the salt is minimized.

Redundancy is included in temperature measurement and flow regulation. The MCS monitors three independent measurements of temperature at crucial locations and selects the median for control. In addition, two valves are used in parallel for each of the two control zones such that should one fail, the second continues to regulate flow without interruption. The redundancy is organized such that smooth control is maintained after the loss of at least one T/C and one valve. See Figures 2-8 for control algorithm and flow diagram.

2.10.3.2 Cold Salt Pump Control - The cold salt pumps provide the following functions: (1) supply cold salt to the cold surge tank for circulation through the receiver; (2) supply cold salt to the receiver return line to reduce the temperature of the salt when it is being returned to the cold salt tank, and (3) supply cold salt to the superheater and evaporator when the attemperation pump is not in operation.

The MCS monitors the salt level in the cold surge tank and cold salt flow in the riser, into the receiver, and at the discharge of each cold salt pump and modulates pump speed to supply the total required cold salt flow. Normally, two pumps will be operating with equal outputs with the third pump as a backup.

When the cold salt pumps are operating, the flow through the pump must not drop below a specified minimum flow. The MCS monitors the flow at the discharge of each pump and controls recirculation valves RSC-CV12, RSC-CV16 and RSC-CV20 to insure the pump flow does not go below this minimum.

See Figure 2-9 for control algorithms.

The MCS monitors the pressure in the attemperation pump discharge line; if this pressure falls below a specified minimum (indicating that the attemperation pump is not operating) an attemperation pump back-up valve will be opened, supplying the required attemperating salt from the cold salt pumps. See paragraphs 2.11.2.3 and 2.11.2.5 for control of attemperating salt to the superheater and evaporator.

2.10.3.3 Receiver Salt Return Control - The MCS monitors the temperature of the salt in the downcomer and controls a three-way valve (RSC-ZV49) to return the salt to either the hot or cold salt storage tank (Fig. 2-10). This salt normally goes to the hot salt storage tank, but if the salt temperature is below a specified value the salt is routed to the cold salt storage tank.

The temperature of the return salt may be too high for the salt to be put directly into the cold salt storage tank. The MCS monitors the salt temperature and modulates RSC-CV55 to mix attemperating cold salt with the return salt and control the temperature of the salt going into the cold salt storage tank to an acceptable level.

The control algorithms are shown in Figure 2-10.

2.10.3.4 Receiver Hot Salt Surge Tank - The MCS monitors the level of salt in the hot salt surge tank and controls it by modulating parallel-redundant salt flow control valves RSC-CV42 and RSC-CV46. See Figure 2-11 for control algorithms.

2.11 SOLAR STEAM GENERATOR REQUIREMENTS

2.11.1 The MCS System Capability

The function of the Master Control System is to provide overall control of the solar steam generator and coordination of the fossil and solar steam generators.

2.11.2 Solar Steam Generation

The following sections describe the main control functions involved for the solar steam generator. See Figure 2-12 for overall control configuration.

2.11.2.1 Hot Salt Flow Rate - The MCS monitors the throttle pressure and turbine first stage pressure (for steam flow). These signals are used to determine the necessary hot salt flow rate to regulate throttle pressure. As shown in figure 2-14, the hot salt flow rate demand is to be used to control the solar and formulate control for the fossil boilers. With solar operation alone, the computed hot salt flow rate is used to modulate the hot salt pump speed. When solar and fossil are operated together, one must be base loaded (normally solar). With solar base loaded, the difference in solar salt flow and computed salt flow is translated into equivalent fossil firing rate and sent to the fossil boiler (via an I/P converter). Any load swings will thus be automatically accommodated by the fossil boiler. Similarly, the fossil boiler can be base loaded and the solar boiler follows the load swings. The operator can make fine readjustments by biasing either loading commands. See Figures 2-13, 2-14, and 2-15 for flow diagram, control algorithm, and pump enable logic.

2.11.2.2 Hot Salt Pump Minimum Flow - When the hot salt pumps are operating the flow through the pumps must not drop below a specified minimum flow. To accomplish this, the MCS monitors the flow at the discharge of each pump and modulates bypass valves which divert hot salt back to the hot salt storage tank.

2.11.2.3 Superheater Steam Temperature Control - The MCS controls the temperature of the salt entering the superheater. During operation, the temperature is varied to control the temperature of the steam leaving the superheater, by modulating the attemperating cold salt flow.

The steam temperature set-point and the monitored steam temperature form a feedback loop which modulates cold salt mixing with the hot salt to control the steam temperature. See Figure 2-16 for control algorithm.

2.11.2.4 Steam Drum Level - The MCS monitors three independent drum level measurements, superheater steam flow, and feedwater flow rates to control the drum level. The MCS selects the median drum level to provide a high integrity feedback path for trimming level. The superheater steam flow provides a feedforward control path. At low flow rates, drum level only will be used for control. See Figure 2-17 for control algorithm.

2.11.2.5 Evaporator Inlet Salt Attemperation - The MCS monitors the temperature of the salt supply to the evaporator and mixes in attemperating cold salt to maintain a temperature which is safe for evaporator operation. See Figure 2-18 for control algorithm.

2.11.2.6 Preheater Inlet Water Temperature - The MCS monitors the preheater inlet water temperature to assure it is never cold enough to freeze the preheater salt. To accomplish this, water from the boiler recirculation pumps is mixed in with the feedwater to ensure a minimum preheater inlet water temperature. See Figure 2-19 for control algorithm.

2.11.2.7 Attemperation control - Cold salt from the discharge of the attemperation pump will be recirculated back to the cold salt storage tank in order to maintain a minimum flow through the pump if the demand to the superheater and/or the evaporator is low. See figure 2-20(a) for control algorithm. If the attemperation pump fails, as determined by monitoring the discharge pressure, cold salt will be diverted from the cold salt pumps to accomplish the required attemperation. See Figure 2-20(b) for control algorithm.

2.11.2.9 Turbine Bypass Control - The MCS provides control of the startup desuperheater during startup and shutdown to avoid introducing steam into the condenser at too high a temperature. If the fossil steam generator is in operation, steam bypass is used until solar steam pressure matches the fossil and the required steam temperature has been reached.

If the turbine has been out of service for just a short period, steam from the solar steam generator will have to be bypassed to the condenser. As soon as the solar steam temperature matches that required to start the turbine, the bypass can be shut off See Figure 2-21 for control algorithm.

2.11.2.10 Startup Warming Control - If the SSG has been out of service for some time, the fossil steam generator may be required to warm up the solar steam generator. This will be accomplished by flowing steam from the fossil fuel main steam line into the solar steam drum and controlling the steam temperature with feed water through the startup warming steam desuperheater. See Figure 2-22(b) for control algorithm. The amount of steam introduced into the steam drum for startup is controlled by the steam drum pressure. See Figure 2-22(a) for control algorithm.

2.12 TESTING

System testing is to consist of both factory test and field tests.

2.12.1 Factory Tests

The factory tests are to include all reasonable exercises which the combination of equipment and software can be expected to perform. The tests are to include the following.

1) A closed loop checkout of all control loops, using a simulation of the process, to verify control strategies.

2) A thorough exercising of each hardware device, including the central processing unit, if one is used.

3) A thorough exercising of each software package.

4) A point by point exercising of each input and output from the termination points.

5) A simulation of channel noise immunity up to the level of failure.

6) A demonstration of required spare system capacity.

7) A thermal stress test of all electronic/computer hardware.

8) A demonstration of diagnostic and maintenance test packages.

9) The CPUs, I/O hardware, memory, and all peripherals shall be operated in a continuous mode without error as the temperature is cycled from ambient (75°F) to maximum (TBD) at a rate of 10°F per hr., held at maximum for 2 hrs., returned to ambient at a rate of 10°F per hr., and held for 1 hr.

10) An analog-to-digital converter test shall consist of at least two points of each type input (thermocouple, RTD, etc.) on each multiplexer, selected at random at the start of the test. The accuracy, repeatability, and linearity of the System shall remain within the limits listed in the Specification. A set of readings of all points under test shall be taken each half hour from the start to the end of the temperature cycle just described.

11) The System operating program shall be loaded and the program started at ambient temperature. The System shall operate within the limits defined under this Specification during the period of this test.

2.12.2 Factory Performance Test

The System shall be completely assembled and operationally tested to demonstrate proper operation of the hardware and software to the System Specifications. The System shall be subjected to a preliminary test prior to running the Factory Performance Test for witnessing by Purchaser to ensure that all hardware and software have been integrated into a complete System capable of real-time operation. The test shall be run with all cables that shall be shipped to the field, installed, and connected. If the System uses remote multiplexing, the test shall be run with approximately the same length of cables that will connect the System to field remote multiplexers.

2.12.3 Field Tests

All diagnostic and software debug tests performed at the factory are also to be performed in the field. All control programs are to be field tested by simulating field inputs and verifying the proper hardware response (valve movement) occurs.

2.12.3.1 System Availability Test - It is the intent that any System faults be detected and eliminated during this availability run. In the event of a software malfunction, although the System may be made operation, the availability run clock shall not be restarted until the malfunction has been corrected.

Conduct a test to demonstrate that the equipment operates for a continuous period of 180 days with an availability of 99.0%. The test shall include all programming and components furnished as part of the System under this Specification. The equipment shall be considered as down when any function, normally available to the plant operator, plant programmer, or plant engineer, is not performing within specifications. The run shall commence within one year of System installation. If the System downtime exceeds 1.0% during the 180-day period, it will be necessary to restart this test.

The formula for calculating availability is: Percent availability equals 4320 hours minus downtime hours, times 100, divided by 4320 hours.

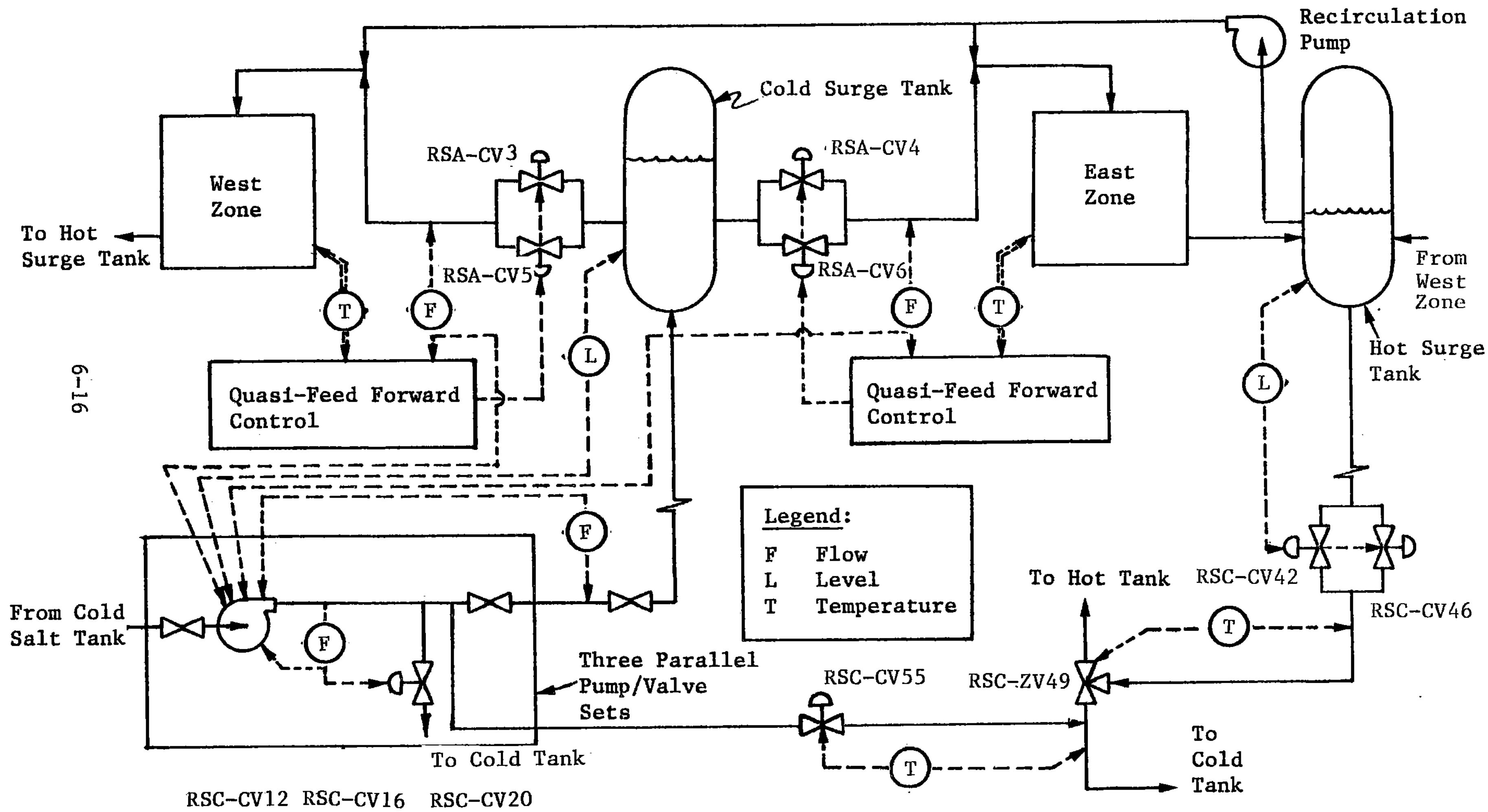
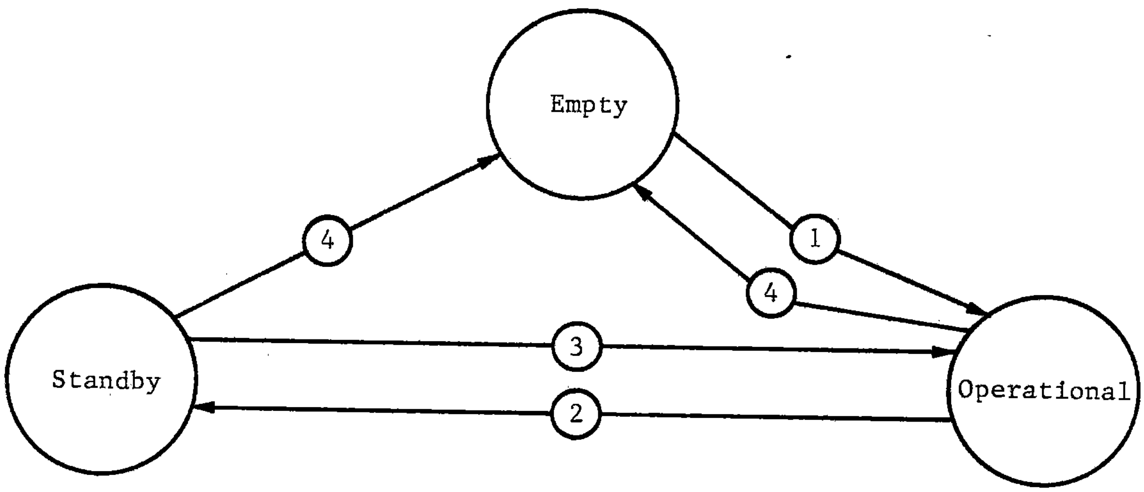


Figure 2-1 Receiver Overall Control Configuration



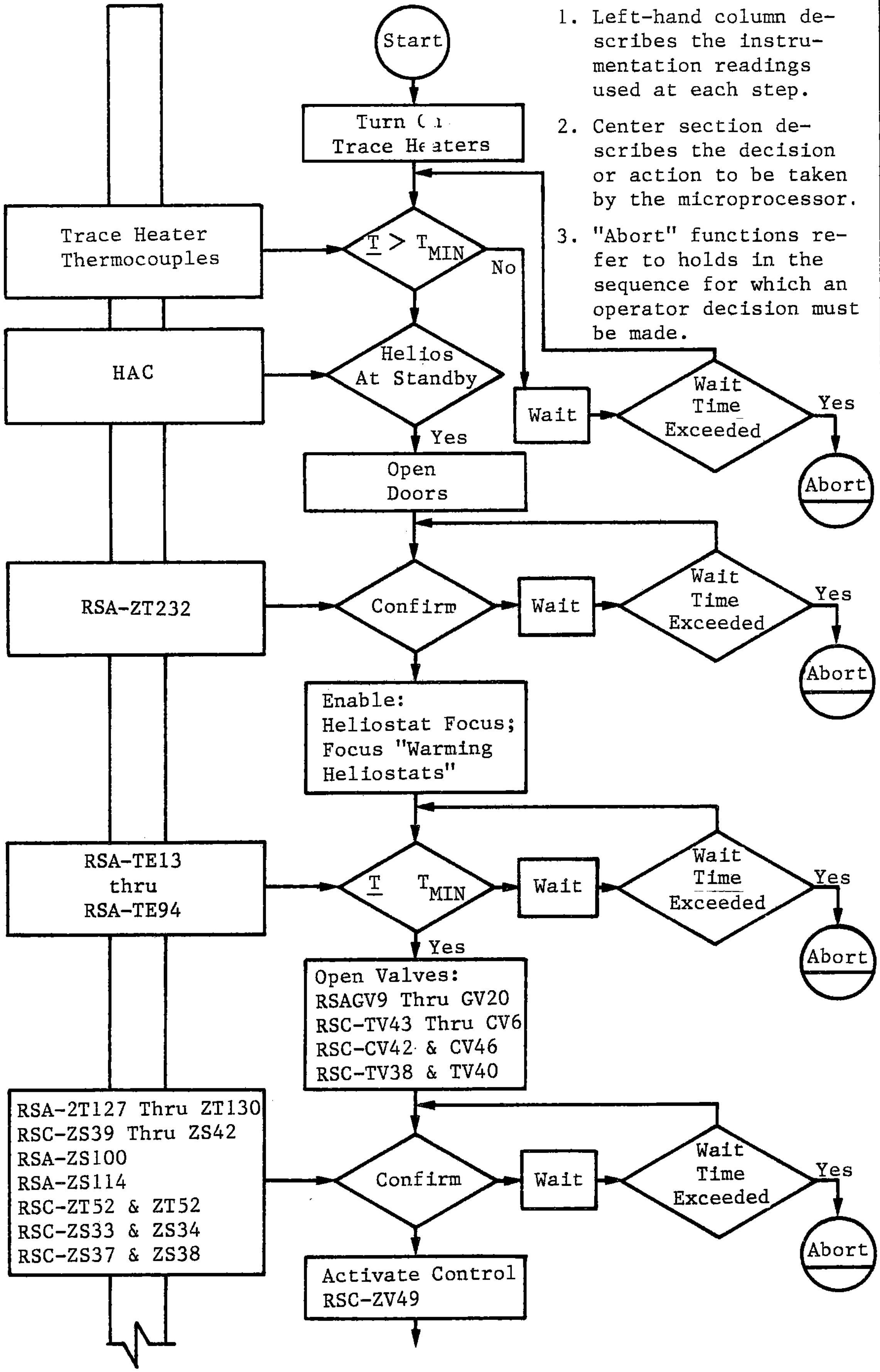
Modes of Operation - 1. Empty
2. Standby
3. Operational

Operation Sequences - 1. Cold Startup
2. Shutdown
3. Normal Startup
4. Drain

Figure 2-2 Receiver Modes of Operation and Operation Sequences

Notes:

1. Left-hand column describes the instrumentation readings used at each step.
2. Center section describes the decision or action to be taken by the microprocessor.
3. "Abort" functions refer to holds in the sequence for which an operator decision must be made.



1. Prewarm reciever first with trace heaters, then with a limited set of heliostats.
   Scan the receiver temperature profile for cold spots before proceeding to fill with salt.

2. Fill salt lines to receiver then fill receiver with salt.

Figure 2-3 Receiver Cold Startup Sequence

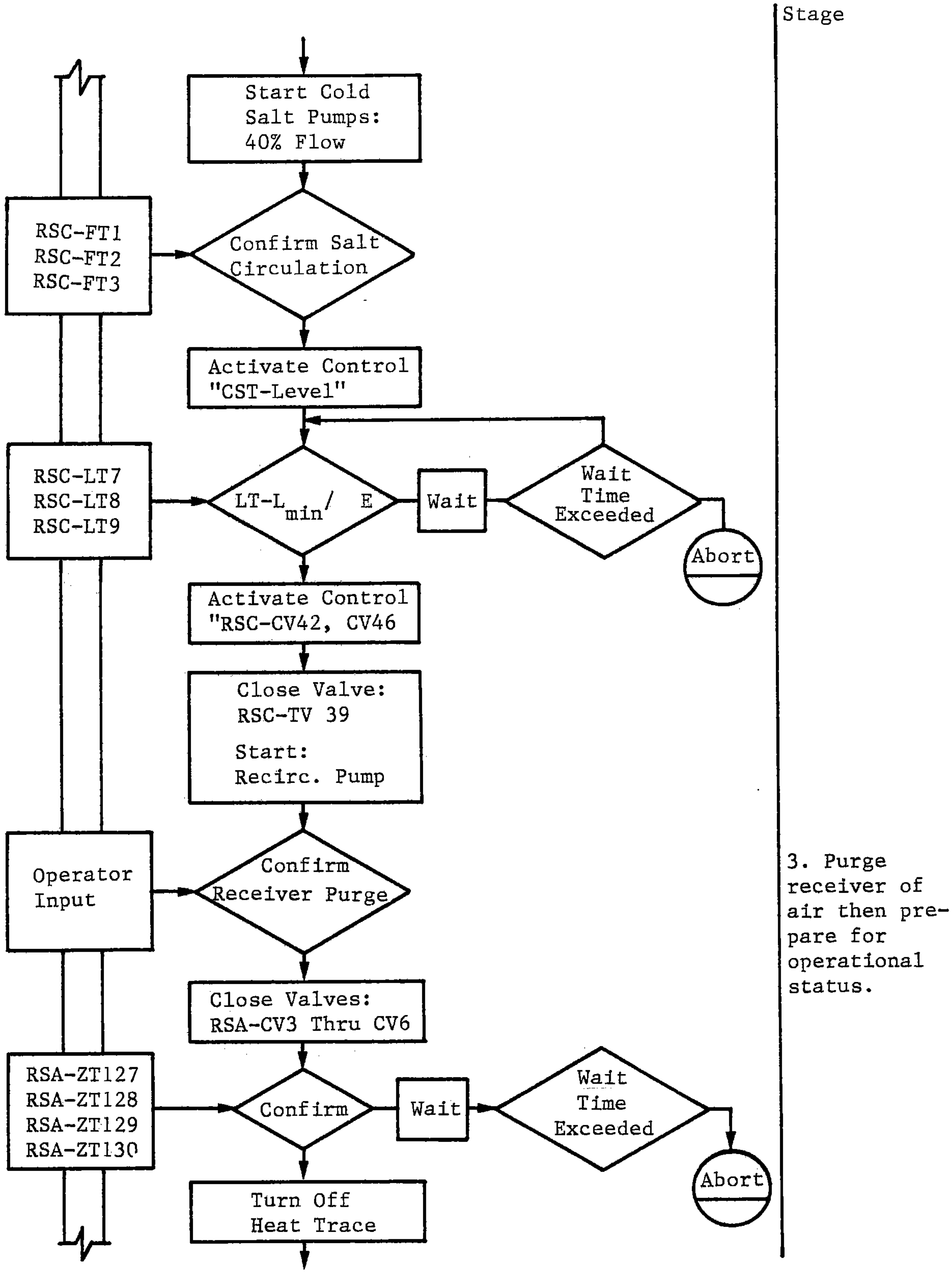
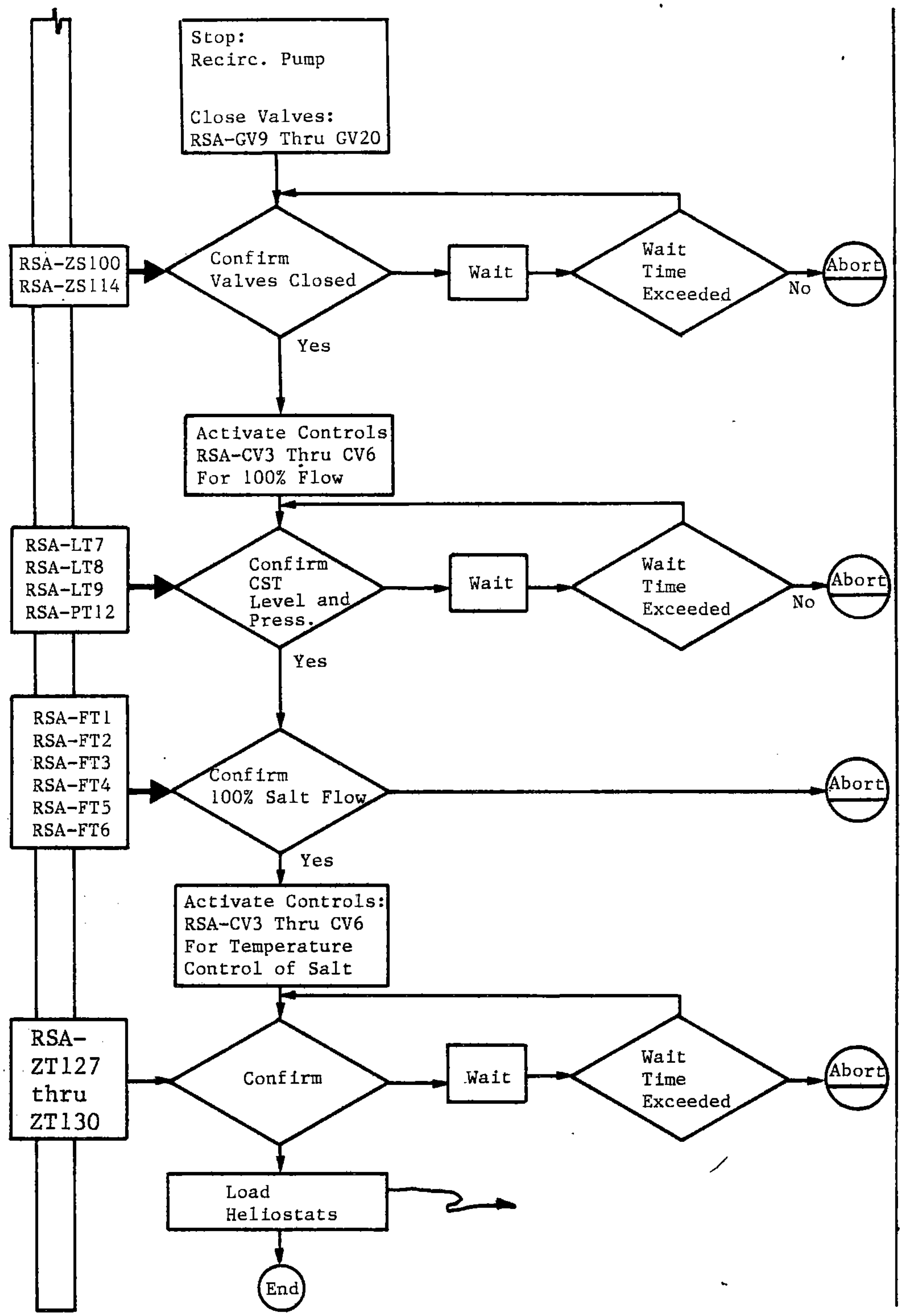


Figure 2-3 (cont)



4. Receivers loaded with heliostats for operational status.

Figure 2-3 (cont)

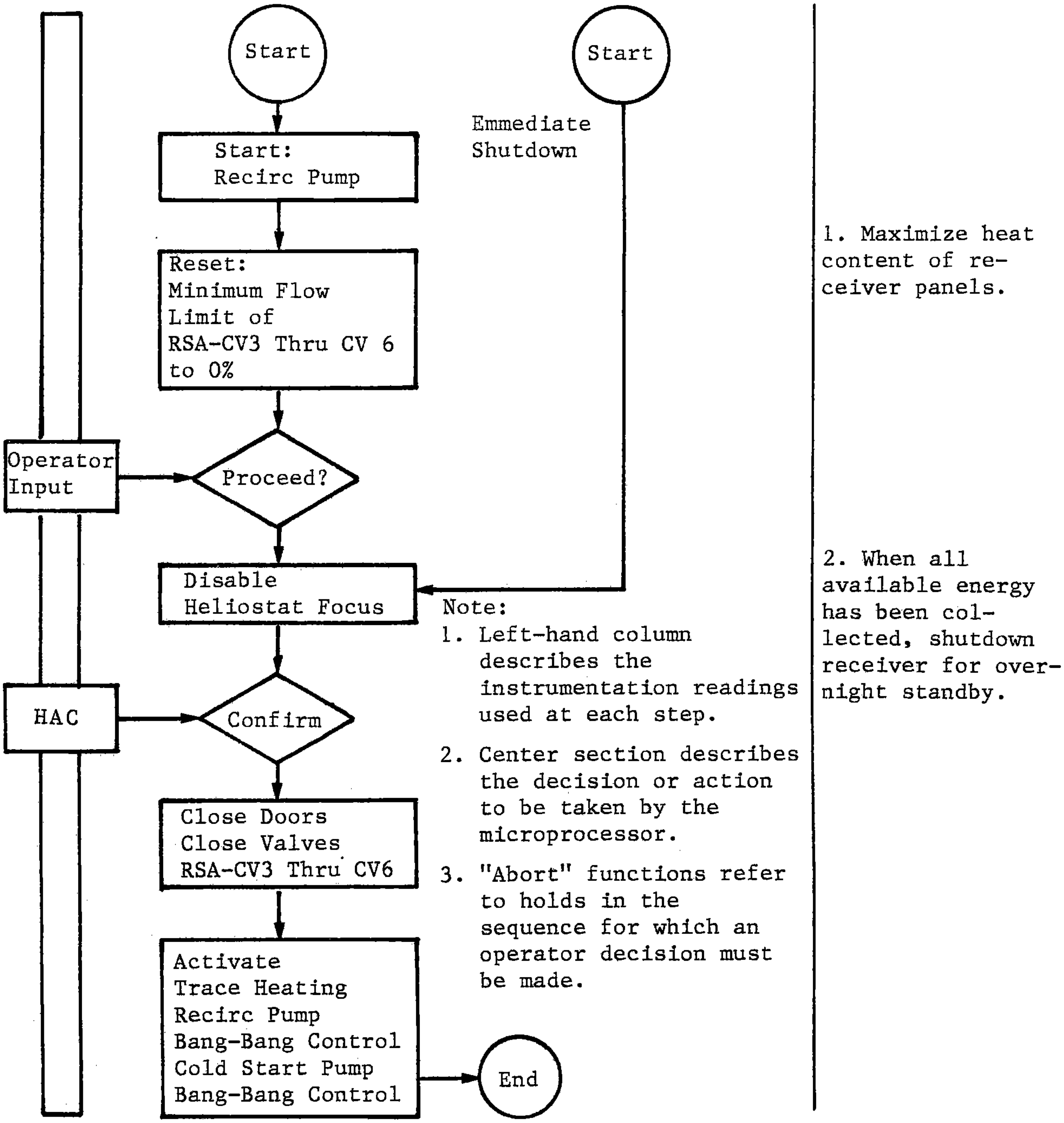
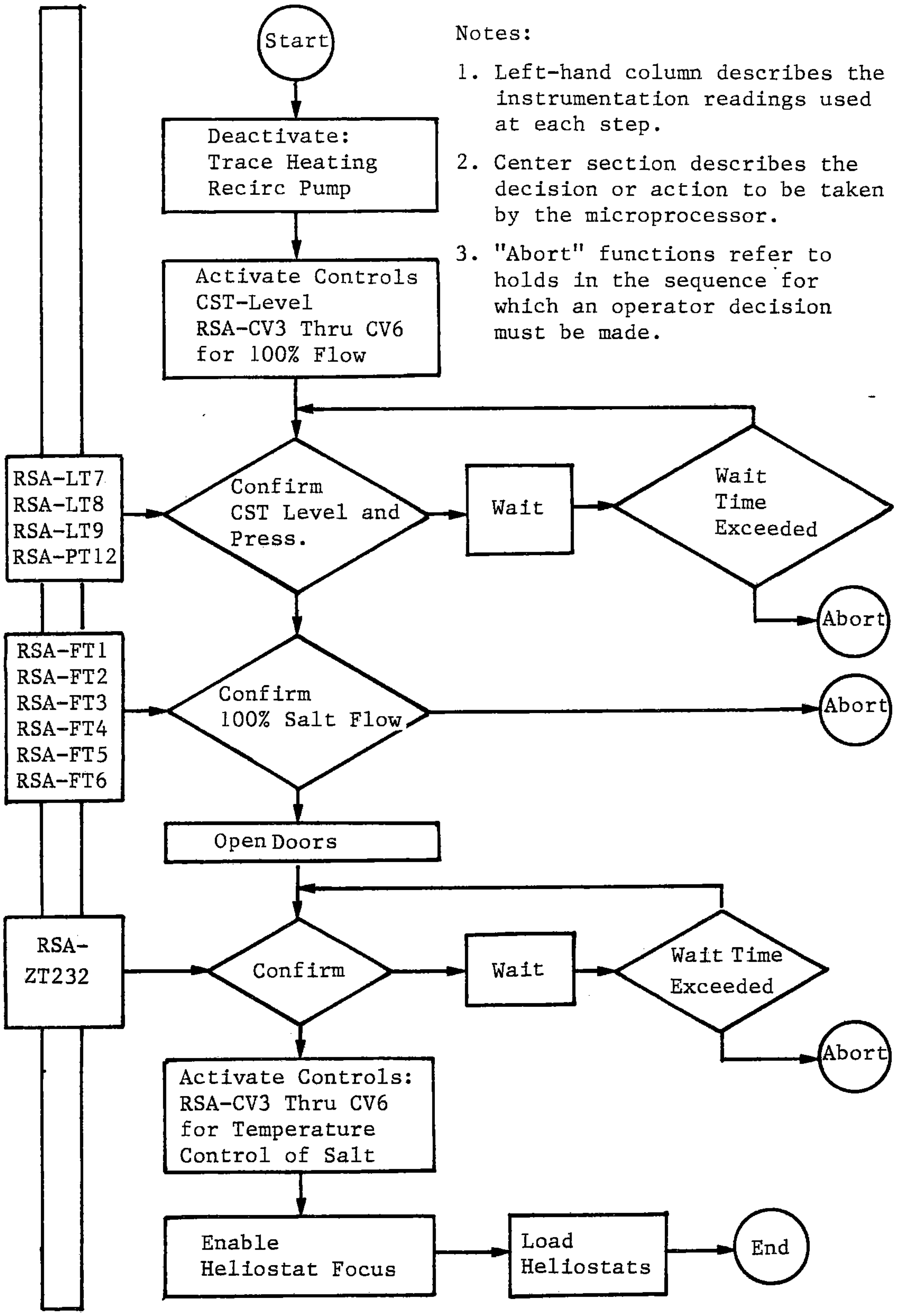


Figure 2-4 Receiver Shutdown Sequence



Notes:

1. Left-hand column describes the instrumentation readings used at each step.
2. Center section describes the decision or action to be taken by the microprocessor.
3. "Abort" functions refer to holds in the sequence for which an operator decision must be made.

1. Reestablish salt flow for operation

2. Open doors, and load heliostats.

Figure 2-5 Receiver Normal Startup Sequence

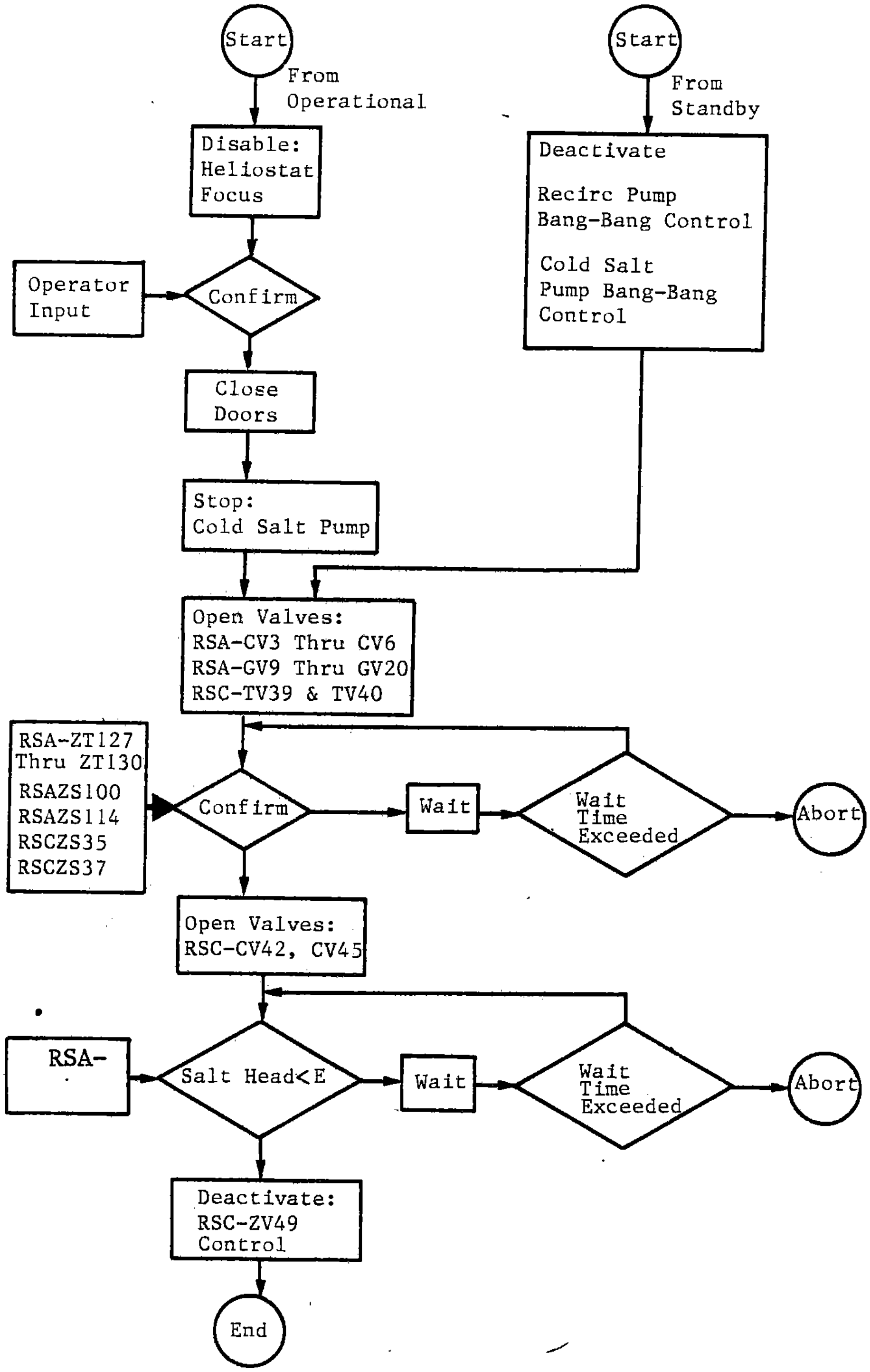


Figure 2-6 Receiver Drain Sequence

1. Turn off controls and open valves ready to drain

2. Drain out salt and deactivate all controls, returning them to manual.

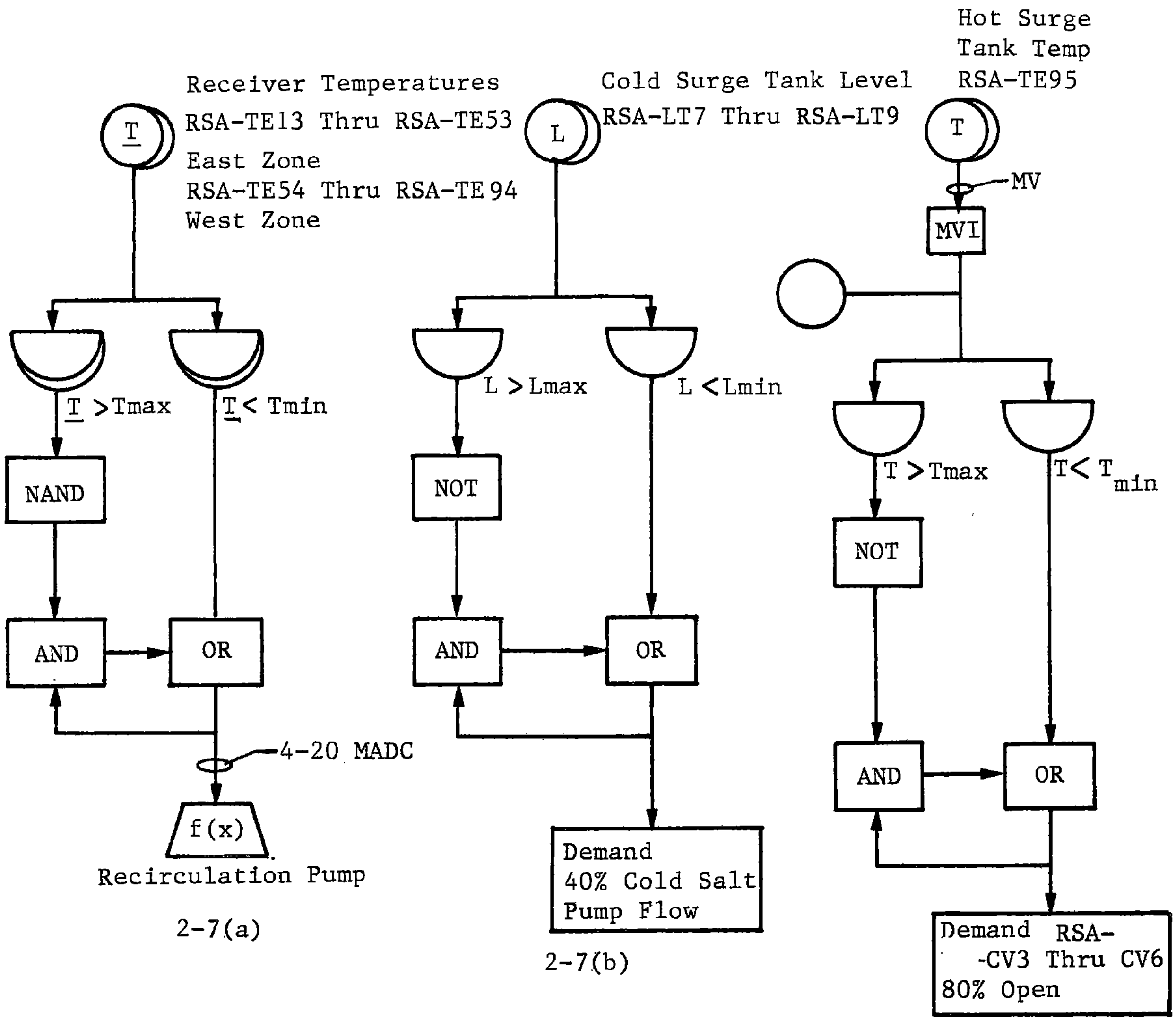


Figure 2-7 Receiver Standby Controls

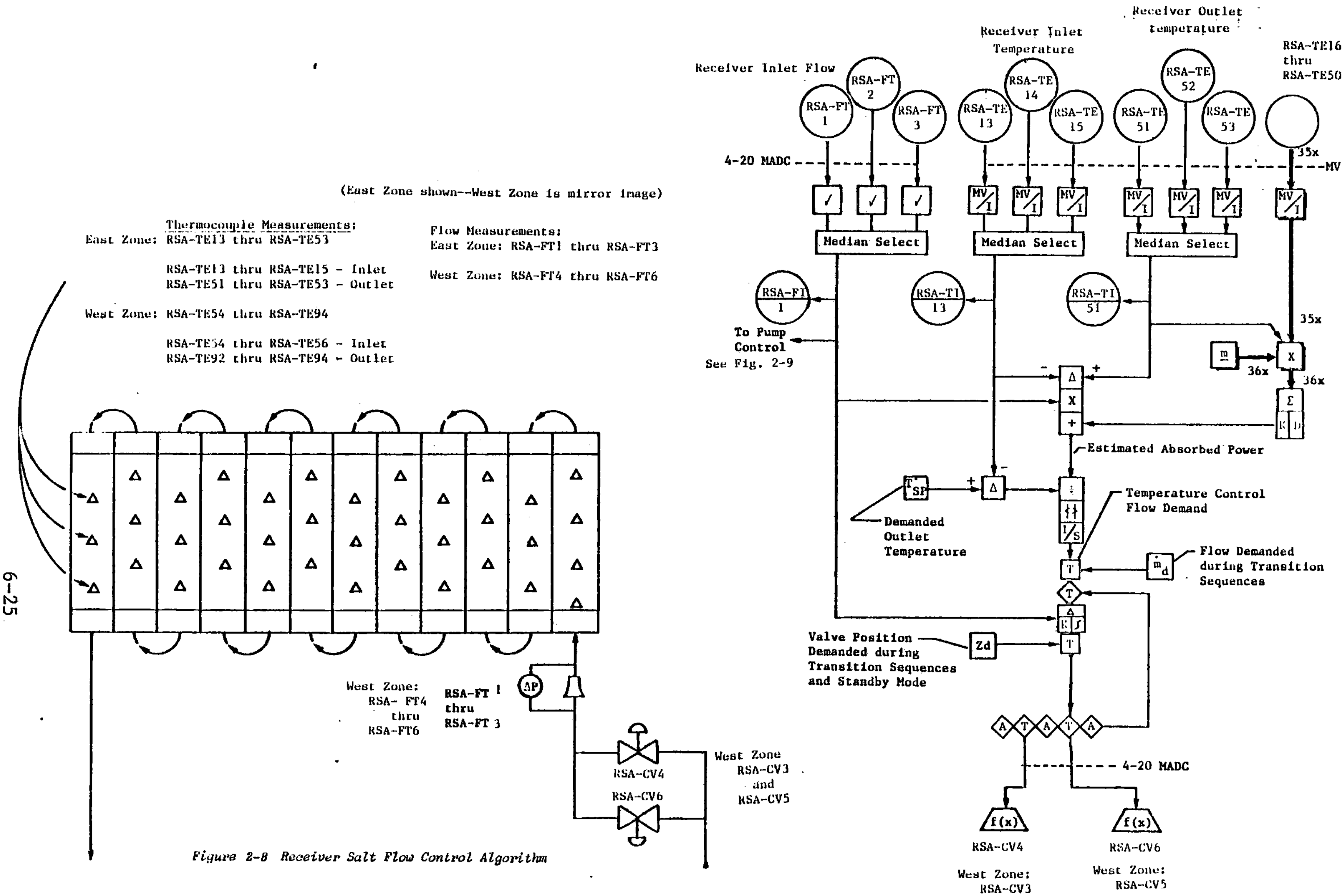


Figure 2-8 Receiver Salt Flow Control Algorithm

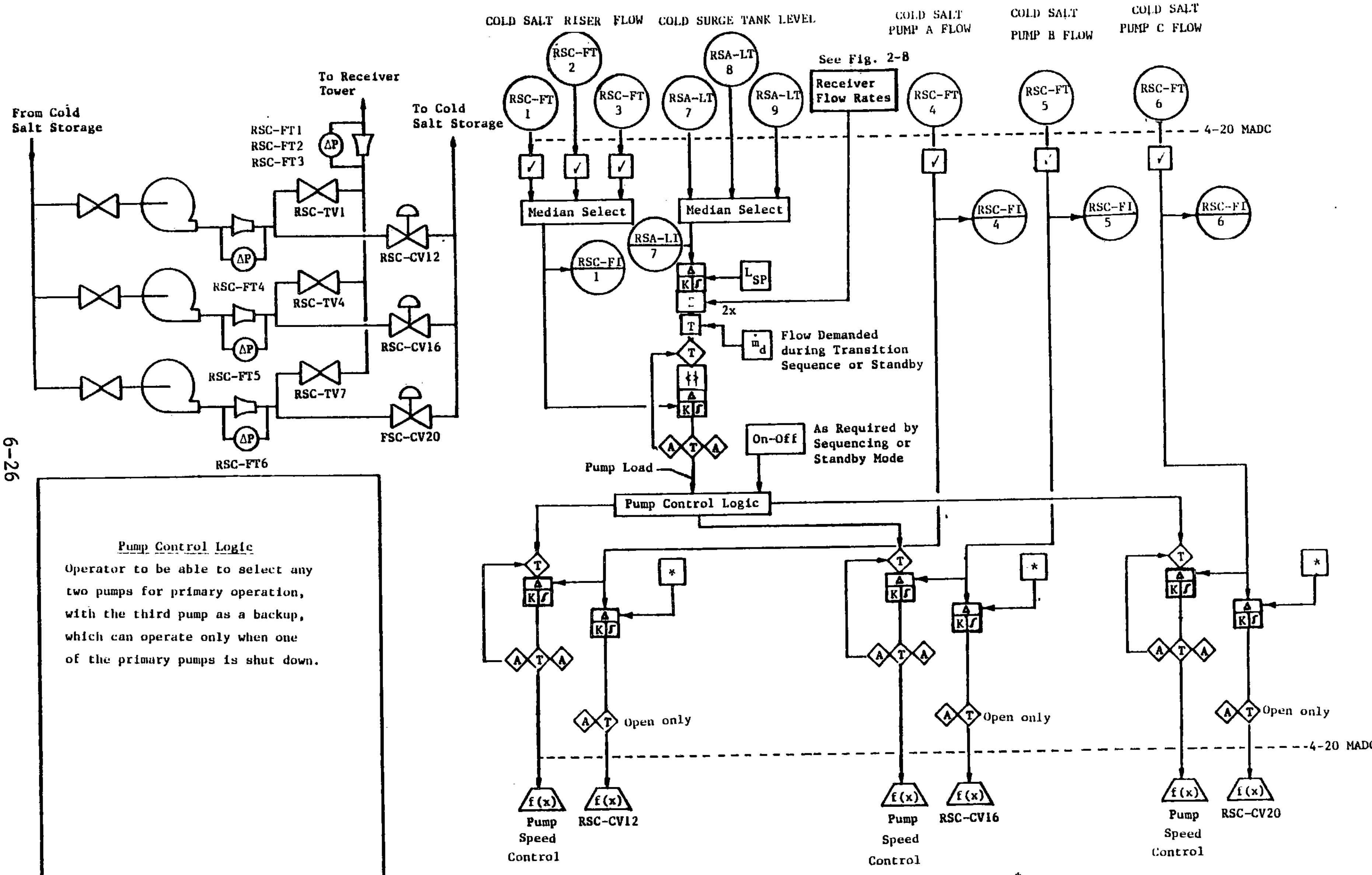
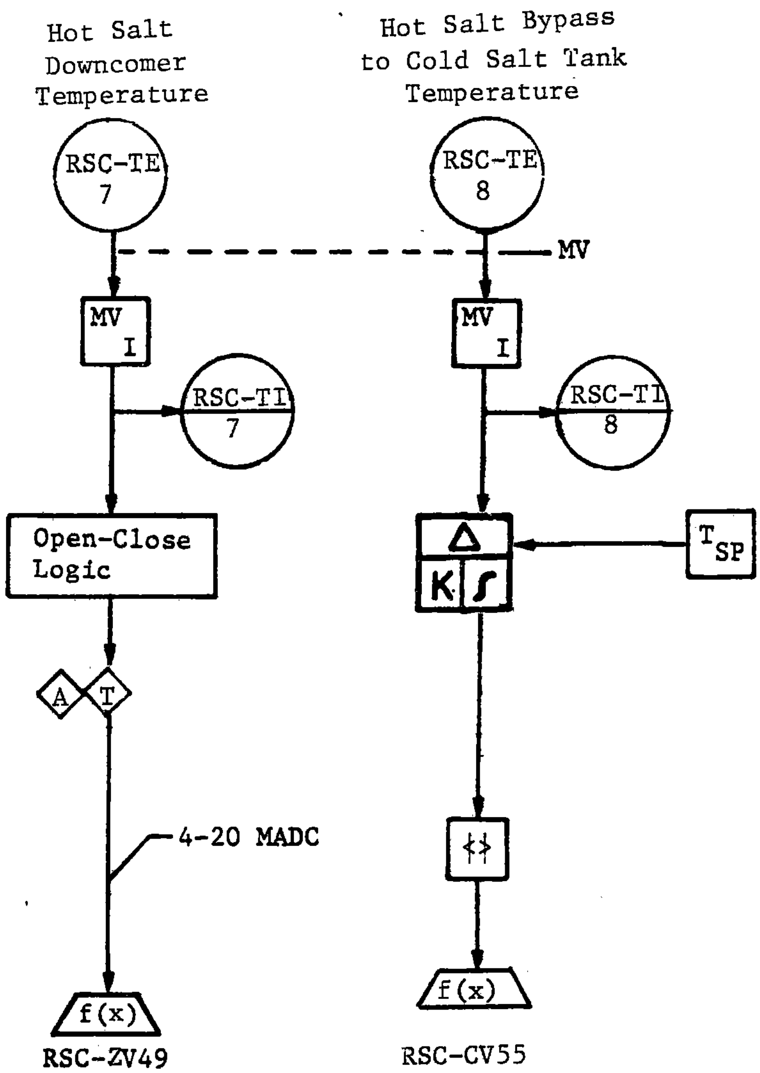


Figure 2-9 Cold Salt Pump Control Algorithm



Open-Close Logic:

RSC-TE7 $> T_{MAX}$ Open to Hot Salt Tank

RSC-TE7 $\leq T_{MIN}$ Open to Cold Salt Tank

Figure 2-10 Receiver Salt Return Control Algorithm

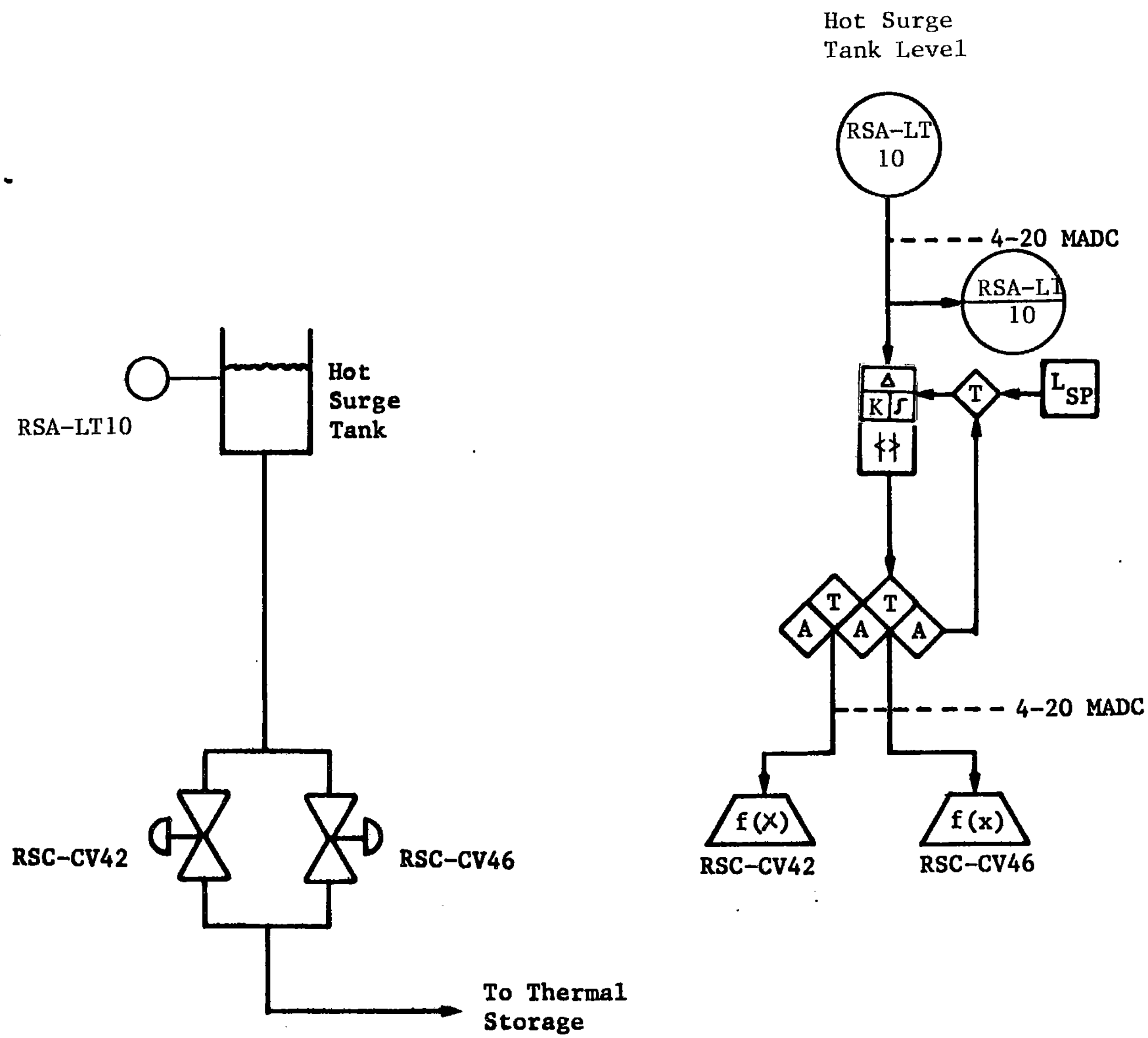


Figure 2-11 Hot Surge Tank Level Control Algorithm

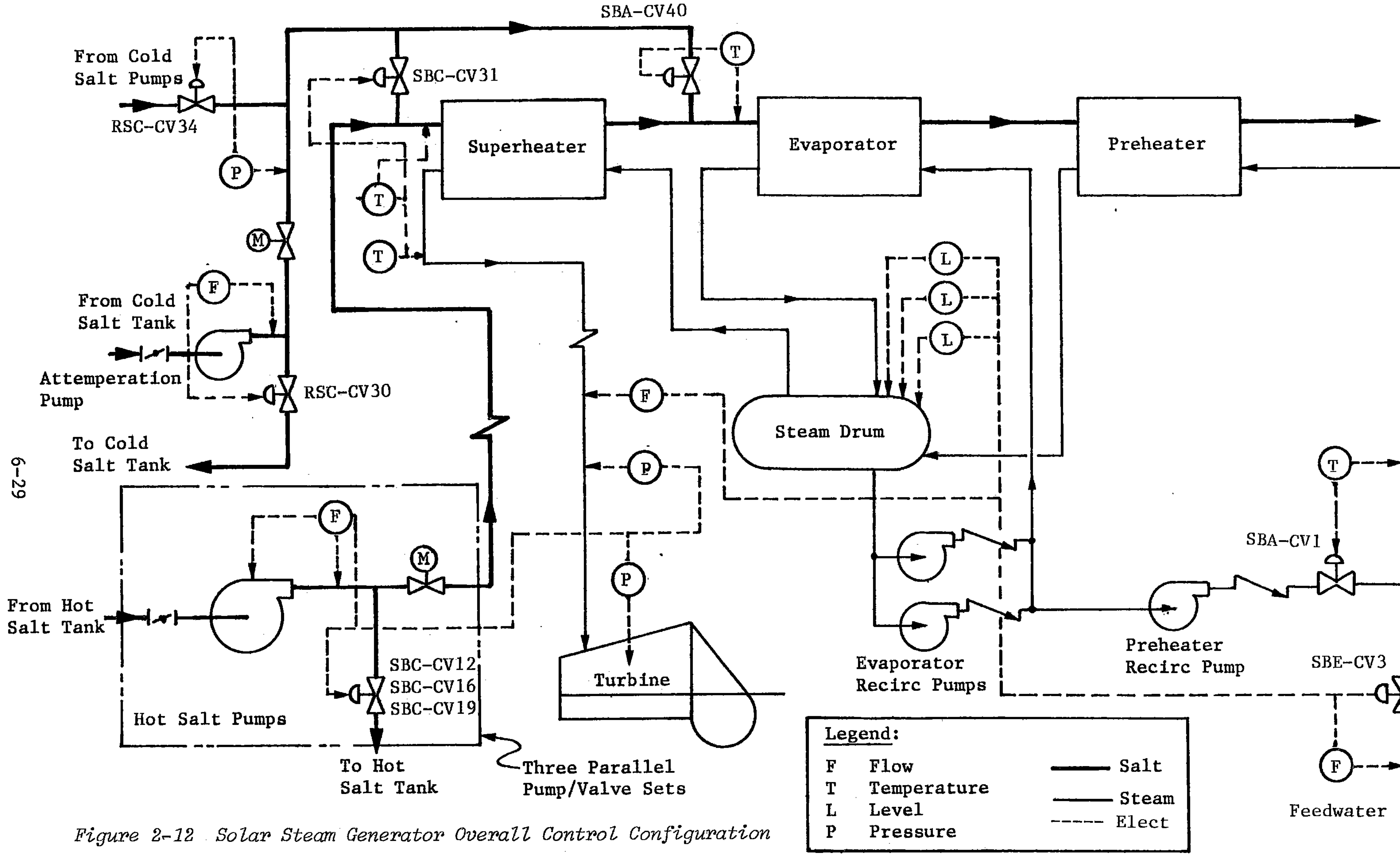


Figure 2-12 Solar Steam Generator Overall Control Configuration

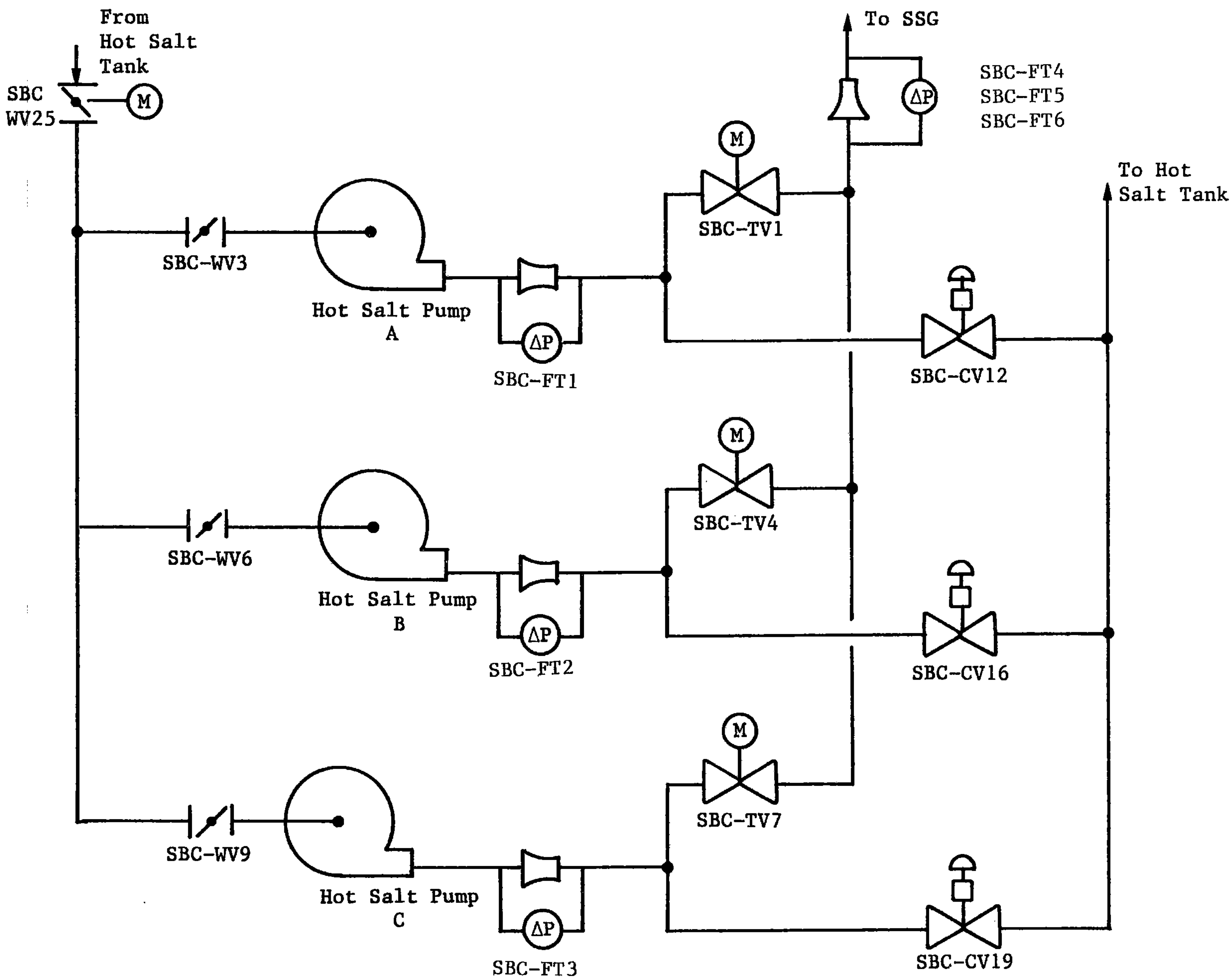


Figure 2-13 Hot Salt Pump Flow Diagram

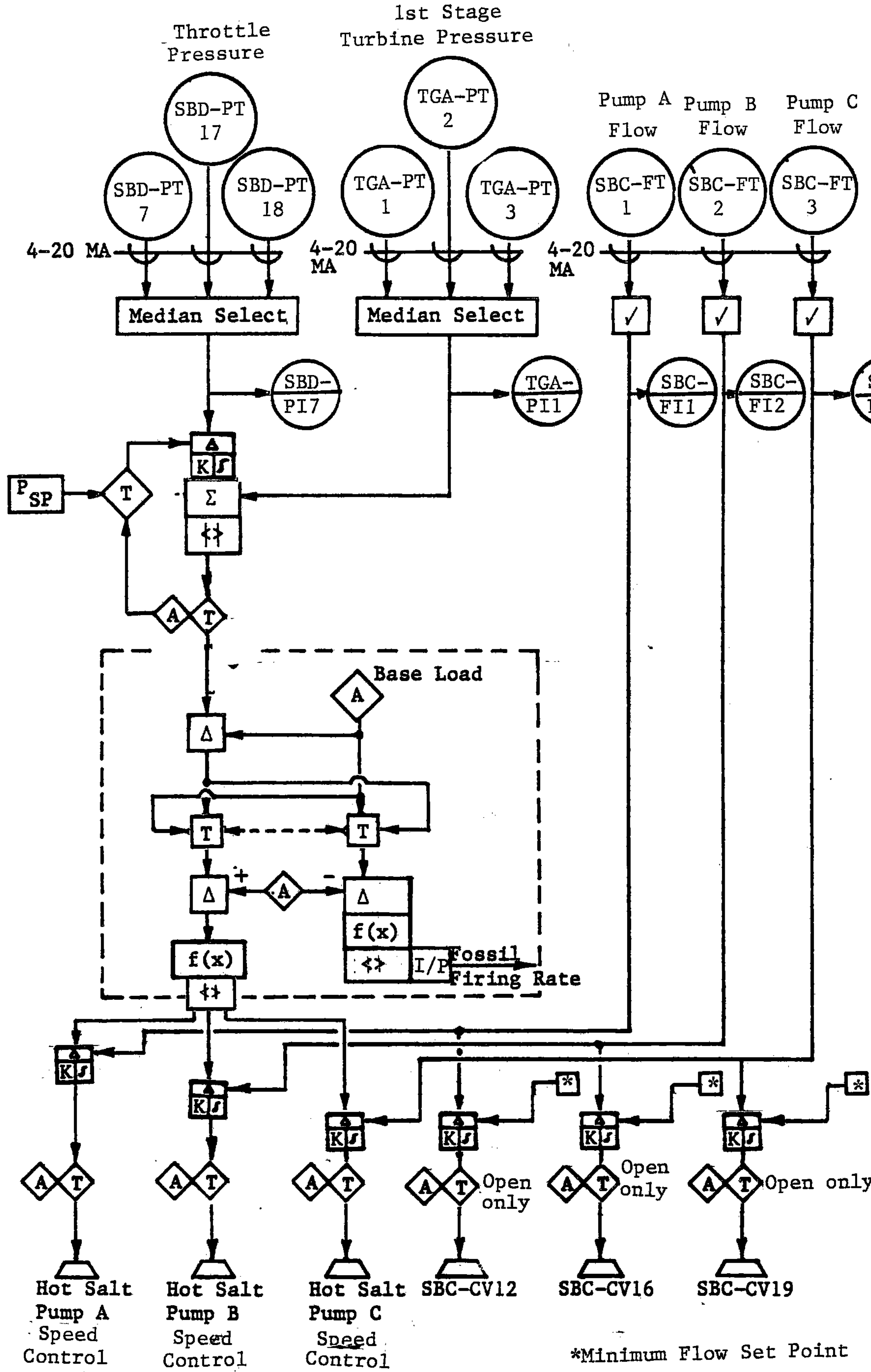


Figure 2-14 Hot Salt Pump Control Algorithm

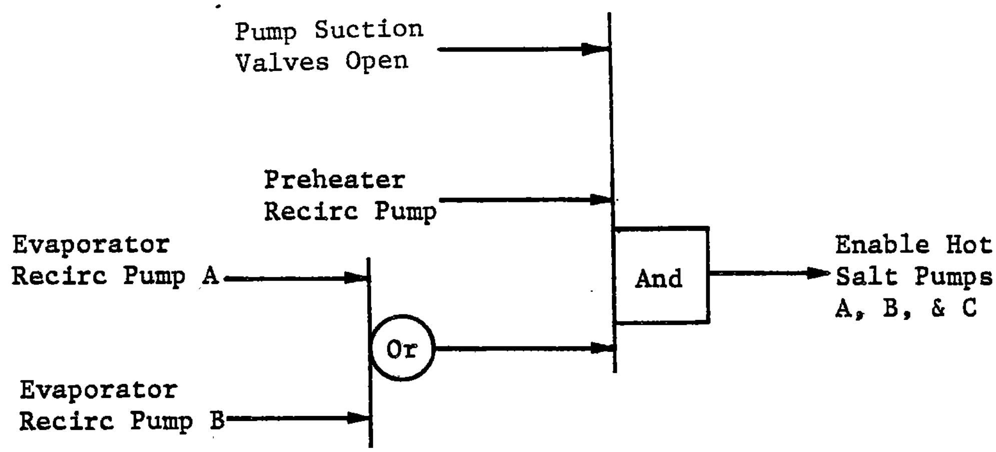


Figure 2-15 Hot Salt Pump Enable Logic

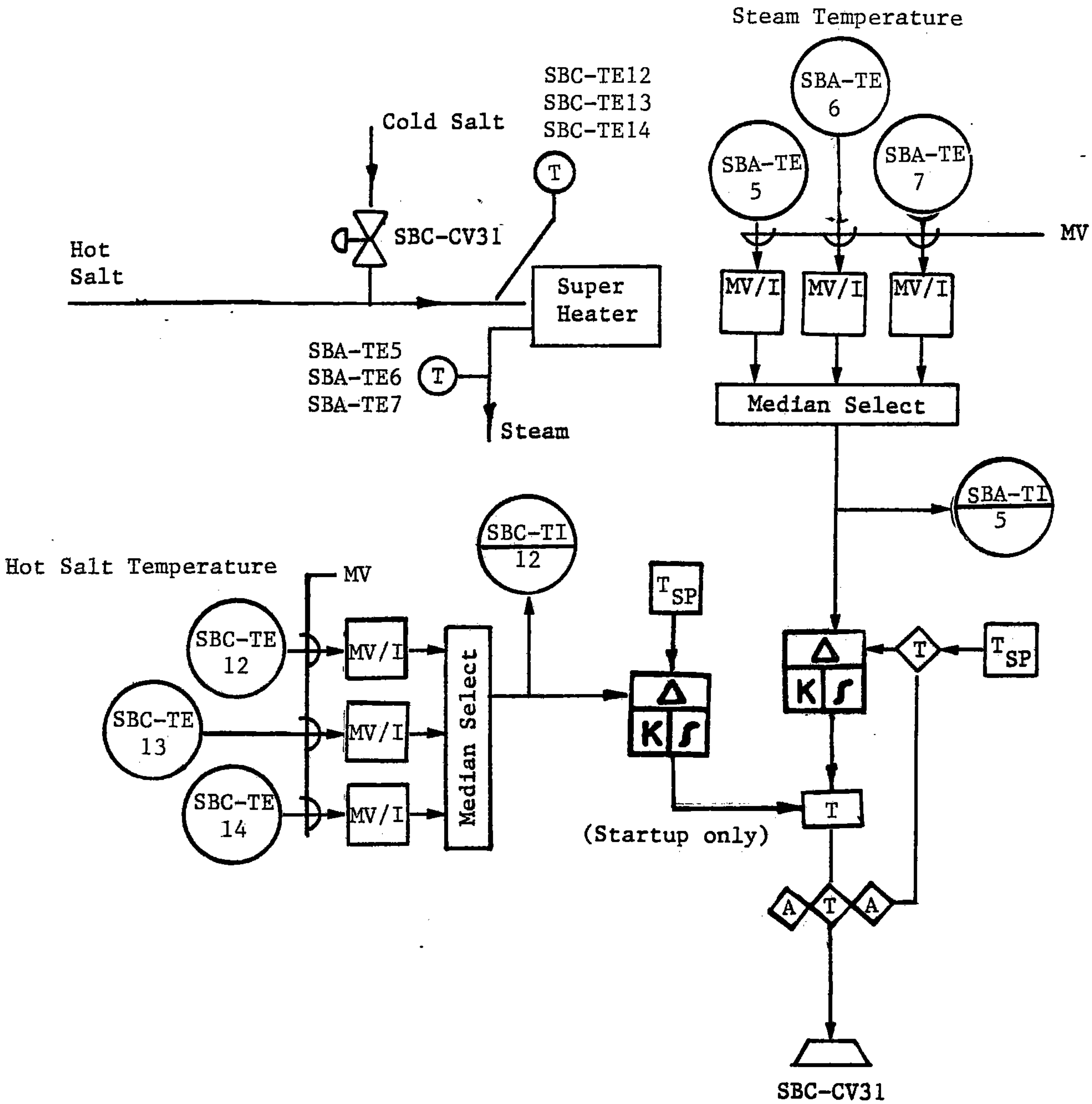


Figure 2-16 Superheated Steam Temperature Control Algorithm

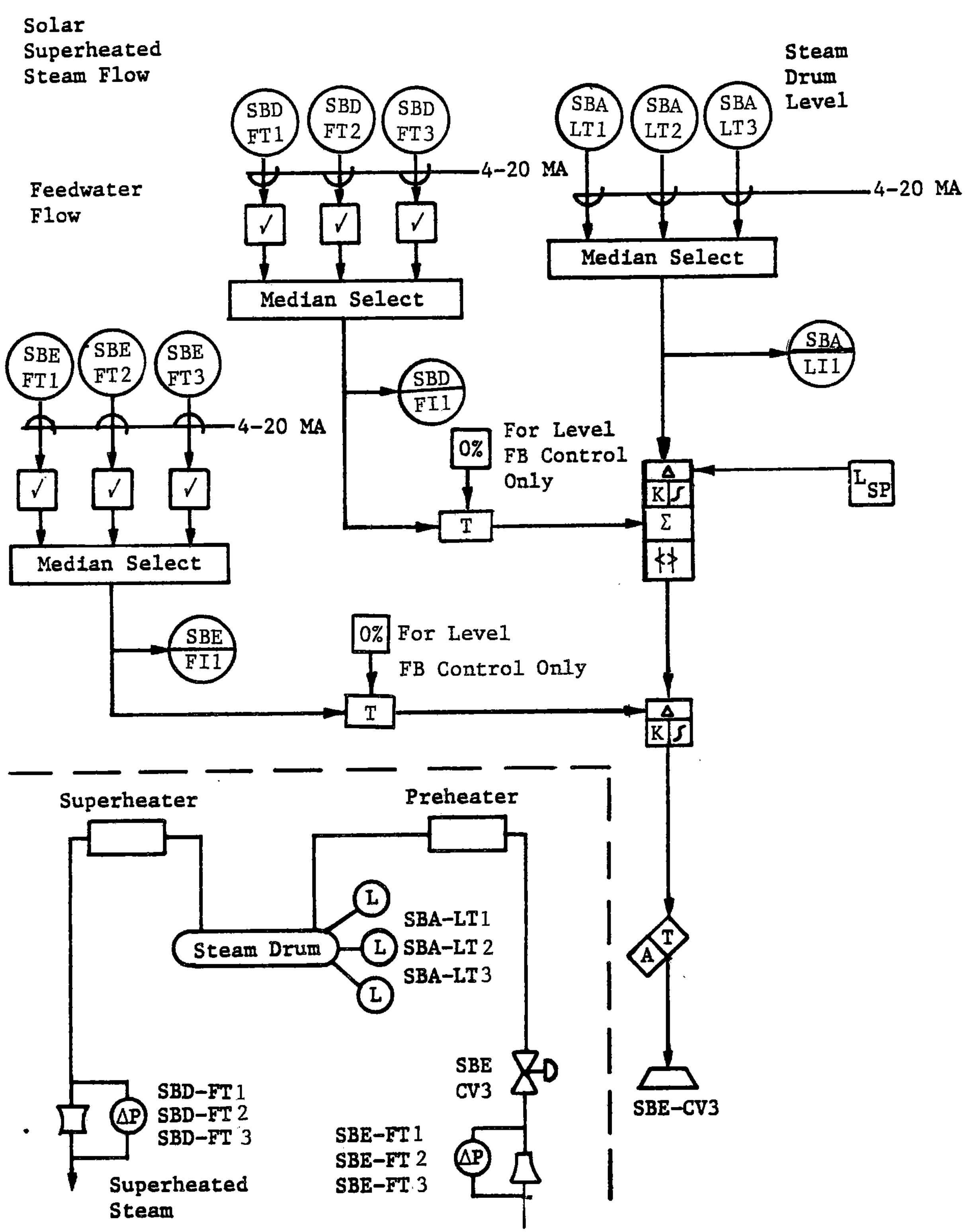


Figure 2-17 Steam Drum Level Control Algorithm

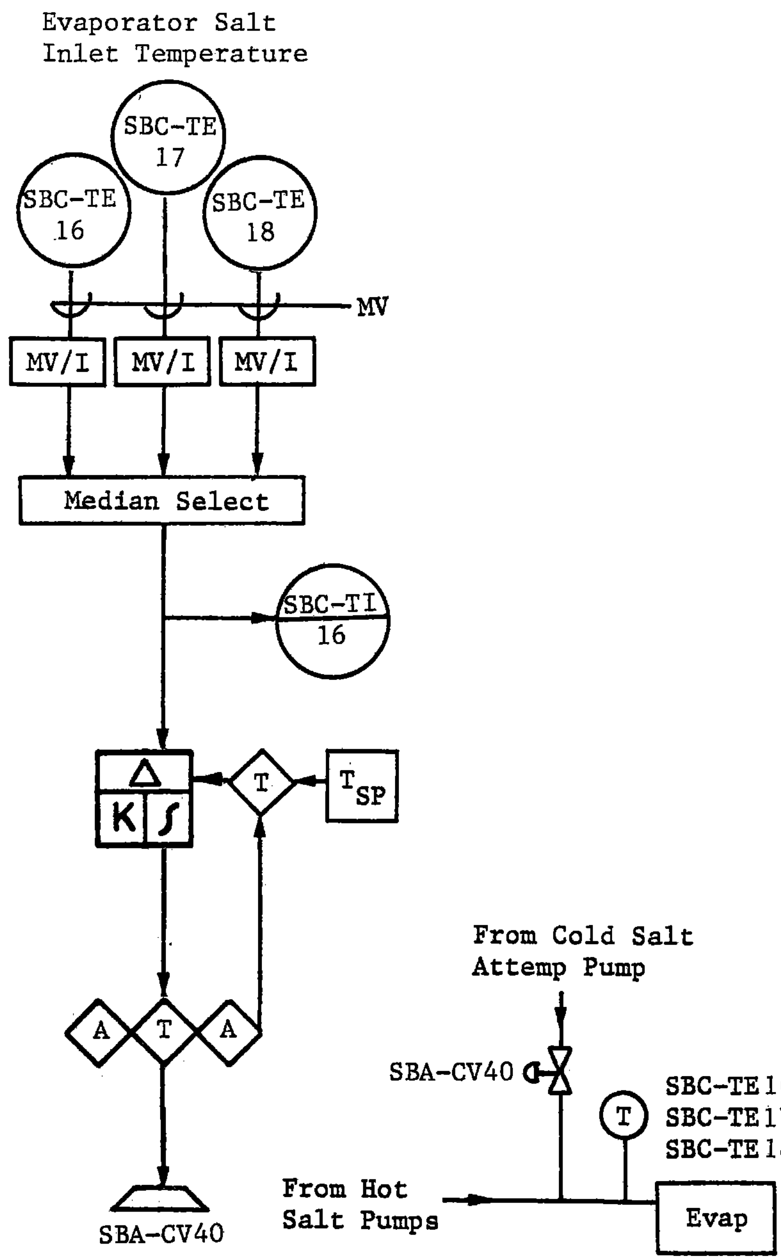
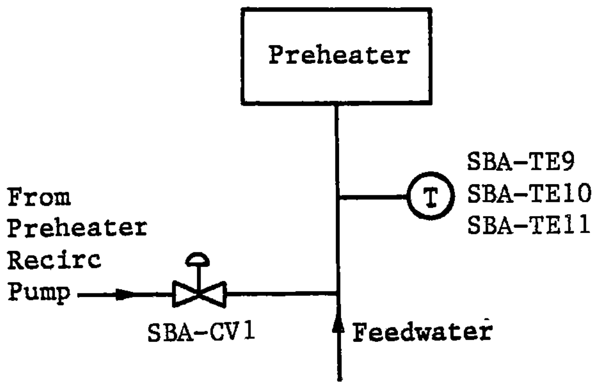


Figure 2-18 Evaporator Temperature Control Algorithm



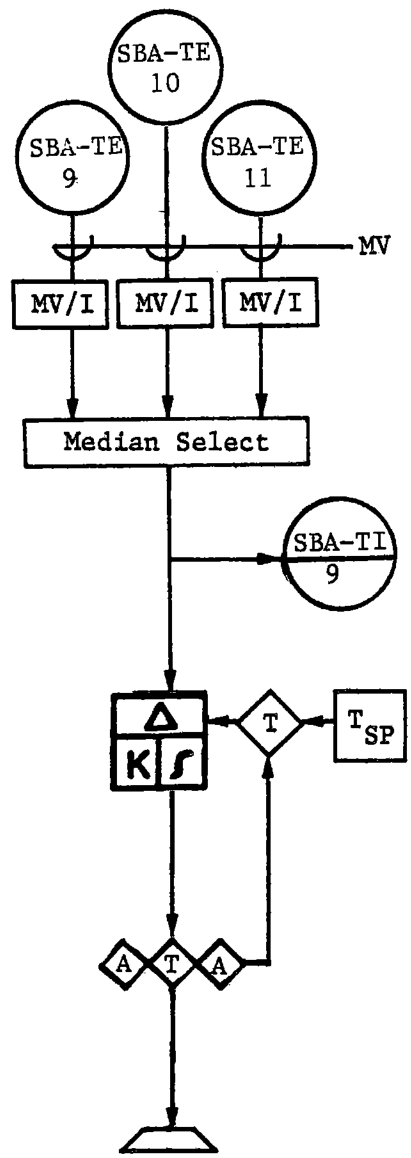
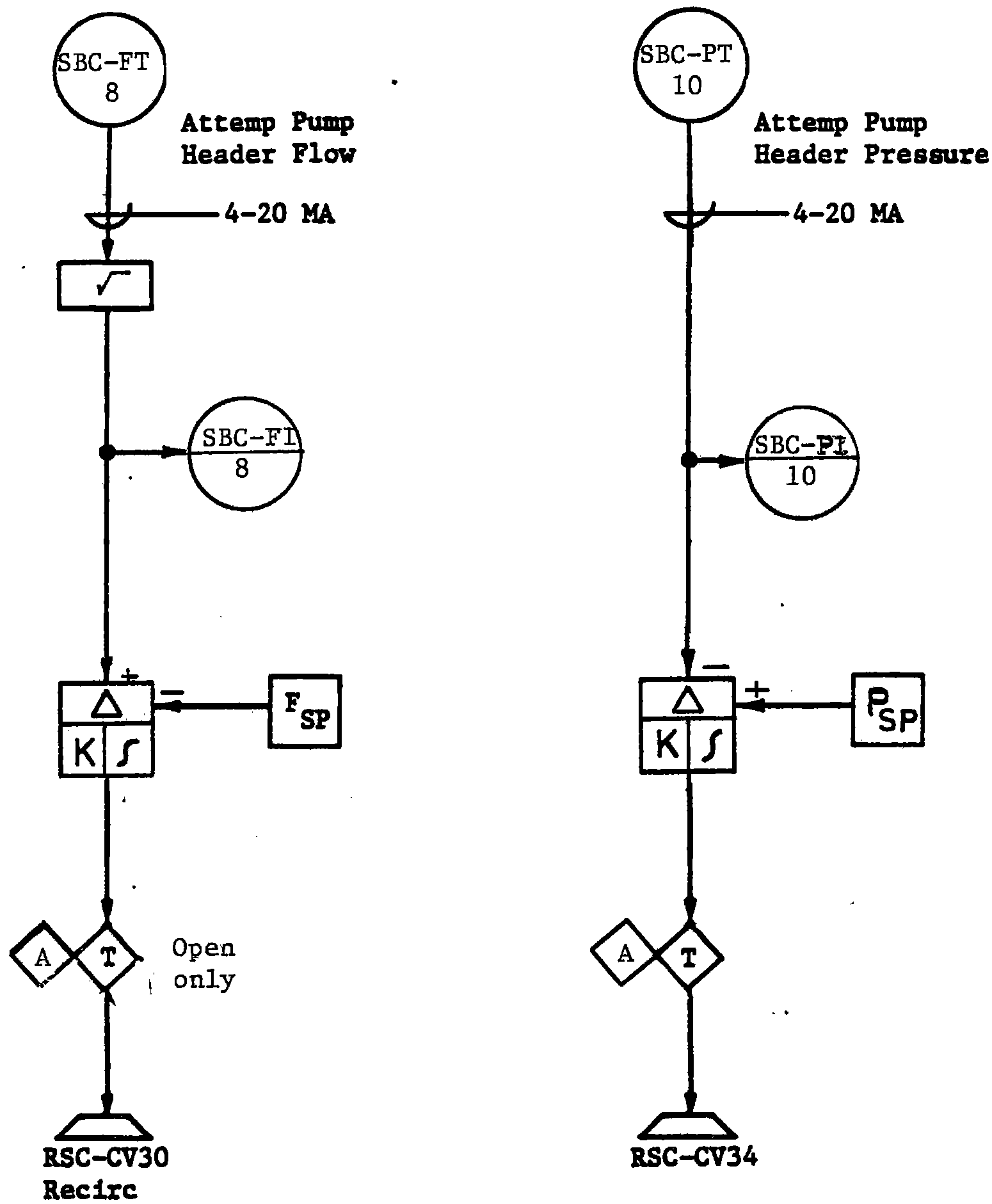


Figure 2-19 Preheater Inlet Water Temperature Control Algorithm



(a) Recirc Control *(b) Backup Control*

Figure 2-20 Attemperator Pump Recirculation Control and Attemperator Pump Backup Control Algorithm

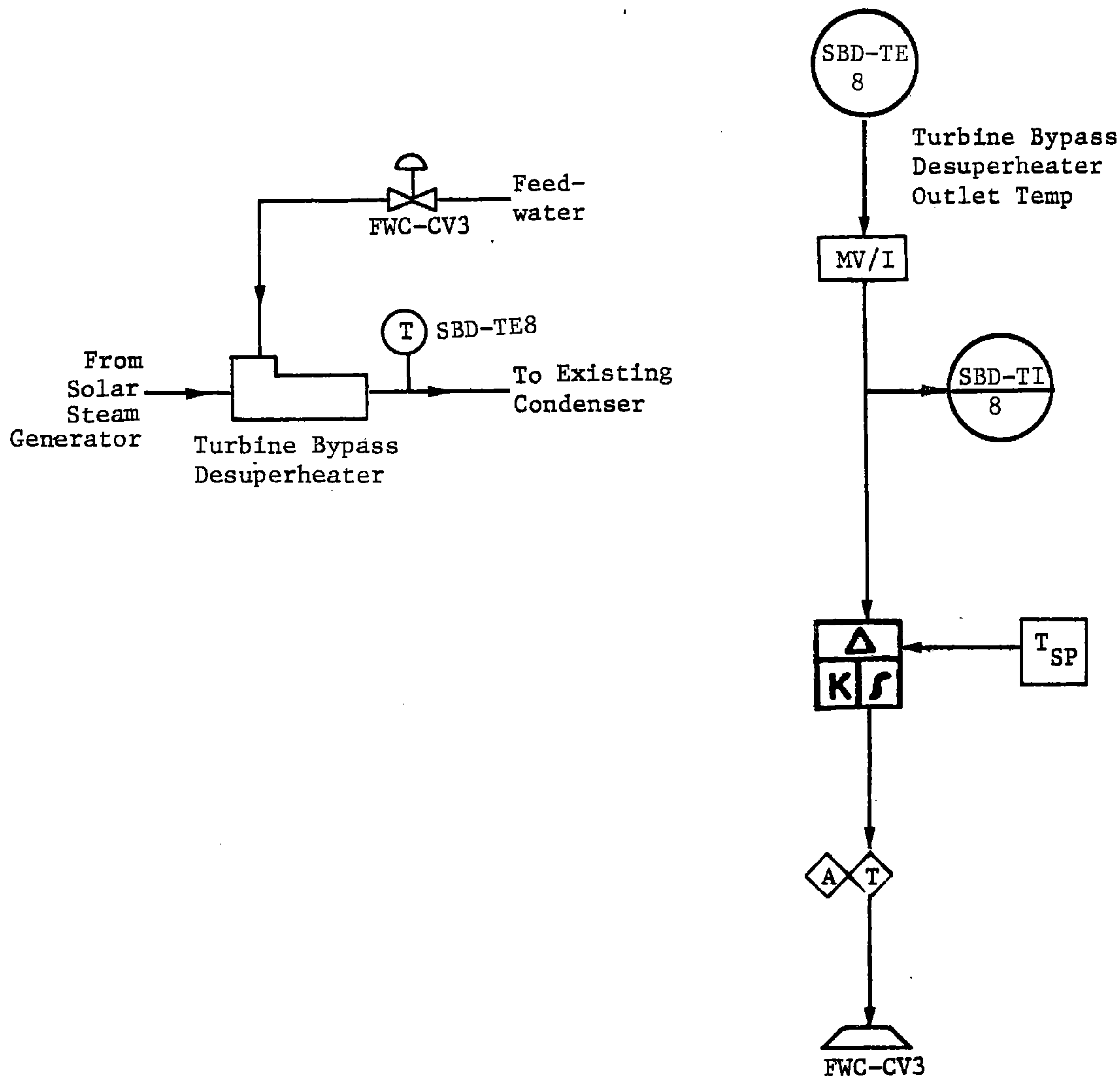
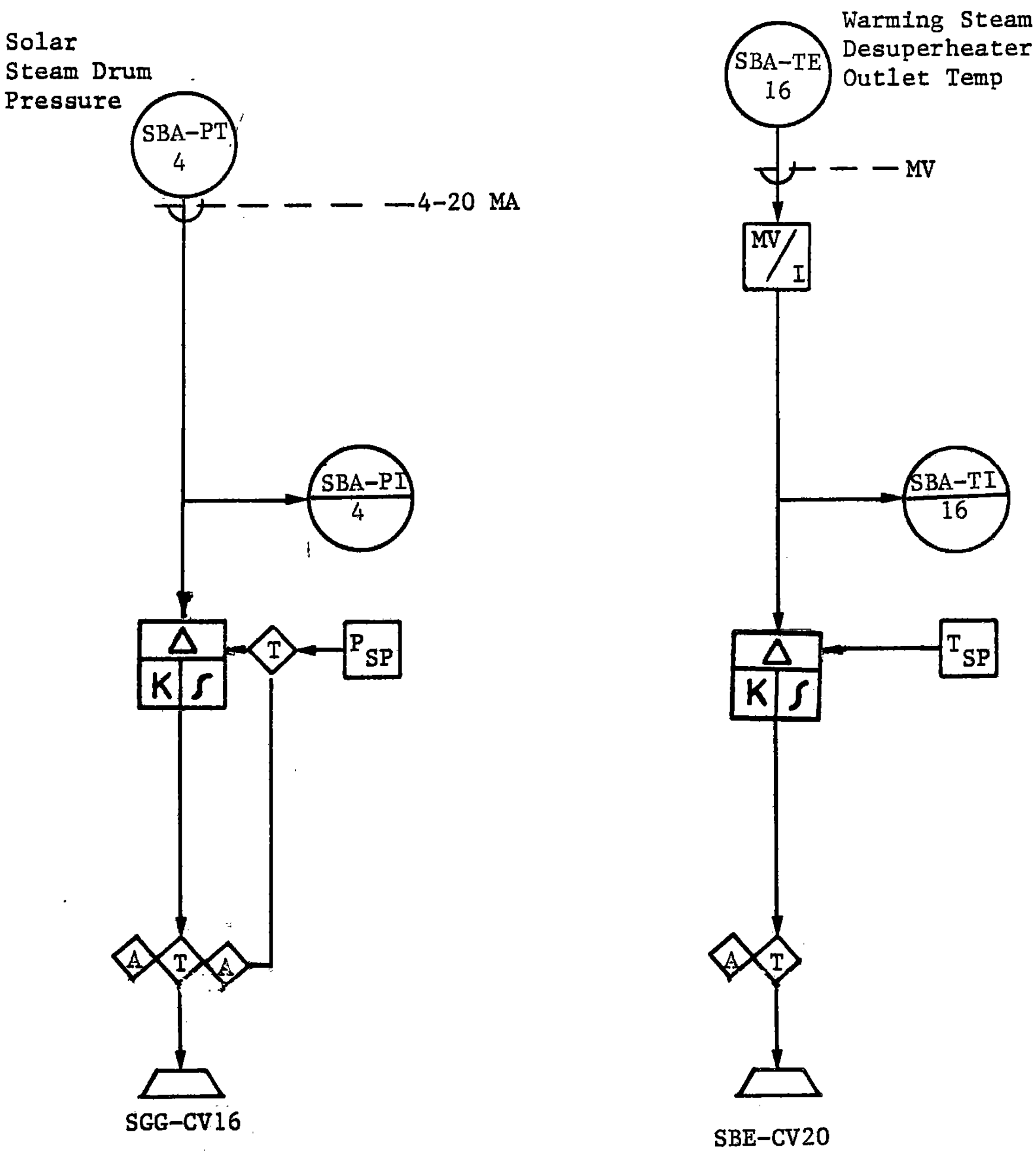


Figure 2-21 Turbine Bypass Control Algorithm



2-22(a)

Figure 2-22 Startup Warming Control Algorithm *2-22(b)*

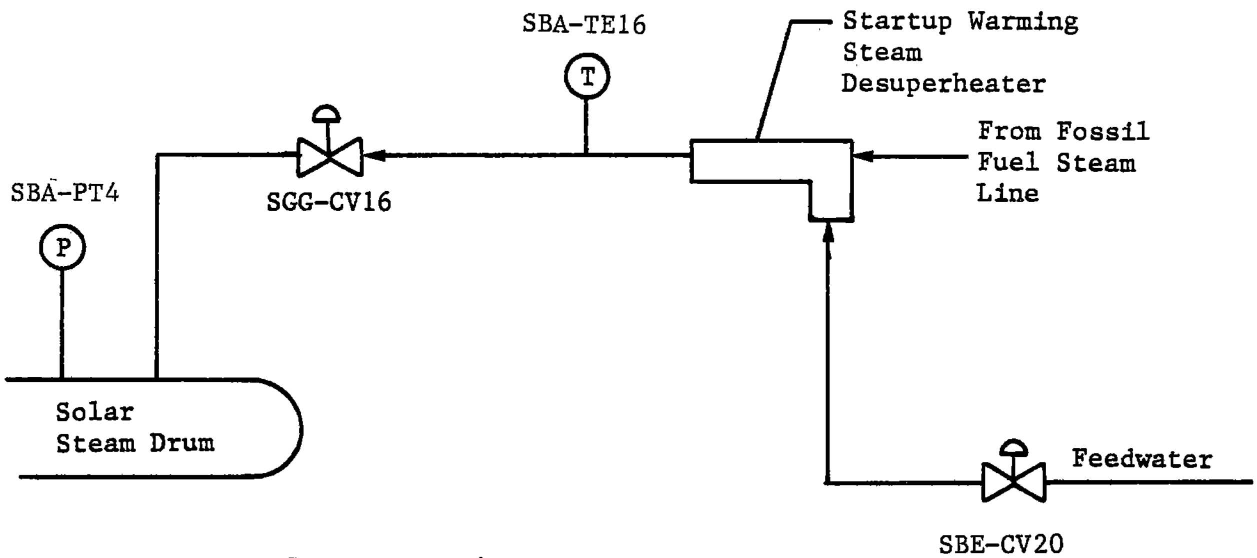
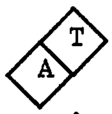


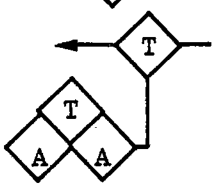
Figure 2-23 Startup Warming Flow Diagram

Control Function Notation

- Operator Requirements



Enables Operator Manual Control of Valve



Enables Operator Manual Control of Either Valve or Process Variable (by Manipulation of Set-Point).

- Control Algorithms

	High-Low Limiter
[+]	Addition
[x]	Multiplication
[÷]	Division
[Σ]	Sum All Inputs
[√]	Square Root Extraction
[MV/I]	Cold Junction Compensation
[1/s]	Filter
[T]	Automatic Transfer
◇T	Manual Transfer
→ nx	Parallel Input (N: Vector Size)
[(X) SP]	Set-Point from MCS

Figure 2-24 Control Function Notations

3.0 COMPONENT DESIGN CRITERIA—PROCESS CONTROL UNITS

3.1 COMPONENT IDENTIFICATION

1) Component Name - Process Control Units

2) System Code - COG

3) Purchase Specification - 64.0212

3.2 FUNCTION

The Master Control Process Control Units perform four functions: feedback control, data acquisition, digital logic control and communication with the rest of the Master Control System via digital data highways.

3.3 DESCRIPTION

The Master Control Process Control Units consist of one or more racks of electronic equipment including microcomputers and input/output circuits.

3.4 BOUNDARIES

Prefabricated cables connect the Process Control Units to the termination cabinets. Prefabricated data highways connect the Process Control Units to each other and to the rest of the Master Control System.

4.0 COMPONENT DESIGN CRITERIA--MASTER CONTROL TERMINATION CABINET(S)

4.1 COMPONENT IDENTIFICATION

Component Name - Master control Termination Cabinets

System Code - COG

Purchase Specification - 64.0212

4.2 FUNCTION

The Master Control Termination Cabinet(s) contains terminal blocks for connection of the input and output cables and, depending on system design, electrical connection devices to attach prefabricated cables.

4.3 DESCRIPTION

The Master Control Termination Cabinet(s) will contain no electronic system devices. Terminal blocks will be arranged to provide an area for field cabling which will be isolated from the area used for internal cabling. Terminal blocks will be mounted on "stand-offs" to move them away from the mounting plates forming a "trough" or wireway for the cables. Terminal blocks will be marked to provide easy identification of terminal points. The cabinet(s) will be provided with a light(s) and receptacle(s).

The termination cabinet(s) will be large enough to house the required terminal blocks allowing sufficient access to conveniently troubleshoot and maintain the system. In addition, 20 per cent spare terminal points will be provided in each modular section to permit future terminations if required.

The termination cabinet(s) will be painted gray on the exterior and glossy white on the interior.

4.4 CODES AND STANDARDS

1) NEMA Standards Publications IS 1.1, enclosure classification.

2) ANSI Z55.1-1967, Gray Finishes for Industrial Apparatus and Equipment.

4.5 MATERIAL SELECTION

The Master Control Termination Cabinet(s) will be constructed of 12 Ga. sheet steel. The doors should be removable to aid installation access. Indoor cabinets shall be NEMA 1 construction. Outdoor cabinets shall be either NEMA 3R or NEMA 4 construction.

4.6 TESTING

The Master Control Termination Cabinet(s) will be visually inspected for buckles in the metal, paint runs and sags, fit of the doors, and general quality of construction prior to shipment from the factory.

5.0 COMPONENT DESIGN CRITERIA—SOFTWARE

5.1 COMPONENT IDENTIFICATION

Component Name - Software

System code - COG

Purchase Specification - 64.0212

5.2 FUNCTION

The software supplied with the Master Control System will, in conjunction with the system hardware, provide the capability for performing real time control, data acquisition, displays, alarms, sequencing, interlocking, logging, sequence of event recording and data storage and retrieval.

5.3 DESCRIPTION

The software provided with the Master Control System will include real-time software that performs the control and data acquisition function and high level language software to assist the engineer in developing the specific programs required for the MCS. The high level language software will provide the capability for control engineers to implement the required functions in the Master Control System with little or no knowledge of software. These high level languages will provide the capability to: (1) develop control logic for feedback control using a library of standard control algorithms, (2) develop custom graphic displays using a library of standard process symbols (pumps, valves, etc.), (3) create headings and assign points to data logs, and (4) implement logic control and timing functions using ladder diagram or flow diagram techniques.

6.0 COMPONENT DESIGN CRITERIA--OPERATOR'S CONSOLE

6.1 COMPONENT IDENTIFICATION

Component Name - Operator's Console

System Code - COG

Purchase Specification - 64.0212

6.2 FUNCTION

The function of the Master Control System Operator's Console is to provide an interface between the operator and the plant. The console will provide easy and rapid access to plant information and control of the plant by an operator unfamiliar with the computer data organization.

The functional capability provided by the Operator's Console is also provided by the Master Control System Control Panel.

6.3 DESCRIPTION

The Operator's Console will be an integrated station consisting of a CRT display, a keyboard and a printer.

7.0 COMPONENT DESIGN CRITERIA--ENGINEER'S CONSOLE

7.1 COMPONENT IDENTIFICATION

Component Name - Engineer's Console

System Code - COG

Purchase Specification - 64.0212

7.2 FUNCTION

The function of the Master Control System Engineer's Console is to provide the capability for the control system engineers to accomplish control system configuration, program development, on-line data base modification and on-line program downloading to the Process Control Units. The Engineer's Console also performs all of the functions of the Operator's Console.

7.3 DESCRIPTION

The Engineer's Console will be an integrated station consisting of a CRT display, a keyboard and a printer.

8.0 COMPONENT DESIGN CRITERIA--LOGGER

8.1 COMPONENT IDENTIFICATION

Component Name - Logger

System code - COG

Purchase Specification - 64.0212

8.2 FUNCTION

The function of the Master Control System Logger is to collect, format and print process data. The types of logs that can be provided will include shift summaries, sequence of events, alarm summaries, and equipment operation logs.

8.3 DESCRIPTION

The Logger will include a medium or high speed printer and the necessary electronics to interface with the distributed digital control system.

9.0 COMPONENT DESIGN CRITERIA--DATA STORAGE AND RETRIEVAL UNIT

9.1 COMPONENT IDENTIFICATION

Component Name - Data Storage and Retrieval Unit

System Code - COG

Purchase Specification - 64.0212

9.2 FUNCTION

The function of the Master Control System Data Storage and Retrieval Unit is to collect and store process data for later retrieval and analysis.

9.3 DESCRIPTION

The Data Storage and Retrieval Unit will include a magnetic tape unit or other suitable means for recording process data in a form suitable for long-term retention. The Data Storage and Retrieval Unit will also include the necessary electronics to interface with the distributed digital control system.

The Data Storage and Retrieval Unit shall also include a magnetic tape storage unit suitable for use with an IBM 3081 Computer.

10.0 INPUT/OUTPUT SUMMARY

A. Control Room

1.	Total Digital Input	166
2.	Total Digital Output	157
3.	Total Analog Input	50
4.	Total Analog Output	82

B. Receiver

1.	Total Digital Input	44
2.	Total Digital Output	33
3.	Total Analog Input	199
	including: a. Thermocouple (MV)	181
	b. Flow ($\sqrt{\ }$)	6
4.	Total Analog Output	6

C. Thermal Storage

1.	Total Digital Input	107
2.	Total Digital Output	67
3.	Total Analog Input	244
	including: a. Thermocouple (MV)	185
	b. Flow ($\sqrt{\ }$)	14
4.	Total Analog Output	16

D. Solar Steam Generator

1.	Total Digital Input	43
2.	Total Digital Output	34
3.	Total Analog Input	166
	including: a. Thermocouple (MV)	142
	b. Flow ($\sqrt{\ }$)	6
4.	Total Analog Output	7

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
RSC-FI1	Cold Salt Riser Flow	Control Panel	4-20 MA
RSC-FI4	Cold Salt Pump A Flow	Control Panel	4-20 MA
RSC-FI5	Cold Salt Pump B Flow	Control Panel	4-20 MA
RSC-FI6	Cold Salt Pump C Flow	Control Panel	4-20 MA
RSA-FI1	Rec East Pass Flow	Control Panel	4-20 MA
RSA-FI4	Rec West Pass Flow	Control Panel	4-20 MA
RSA-PI12	Cold Surge Tank Press	Control Panel	4-20 MA
RSA-TI54	West Pass Inlet Temp	Control Panel	4-20 MA
RSA-TI92	West Pass Outlet Temp	Control Panel	4-20 MA
RSA-TI13	East Pass Inlet Temp	Control Panel	4-20 MA
RSA-TI51	East Pass Outlet Temp	Control Panel	4-20 MA
RSA-TI7	Hot Salt Downcomer Temp	Control Panel	4-20 MA
RSA-LI10	Hot Surge Tank Level	Control Panel	4-20 MA
RSA-PI11	Hot Surge Tank Press	Control Panel	4-20 MA
RSA-PI131	Recirc Pump Outlet Press	Control Panel	4-20 MA
CAD-PI1	Solar Receiver A Air Press	Control Panel	4-20 MA
CAD-PI2	Solar Receiver B Air Press	Control Panel	4-20 MA
RSA-TI8	Cold Salt Return Temp	Control Panel	4-20 MA
SBA-TI5	Super Htr Outlet Steam Temp	Control Panel	4-20 MA

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
SBC-TI12	Super Htr Inlet Salt Temp	Control Panel	4-20 MA
SBC-TI16	Evap Inlet Salt Temp	Control Panel	4-20 MA
SBC-TI18	Preheater Inlet Salt Temp	Control Panel	4-20 MA
SBE-TI5	Feedwater Temp	Control Panel	4-20 MA
SBD-TI9	Feedwater to Prehtr Temp	Control Panel	4-20 MA
SBA-LI1	Steam Drum Level	Control Panel	4-20 MA
SBA-PI4	Steam Drum Pressure	Control Panel	4-20 MA
	Steam Drum Temp	Control Panel	4-20 MA
SBC-FI4	Hot Salt To Super Htr Flow	Control Panel	4-20 MA
SBC-PI9	Hot Salt Disch. Header Press	Control Panel	4-20 MA
SBC-FI1	Hot Salt Pump A Flow	Control Panel	4-20 MA
SBC-FI2	Hot Salt Pump B Flow	Control Panel	4-20 MA
SBC-FI3	Hot Salt Pump C Flow	Control Panel	4-20 MA
SBC-FI8	Attemp Pump Header Flow	Control Panel	4-20 MA
SBC-FI7	Attemp Pump Flow	Control Panel	4-20 MA
TGA-PI1	Turbine First Stage Pressure	Control Panel	4-20 MA
SBD-PI7	Solar Steam Throttle Press	Control Panel	4-20 MA
SBA-TI12	Preheater Outlet Temp	Control Panel	4-20 MA
ESA-LI1	Hot Salt Storage Tank Level	Control Panel	4-20 MA

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
ESB-LI1	Cold Salt Storage Tank Level	Control Panel	4-20 MA
ESC-LI1	Molten Salt Drain Sump A Level	Control Panel	4-20 MA
ESC-LI4	Molten Salt Drain Sump B Level	Control Panel	4-20 MA
	West Pass Salt Flow Cont	Control Panel	4-20 MA
	East Pass Salt Flow Cont	Control Panel	4-20 MA
	HST Level Control	Control Panel	4-20 MA
	Cold Salt Pump Load Control	Control Panel	4-20 MA
	Cold Salt Pump A Control	Control Panel	4-20 MA
	Cold Salt Pump B Control	Control Panel	4-20 MA
	Cold Salt Pump C Control	Control Panel	4-20 MA
H/A Switches	Cold Salt Recirc Valve A Control	Control Panel	4-20 MA
	Cold Salt Recirc Valve B Control	Control Panel	4-20 MA
	Cold Salt Recirc Valve C Control	Control Panel	4-20 MA
	Hot Salt Return 3-Way Valve	Control Panel	4-20 MA
	Hot Salt Pump Load Control	Control Panel	4-20 MA
	Hot Salt Pump A Control	Control Panel	4-20 MA
	Hot Salt Pump B Control	Control Panel	4-20 MA
	Hot Salt Pump C Control	Control Panel	4-20 MA

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
	Hot Salt Recirc Valve A Control	Control Panel	4-20 MA
	Hot Salt Recirc Valve B Control	Control Panel	4-20 MA
	Hot Salt Recirc Valve C Control	Control Panel	4-20 MA
	Steam Drum Level Control		
	Superheated Steam Temp Control	Control Panel	4-20 MA
	Evaporator Temp. Control	Control Panel	4-20 MA
	Preheater Inlet Water Temp. Control	Control Panel	4-20 MA
	Attemp Pump Recirc Control	Control Panel	4-20 MA
	Attemp Pump Bypass Control	Control Panel	4-20 MA
	Turbine Bypass Control	Control Panel	4-20 MA
	Startup Warming Control	Control Panel	4-20 MA
	Startup Warming Desuperheater Control	Control Panel	4-20 MA
RSA-LI7	Cold Surge Tank Level	Control Panel	4-20 MA
RSA-TI96	Cold Surge Tank Temp	Control Panel	4-20 MA
RSA-TI95	Hot Surge Tank Temp	Control Panel	4-20 MA
	Molten Salt Sump Pumps Temp	Control Panel	4-20 MA
SBE-FI1	Feedwater Flow	Control Panel	4-20 MA
SBD-FI1	Superheated Steam Flow	Control Panel	4-20 MA

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
SBC-TI11	Hot Salt Header Temp	Control Panel	4-20 MA
SBC-TI19	Attemp Pump Header Temp	Control Panel	4-20 MA
SBC-PI10	Attemp Pump Header Pressure	Control Panel	4-20 MA
SBA-TI8	Superheater Inlet Steam Temp	Control Panel	4-20 MA
SBA-TI13	Evap Recirc Pump A Inlet Temp.	Control Panel	4-20 MA
SBA-TI14	Evap Recirc Pump B Inlet Temp.	Control Panel	4-20 MA
SBD-TI8	Turbine Bypass Desuperheater Temp.	Control Panel	4-20 MA
SBA-TI16	Startup Warming Desuperheater Temp.	Control Panel	4-20 MA
SBE-PI4	Feedwater Pressure	Control Panel	4-20 MA
RSC-ZI31	RSC-TV61 Open	Control Panel	On/Off
RSC-ZI32	RSC-TV61 Closed	Control Panel	On/Off
	Air Compressor Running	Control Panel	On/Off
RSC-ZI9	RSC-TV1 Open	Control Panel	On/Off
RSC-ZI10	RSC-TV1 Closed	Control Panel	On/Off
RSC-ZI13	RSC-TV4 Open	Control Panel	On/Off
RSC-ZI14	RSC-TV4 Closed	Control Panel	On/Off
RSC-ZI17	RSC-TV7 Open	Control Panel	On/Off
RSC-ZI18	RSC-TV7 Closed	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
RSC-ZI35	RSC-TV39 Open	Control Panel	On/Off
RSC-ZI36	RSC-TV39 Closed	Control Panel	On/Off
RSCZI-37	RSC-TV40 Open	Control Panel	On/Off
RSC-ZI38	RSC-TV40 Closed	Control Panel	On/Off
RSC-ZI33	RSC-TV38 Open	Control Panel	On/Off
RSC-ZI34	RSC-TV38 Closed	Control Panel	On/Off
	Recirc Pump Valve Open	Control Panel	On/Off
	Recirc Pump Valve Closed	Control Panel	On/Off
RSC-ZI43	RSC-ZV49 To Hot Salt Tank	Control Panel	On/Off
RSC-ZI44	RSC-ZV49 To Cold Salt Tank	Control Panel	On/Off
RSA-ZI99	East Zone Fill Valves Open	Control Panel	On/Off
RSA-ZI100	East Zone Fill Valves Closed	Control Panel	On/Off
RSA-ZI101	East Vent Valve 1 Open	Control Panel	On/Off
RSC-ZI56	RSC-TV60 Open	Control Panel	On/Off
RSC-ZI57	RSC-TV60 Closed	Control Panel	On/Off
RSA-ZI102	East Vent Value 1 Closed	Control Panel	On/Off
RSA-ZI103	East Vent Valve 2 Open	Control Panel	On/Off
RSA-ZI104	East Vent Valve 2 Closed	Control Panel	On/Off
RSA-ZI105	East Vent Valve 3 Open	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
RSA-ZI106	East Vent Valve 3 Closed	Control Panel	On/Off
RSA-ZI107	East Vent Valve 4 Open	Control Panel	On/Off
RSA-ZI108	East Vent Valve 4 Closed	Control Panel	On/Off
RSA-ZI109	East Vent Valve 5 Open	Control Panel	On/Off
RSA-ZI110	East Vent Valve 5 Closed	Control Panel	On/Off
RSA-ZI111	East Vent Valve 6 Open	Control Panel	On/Off
RSA-ZI112	East Vent Valve 6 Closed	Control Panel	On/Off
RSA-ZI113	West Zone Fill Valves Open	Control Panel	On/Off
RSA-ZI114	West Zone Fill Valves Closed	Control Panel	On/Off
RSA-ZI115	West Vent Valve 1 Open	Control Panel	On/Off
RSA-ZI116	West Vent Valve 1 Closed	Control Panel	On/Off
RSA-ZI117	West Vent Valve 2 Open	Control Panel	On/Off
RSA-ZI118	West Vent Valve 2 Closed	Control Panel	On/Off
RSA-ZI119	West Vent Valve 3 Open	Control Panel	On/Off
RSA-ZI120	West Vent Valve 3 Closed	Control Panel	On/Off
RSA-ZI121	West Vent Valve 4 Open	Control Panel	On/Off
RSA-ZI122	West Vent Valve 4 Closed	Control Panel	On/Off
RSA-ZI123	West Vent Valve 5 Open	Control Panel	On/Off
RSA-ZI124	West Vent Valve 5 Closed	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
RSA-ZI125	West Vent Valve 6 Open	Control Panel	On/Off
RSA-ZI126	West Vent Valve 6 Closed	Control Panel	On/Off
RSC-ZI47	RSC-TV62 Open	Control Panel	On/Off
RSC-ZI48	RSC-TV62 Closed	Control Panel	On/Off
RSC-ZI21	RSC-TV21 Open	Control Panel	On/Off
RSC-ZI22	RSC-TV21 Closed	Control Panel	On/Off
RSC-ZI23	RSC-TV22 Open	Control Panel	On/Off
RSC-ZI24	RSC-TV22 Closed	Control Panel	On/Off
RSC-ZI26	RSC-TV23 Open	Control Panel	On/Off
RSC-ZI25	RSC-TV23 Closed	Control Panel	On/Off
RSC-ZI27	RSC-TV24 Open	Control Panel	On/Off
RSC-ZI28	RSC-TV24Closed	Control Panel	On/Off
RSC-ZI29	RSC-TV25 Open	Control Panel	On/Off
RSC-ZI30	RSC-TV25 Closed	Control Panel	On/Off
RSC-ZI45	RSC-TV50 Open	Control Panel	On/Off
RSC-ZI46	RSC-TV50 Closed	Control Panel	On/Off
RSC-ZI39	RSC-TV43 Open	Control Panel	On/Off
RSC-ZI40	RSC-TV43 Closed	Control Panel	On/Off
RSC-ZI41	RSC-TV47 Open	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
RSC-ZI42	RSC-TV47 Closed	Control Panel	On/Off
	Recirc Pump Running	Control Panel	On/Off
	Door Open	Control Panel	On/Off
	Door Closed	Control Panel	On/Off
ESD-ZI5	ESD-TV10 Open	Control Panel	On/Off
ESC-ZI6	ESD-TV10 Closed	Control Panel	On/Off
ESD-ZI7	ESD-TV11 Open	Control Panel	On/Off
ESD-ZI8	ESD-TV11 Closed	Control Panel	On/Off
ESC-ZI22	ESC-TV1 Open	Control Panel	On/Off
ESC-ZI23	ESC-TV1 Closed	Control Panel	On/Off
ESC-ZI24	ESC-TV2 Open	Control Panel	On/Off
ESC-ZI25	ESC-TV2 Closed	Control Panel	On/Off
ESD-ZI3	ESD-TV7 Open	Control Panel	On/Off
ESD-ZI4	ESD-TV7 Closed	Control Panel	On/Off
	Sump Pump A Running	Control Panel	On/Off
	Sump Pump B Running	Control Panel	On/Off
	Sump Drainage Pump Running	Control Panel	On/Off
	Sump A Agitator Running	Control Panel	On/Off
	Sump B Agitator Running	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
	Salt Make Up Pump Running	Control Panel	On/Off
	Foundation Cooling Pump A Running	Control Panel	On/Off
	Foundation Cooling Pump B Running	Control Panel	On/Off
	Evaporator Recirc Pump A Running		
	Prehtr Recirc B Pump Running	Control Panel	On/Off
	Attemperation Pump Running	Control Panel	On/Off
RSC-ZI1	RSC-TV26 Open	Control Panel	On/Off
RSC-ZI2	RSC-TV26 Closed	Control Panel	On/Off
RSC-ZI3	RSC-WV54 Open	Control Panel	On/Off
RSC-ZI4	RSC-WV54 Closed	Control Panel	On/Off
RSC-ZI5	RSC-TV35 Open	Control Panel	On/Off
RSC-ZI6	RSC-TV35 Closed	Control Panel	On/Off
SBC-ZI24	SBC-TV1 Open	Control Panel	On/Off
SBC-ZI25	SBC-TV1 Closed	Control Panel	On/Off
SBC-ZI26	SBC-TV4 Open	Control Panel	On/Off
SBC-ZI27	SBC-TV4 Closed	Control Panel	On/Off
SBC-ZI28	SBC-TV7 Open	Control Panel	On/Off
SBC-ZI29	SBC-TV7 Closed	Control Panel	On/Off
SBC-ZI30	SBC-WV25 Open	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
SBC-ZI31	SBC-WV25 Closed	Control Panel	On/Off
SBC-ZI32	SBC-TV23 Open	Control Panel	On/Off
SBC-ZI33	SBC-TV23 Closed	Control Panel	On/Off
SBC-ZI38	SBC-TV26 Open	Control Panel	On/Off
SBC-ZI39	SBC-TV26 Closed	Control Panel	On/Off
SBC-ZI49	SBC-TV20 Open	Control Panel	On/Off
SBC-ZI41	SBC-TV20 Closed	Control Panel	On/Off
SBC-ZI42	SBC-TV21 Open	Control Panel	On/Off
SBC-ZI43	SBC-TV21 Closed	Control Panel	On/Off
SBC-ZI44	SBC-TV22 Open	Control Panel	On/Off
SBC-ZI45	SBC-TV22 Closed	Control Panel	On/Off
RSC-ZI7	RSC-TV32 Open	Control Panel	On/Off
RSC-ZI8	RSC-TV32 Closed	Control Panel	On/Off
SBC-ZI34	SBC-TV27 Open	Control Panel	On/Off
SBC-ZI35	SBC-TV27 Closed	Control Panel	On/Off
SBC-ZI36	SBC-TV38 Open	Control Panel	On/Off
SBC-ZI37	SBC-TV38 Closed	Control Panel	On/Off
SBC-ZI20	SBC-TV24 Open	Control Panel	On/Off
SBC-ZI21	SBC-TV24 Closed	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
SBC-ZI22	SBC-TV29 Open	Control Panel	On/Off
SBC-ZI23	SBC-TV29 Closed	Control Panel	On/Off
SBC-ZI152	SBC-TV39 Open	Control Panel	On/Off
SBC-ZI153	SBC-TV39 Closed	Control Panel	On/Off
SBC-ZI154	SBC-TV41 Open	Control Panel	On/Off
SBC-ZI155	SBC-TV41 Closed	Control Panel	On/Off
SBC-ZI156	SBC-TV45 Open	Control Panel	On/Off
SBC-ZI157	SBC-TV45 Closed	Control Panel	On/Off
SBA-ZI17	SBA-TV1 Open	Control Panel	On/Off
SBA-ZI18	SBA-TV1 Closed	Control Panel	On/Off
SBA-ZI19	SBA-TV36 Open	Control Panel	On/Off
SBA-ZI20	SBA-TV36 Closed	Control Panel	On/Off
SBA-ZI21	SBA-TV37 Open	Control Panel	On/Off
SBA-ZI22	SBA-TV37 Closed	Control Panel	On/Off
SBB-ZI1	SBB-TV1 Open	Control Panel	On/Off
SBB-ZI2	SBB-TV1 Closed	Control Panel	On/Off
SBD-ZI9	SBD-TV1 Open	Control Panel	On/Off
SBD-ZI10	SBD-TV1 Closed	Control Panel	On/Off
SGG-ZI9	SGG-TV2 Open	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
SGG-ZI10	SGG-TV2 Closed	Control Panel	On/Off
SBD-ZI11	SBD-TV3 Open	Control Panel	On/Off
SBD-ZI12	SBD-TV3 Closed	Control Panel	On/Off
SGG-ZI1	SGG-TV4 Open	Control Panel	On/Off
SGG-ZI2	SGG-TV4 Closed	Control Panel	On/Off
SGG-ZI3	SGG-TV5 Open	Control Panel	On/Off
SGG-ZI4	SGG-TV5 Closed	Control Panel	On/Off
SGG-ZI5	SGG-TV9 Open	Control Panel	On/Off
SGG-ZI6	SGG-TV9 Closed	Control Panel	On/Off
SGG-ZI7	SGG-ZV1 Open	Control Panel	On/Off
SGG-ZI8	SGG-ZV1 Closed	Control Panel	On/Off
SBD-ZI13	SBD-ZV2 Open	Control Panel	On/Off
SBD-ZI14	SBD-ZV2 Closed	Control Panel	On/Off
SGG-ZI11	SGG-ZV3 Open	Control Panel	On/Off
SGG-ZI12	SGG-ZV3 Closed	Control Panel	On/Off
SBD-ZI15	SBD-ZV4 Open	Control Panel	On/Off
SBD-ZI16	SBD-ZV4 Closed	Control Panel	On/Off
SGG-ZI13	SGG-ZV6 Open	Control Panel	On/Off
SGG-ZI14	SGG-ZV6 Closed	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	OUTPUT SIGNAL
SGG-ZI15	SGG-ZV10 Open	Control Panel	On/Off
SGG-ZI16	SGG-ZV10 Closed	Control Panel	On/Off

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	East Pass Flow Control Set Point	Control Panel	4-20AM
	Flow Control Valve-RSA-CV3	Control Panel	4-20MA
	Flow Control Valve-RSA-CV4	Control Panel	4-20MA
	West Pass Flow Control Set Point	Control Panel	4-20MA
	Flow Control Valve RSA-CV5	Control Panel	4-20MA
	Flow Control Valve RSA-CV6	Control Panel	4-20MA
	Cold Salt Pump Load Set Point	Control Panel	4-20MA
	Cold Salt Pump A Speed Set Point	Control Panel	4-20MA
	Cold Salt Pump A Control	Control Panel	4-20MA
	Cold Salt Pump B Speed Set Point	Control Panel	4-20MA
	Cold Salt Pump B Control	Control Panel	4-20MA
	Cold Salt Pump C Speed Set Point	Control Panel	4-20MA
	Cold Salt Pump C Control	Control Panel	4-20MA
	Valve RSC-CV12 Control	Control Panel	4-20MA
	Valve RSC-CV16 Control	Control Panel	4-20MA
	Valve RSC-CV20 Control	Control Panel	4-20MA
	Valve RSC-ZV49 Control	Control Panel	4-20MA
	Hot Surge Tank Level Set Point	Control Panel	4-20MA
	RSC-CV42 Control	Control Panel	4-20MA

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	RSC-CV46 Control	Control Panel	4-20MA
	Steam Throttle Pressure S.P.	Control Panel	4-20MA
	Hot Salt Pump A Control	Control Panel	4-20MA
	Hot Salt Pump B Control	Control Panel	4-20MA
	Hot Salt Pump C Control	Control Panel	4-20MA
	Valve SBC-CV12 Control	Control Panel	4-20MA
	Valve SBC-CV16 Control	Control Panel	4-20MA
	Valve SBC-CV19 Control	Control Panel	4-20MA
	Throttle Steam temp set point	Control Panel	4-20MA
	Valve SBC-CV31 Control	Control Panel	4-20MA
	Valve SBE-CV3 Control	Control Panel	4-20MA
	Evap. Inlet Temp Set Point	Control Panel	4-20MA
	Valve SBA-CV40 Control	Control Panel	4-20MA
	Prehtr Inlet Water Temp Set Point	Control Panel	4-20MA
	Feedwater Temp Cont. Valve Control	Control Panel	4-20MA
	RSC-CV30 Control	Control Panel	4-20MA
	RSC-CV34 Control	Control Panel	4-20MA
	Turb. Bypass Desuperheater Temp S.P.	Control Panel	4-20MA
	FWC-CV3 Control	Control Panel	4-20MA

APPENDIX A - CONTROL ROOM CONTROL AND INSTRUMENT LIST

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Solar Steam Drum Pressure S.P.	Control Panel	4-20MA
	SGG-CV16 Control	Control Panel	4-20MA
	Warming Steam Desuperheater Temp S.P.	Control Panel	4-20MA
	FWA-CV16 Control	Control Panel	4-20MA
	Open RSC-TV1	Control Panel	Micro
	Close RSC-TV1	Control Panel	Micro
	Open RSC-TV4	Control Panel	Micro
	Close RSC-TV4	Control Panel	Micro
	Open RSC-TV7	Control Panel	Micro
	Close RSC-TV-7	Control Panel	Micro
	Open East Fill Valves	Control Panel	Micro
	Close East Fill Valves	Control Panel	Micro
	Open East Vent Valve 1	Control Panel	Micro
	Close East Vent Valve 1	Control Panel	Micro
	Open East Vent Valve 2	Control Panel	Micro
	Close East Vent Valve 2	Control Panel	Micro
	Open East Vent Valve 3	Control Panel	Micro
	Close East Vent Valve 3	Control Panel	Micro
	Open East Vent Valve 4	Control Panel	Micro

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Close East Vent Valve 4	Control Panel	Micro
	Open East Vent Valve 5	Control Panel	Micro
	Close East Vent Valve 5	Control Panel	Micro
	Open East Vent Valve 6	Control Panel	Micro
	Close East Vent Valve 6	Control Panel	Micro
	Open West Fill Valves	Control Panel	Micro
	Close West Fill Valves	Control Panel	Micro
	Open West Vent Valve 1	Control Panel	Micro
	Close West Vent Valve 1	Control Panel	Micro
	Open West Vent Valve 2	Control Panel	Micro
	Close West Vent Valve 2	Control Panel	Micro
	Open West Vent Valve 3	Control Panel	Micro
	Close West Vent Valve 3	Control Panel	Micro
	Open West Vent Valve 4	Control Panel	Micro
	Close West Vent Valve 4	Control Panel	Micro
	Open West Vent Valve 5	Control Panel	Micro
	Close West Vent Valve 5	Control Panel	Micro
	Open West Vent Valve 6	Control Panel	Micro
	Close West Vent Valve 6	Control Panel	Micro

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Open RSC-TV39	Control Panel	Micro
	Close RSC-TV39	Control Panel	Micro
	Open RSC-TV40	Control Panel	Micro
	Close RSC-TV40	Control Panel	Micro
	Open RSCTV38	Control Panel	Micro
	Close RSC-TV-38	Control Panel	Micro
	Open Recirc. Pump Shut-off Valve	Control Panel	Micro
	Close Recirc. Pump Shut-off Valve	Control Panel	Micro
	Open RSC-TV60	Control Panel	Micro
	Close RSC-TV60	Control Panel	Micro
	Open RSC-TV54	Control Panel	Micro
	Close RSC-TV54	Control Panel	Micro
	Open RSC-TV21	Control Panel	Micro
	Close RSC-TV21	Control Panel	Micro
	Open RSC-TV22	Control Panel	Micro
	Close RSC-TV22	Control Panel	Micro
	Open RSC-TV23	Control Panel	Micro
	Close RSC-TV23	Control Panel	Micro
	Open RSC-TV24	Control Panel	Micro

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Close RSC-TV24	Control Panel	Micro
	Open RSC-WV25	Control Panel	Micro
	Close RSC-WV25	Control Panel	Micro
	Open RSC-TV50	Control Panel	Micro
	Close RSC-TV50	Control Panel	Micro
	Open RSC-TV43	Control Panel	Micro
	Close RSC-TV43	Control Panel	Micro
	Open RSC-TV47	Control Panel	Micro
	Close RSC-TV47	Control Panel	Micro
	Start Air Compressor	Control Panel	Micro
	Stop Air Compressor	Control Panel	Micro
	Start Recirc Pump	Control Panel	Micro
	Stop Recirc Pump	Control Panel	Micro
	Open Door	Control Panel	Micro
	Close Door	Control Panel	Micro
	Open RSC-TV61	Control Panel	Micro
	Close RSC-TV61	Control Panel	Micro
	Open ESD-TV10	Control Panel	Micro
	Close ESD-TV10	Control Panel	Micro

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Open ESD-TV11	Control Panel	Micro
	Close ESD-TV11	Control Panel	Micro
	Open ESF TV1	Control Panel	Micro
	Close ESF-TV1	Control Panel	Micro
	Open ESC-TV1	Control Panel	Micro
	Close ESC-TV1	Control Panel	Micro
	Open ESC-TV2	Control Panel	Micro
	Close ESC-TV2	Control Panel	Micro
	Open ESD-TV7	Control Panel	Micro
	Close ESD-TV7	Control Panel	Micro
	Start Sump Pump A	Control Panel	Micro
	Stop Sump Pump A	Control Panel	Micro
	Start Sump Pump B	Control Panel	Micro
	Stop Sump Pump B	Control Panel	Micro
	Start Sump Drainage Pump	Control Panel	Micro
	Stop Sump Drainage Pump	Control Panel	Micro
	Start Sump A Agitator	Control Panel	Micro
	Stop Sump A Agitator	Control Panel	Micro
	Start Sump B Agitator	Control Panel	Micro

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Stop Sump B Agitator	Control Panel	Micro
	Start Salt Make-Up Pump	Control Panel	Micro
	Stop Salt Make-Up Pump	Control Panel	Micro
	Start Foundation Cooling Pump A	Control Panel	Micro
	Stop Foundation Cooling Pump A	Control Panel	Micro
	Start Foundation Cooling Pump B	Control Panel	Micro
	Stop Foundation Cooling Pump B	Control Panel	Micro
	Start Evap. Recirc. Pump A	Control Panel	Micro
	Stop Evap. Recirc. Pump A	Control Panel	Micro
	Start Evap. Recirc. Pump B	Control Panel	Micro
	Stop Evap. Recirc. Pump B	Control Panel	Micro
	Start Prehtr. Recirc. Pump	Control Panel	Micro
	Stop Prehtr. Recirc. Pump	Control Panel	Micro
	Start Attemperation Pump	Control Panel	Micro
	Stop Attemperation Pump	Control Panel	Micro
	Open RSC-TV26	Control Panel	Micro
	Close RSC-TV26	Control Panel	Micro
	Open RSC-WV54	Control Panel	Micro
	Close RSC-WV54	Control Panel	Micro

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Open RSC-TV35	Control Panel	Micro
	Close RSC-TV35	Control Panel	Micro
	Open SBC-TV1	Control Panel	Micro
	Close SBC-TV1	Control Panel	Micro
	Open SBC-TV4	Control Panel	Micro
	Close SBC-TV4	Control Panel	Micro
	Open SBC-TV7	Control Panel	Micro
	Close SBC-TV7	Control Panel	Micro
	Open SBC-WV25	Control Panel	Micro
	Close SBC-WV25	Control Panel	Micro
	Open SBC-TV23	Control Panel	Micro
	Close SBC-TV23	Control Panel	Micro
	Open SBC-TV26	Control Panel	Micro
	Close SBC-TV26	Control Panel	Micro
	Open SBC-TV20	Control Panel	Micro
	Close SBC-TV20	Control Panel	Micro
	Open SBC-TV21	Control Panel	Micro
	Close SBC-TV21	Control Panel	Micro
	Open SBC-TV22	Control Panel	Micro

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Close SBC-TV22	Control Panel	Micro
	Open RSC-TV32	Control Panel	Micro
	Close RSC-TV32	Control Panel	Micro
	Open SBC-TV27	Control Panel	Micro
	Close SBC-TV27	Control Panel	Micro
	Open SBC-TV38	Control Panel	Micro
	Close SBC-TV38	Control Panel	Micro
	Open SBC-TV24	Control Panel	Micro
	Close SBC-TV24	Control Panel	Micro
	Open SBC-TV29	Control Panel	Micro
	Close SBC-TV29	Control Panel	Micro
	Open SBA-TV1	Control Panel	Micro
	Close SBA-TV1	Control Panel	Micro
	Open SBC-TV39	Control Panel	Micro
	Close SBC-TV39	Control Panel	Micro
	Open SBC-TV41	Control Panel	Micro
	Close SBC-TV41	Control Panel	Micro
	Open SBC-TV45	Control Panel	Micro
	Close SBC-TV45	Control Panel	Micro

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Open SBA-TV2	Control Panel	Micro
	Close SBA-TV2	Control Panel	Micro
	Open SBA-TV3	Control Panel	Micro
	Close SBA-TV3	Control Panel	Micro
	Open SBB-TV1	Control Panel	Micro
	Close SBB-TV1	Control Panel	Micro
	Open SBD-TV1	Control Panel	Micro
	Close SBD-TV1	Control Panel	Micro
	Open SGG-TV2	Control Panel	Micro
	Close SGG-TV2	Control Panel	Micro
	Open SBD-TV3	Control Panel	Micro
	Close SBD-TV3	Control Panel	Micro
	Open SGG-TV4	Control Panel	Micro
	Close SGG-TV4	Control Panel	Micro
	Open SGG-TV5	Control Panel	Micro
	Close SGG-TV5	Control Panel	Micro
	Open SGG-TV9	Control Panel	Micro
	Close SGG-TV9	Control Panel	Micro
	Open SGG-ZV1	Control Panel	Micro

IDENTIFIER	DESCRIPTION	EQUIP. LOCATION	INPUT SIGNAL
	Close SGG-ZV1	Control Panel	Micro
	Open SBD-ZV2	Control Panel	Micro
	Close SBD-ZV2	Control Panel	Micro
	Open SGG-ZV3	Control Panel	Micro
	Close SGG-ZV3	Control Panel	Micro
	Open SBD-ZV4	Control Panel	Micro
	Close SBD-ZV4	Control Panel	Micro
	Open SGG-ZV6	Control Panel	Micro
	Close SGG-ZV6	Control Panel	Micro
	Open SGG-ZV10	Control Panel	Micro
	Close SGG-ZV10	Control Panel	Micro

Identifier	Description	Equip. Location	Output Signal
RSA-CV4	East Salt Flow Valve #1	Receiver	4-20 MA
RSA-CV6	East Salt Flow Valve #2	Receiver	4-20 MA
RSA-CV3	West Salt Flow Valve #1	Receiver	4-20 MA
RSA-CV5	West Salt Flow Valve #2	Receiver	4-20 MA
RSA-TV1	West Zone Flow Shutoff Valve	Receiver	On/Off
RSA-TV2	East Zone Flow Shutoff Valve	Receiver	On/Off
RSA-TV35	Cold Surge Tank Vent Valve	Receiver	On/Off
RSA-TV10	East Fill Valves	Receiver	On/Off
RSA-TV12	East Fill Valves	Receiver	On/Off
RSA-TV14	East Fill Valves	Receiver	On/Off
RSA-TV16	East Fill Valves	Receiver	On/Off
RSA-TV18	East Fill Valves	Receiver	On/Off
RSA-TV20	East Fill Valves	Receiver	On/Off
RSA-TV9	West Fill Valves	Receiver	On/Off
RSA-TV11	West Fill Valves	Receiver	On/Off
RSA-TV13	West Fill Valves	Receiver	On/Off
RSA-TV15	West Fill Valves	Receiver	On/Off
RSA-TV17	West Fill Valves	Receiver	On/Off
RSA-TV19	West Fill Valves	Receiver	On/Off
RSA-GV22	East Panels 1, 2 Vent Valve	Receiver	On/Off
RSA-GV24	East Panels 3, 4 Vent Valve	Receiver	On/Off
RSA-GV26	East Panels 5, 6 Vent Valve	Receiver	On/Off

Identifier	Description	Equip. Location	Output Signal
RSA-GV28	East Panels 7, 8 Vent Valve	Receiver	On/Off
RSA-GV30	East Panels 9, 10 Vent Valve	Receiver	On/Off
RSA-GV32	East Panels 11, 12 Vent Valve	Receiver	On/Off
RSA-GV21	West Panels 1, 2 Vent Valve	Receiver	On/Off
RSA-GV23	West Panels 3, 4 Vent Valve	Receiver	On/Off
RSA-GV25	West Panels 5, 6 Vent Valve	Receiver	On/Off
RSA-GV27	West Panels 7, 8 Vent Valve	Receiver	On/Off
RSA-GV29	West Panels 9, 10 Vent Valve	Receiver	On/Off
RSA-GV31	West Panels 11, 12 Vent Valve	Receiver	On/Off
RSA-TV39	Recirculation Pump Shut-Off Valve	Receiver	On/Off
RSC-CV12	Cold Salt Pump A Flow By-Pass	Thermal Storage	4-20 MA
RSC-CV16	Cold Salt Pump B Flow By-Pass	Thermal Storage	4-20 MA
RSC-CV20	Cold Salt Pump C Flow By-Pass	Thermal Storage	4-20 MA
RSC-CV42	Hot Surge Tank Level Control Valve	Receiver	4-20 MA
RSC-CV46	Hot Surge Tank Level Control Valve	Receiver	4-20 MA
RSC-CV55	Cold Salt Return Attemp. Valve	Thermal Storage	4-20 MA
RSC-TV1	Cold Salt Pump A Discharge Valve	Thermal Storage	On/Off
RSC-TV4	Cold Salt Pump B Discharge Valve	Thermal Storage	On/Off
RSC-TV7	Cold Salt Pump C Discharge Valve	Thermal Storage	On/Off
RSC-TV21	Cold Salt to Drainage Sump Valve	Thermal Storage	On/Off
RSC-TV22	Cold Salt Pump A Drain Valve	Thermal Storage	On/Off
RSC-TV23	Cold Salt Pump B Drain Valve	Thermal Storage	On/Off

Identifier	Description	Equip. Location	Output Signal
RSC-TV24	Cold Salt Pump C Drain Valve	Thermal Storage	On/Off
RSC-TV61	Rec to Drain Sump Valve	Thermal Storage	On/Off
RSC-TV38	Receiver Isolation Valve	Thermal Storage	On/Off
RSC-TV39	Fill & Drain Valve	Receiver	On/Off
RSC-TV40	Fill & Drain Valve	Receiver	On/Off
RSC-TV43	Hst Level Cont. Sta. Isolation Valve	Receiver	On/Off
RSC-TV47	Hst Level Cont. Sta. Isolation Valve	Receiver	On/Off
RSC-TV50	Hot Salt Return Line to Drain Sump	Thermal Storage	On/Off
RSC-TV62	Valve-Cold Salt to Hot Salt Tank	Thermal Storage	On/Off
RSC-WV25	Cold Salt Storage Tank Outlet Valve	Thermal Storage	On/Off
RSC-ZV49	Hot Salt Return 3-Way Valve	Thermal Storage	4-20 MA
	Cold Salt Pump A Speed	Thermal Storage	4-20 MA
	Cold Salt Pump A Start-Stop	Thermal Storage	On/Off
	Cold Salt Pump B Speed	Thermal Storage	4-20 MA
	Cold Salt Pump B Start-Stop	Thermal Storage	On/Off
	Cold Salt Pump C Speed	Thermal Storage	4-20 MA
	Cold Salt Pump C Start-Stop	Thermal Storage	On/Off
	Air Compressor Start-Stop	Receiver	On/Off
	Recirc Pump Start-Stop	Receiver	On/Off
	Door Open	Receiver	On/Off
	Door Close	Receiver	On/Off
	Heat Trace Relay	Receiver	On/Off

Identifier	Description	Equip. Location	Output Signal
	Heat Trace Relay	Receiver	On/Off
	Heat Trace Relay	Receiver	On/Off
	Heat Trace Relay	Receiver	On/Off
	Heat Trace Relay	Receiver	On/Off
	Heat Trace Relay	Receiver	On/Off

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
CAD-PT1	Air Receiver A Pressure	Receiver	4-20 MA						
CAD-PT2	Air Receiver B Pressure	Receiver	4-20 MA						
RSA-FT1	Inlet to East Pass Flow	Receiver	4-20 MA						
RSA-FT2	Inlet to East Pass Flow	Receiver	4-20 MA						
RSA-FT3	Inlet to East Pass Flow	Receiver	4-20 MA						
RSA-FT4	Inlet to West Pass Flow	Receiver	4-20 MA						
RSA-FT5	Inlet to West Pass Flow	Receiver	4-20 MA						
RSA-FT6	Inlet to West Pass Flow	Receiver	4-20 MA						
RSA-LT7	Cold Surge Tank Level	Receiver	4-20 MA						
RSA-LT8	Cold Surge Tank Level	Receiver	4-20 MA						
RSA-LT9	Cold Surge Tank Level	Receiver	4-20 MA						
RSA-LT10	Hot Surge Tank Level	Receiver	4-20 MA						
RSA-PT11	Hot Surge Tank Pressure	Receiver	4-20 MA						
RSA-PT12	Cold Surge Tank Pressure	Receiver	4-20 MA						
RSA-PT131	Recirc Pump Outlet Pressure	Receiver	4-20 MA						
RSA-TE13	East Receiver Inlet Temp 1	Receiver	Type K						
RSA-TE14	East Receiver Inlet Temp 2	Receiver	Type K						
RSA-TE15	East Receiver Inlet Temp 3	Receiver	Type K						
RSA-TE16	East Receiver Back, Upper 1	Receiver	Type K						
RSA-TE17	East Receiver Back, Upper 2	Receiver	Type K						
RSA-TE18	East Receiver Back, Upper 3	Receiver	Type K						
RSA-TE19	East Receiver Back, Upper 4	Receiver	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-TE20	East Receiver Back, Upper 5	Receiver	Type K						
RSA-TE21	East Receiver Back, Upper 6	Receiver	Type K						
RSA-TE22	East Receiver Back, Upper 7	Receiver	Type K						
RSA-TE23	East Receiver Back, Upper 8	Receiver	Type K						
RSA-TE24	East Receiver Back, Upper 9	Receiver	Type K						
RSA-TE25	East Receiver Back, Upper 10	Receiver	Type K						
RSA-TE26	East Receiver Back, Upper 11	Receiver	Type K						
RSA-TE27	East Receiver Back, Upper 12	Receiver	Type K						
RSA-TE28	East Receiver Back, Middle 1	Receiver	Type K						
RSA-TE29	East Receiver Back, Middle 2	Receiver	Type K						
RSA-TE30	East Receiver Back, Middle 3	Receiver	Type K						
RSA-TE31	East Receiver Back, Middle 4	Receiver	Type K						
RSA-TE32	East Receiver Back, Middle 5	Receiver	Type K						
RSA-TE33	East Receiver Back, Middle 6	Receiver	Type K						
RSA-TE34	East Receiver Back, Middle 7	Receiver	Type K						
RSA-TE35	East Receiver Back, Middle 8	Receiver	Type K						
RSA-TE36	East Receiver Back, Middle 9	Receiver	Type K						
RSA-TE37	East Receiver Back, Middle 10	Receiver	Type K						
RSA-TE38	East Receiver Back, Middle 11	Receiver	Type K						
RSA-TE39	East Receiver Back, Middle 12	Receiver	Type K						
RSA-TE40	East Receiver Back, Lower 1	Receiver	Type K						
RSA-TE41	East Receiver Back, Lower 2	Receiver	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-TE42	East Receiver Back, Lower 3	Receiver	Type K						
RSA-TE43	East Receiver Back, Lower 4	Receiver	Type K						
RSA-TE44	East Receiver Back, Lower 5	Receiver	Type K						
RSA-TE45	East Receiver Back, Lower 6	Receiver	Type K						
RSA-TE46	East Receiver Back, Lower 7	Receiver	Type K						
RSA-TE47	East Receiver Back, Lower 8	Receiver	Type K						
RSA-TE48	East Receiver Back, Lower 9	Receiver	Type K						
RSA-TE49	East Receiver Back, Lower 10	Receiver	Type K						
RSA-TE50	East Receiver Back, Lower 11	Receiver	Type K						
RSA-TE51	East Receiver Outlet 1	Receiver	Type K						
RSA-TE52	East Receiver Outlet 2	Receiver	Type K						
RSA-TE53	East Receiver Outlet 3	Receiver	Type K						
RSA-TE54	West Receiver Inlet 1	Receiver	Type K						
RSA-TE55	West Receiver Inlet 2	Receiver	Type K						
RSA-TE56	West Receiver Inlet 3	Receiver	Type K						
RSA-TE57	West Receiver Back, Upper 1	Receiver	Type K						
RSA-TE58	West Receiver Back, Upper 2	Receiver	Type K						
RSA-TE59	West Receiver Back, Upper 3	Receiver	Type K						
RSA-TE60	West Receiver Back, Upper 4	Receiver	Type K						
RSA-TE61	West Receiver Back, Upper 5	Receiver	Type K						
RSA-TE62	West Receiver Back, Upper 6	Receiver	Type K						
RSA-TE63	West Receiver Back, Upper 7	Receiver	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-TE64	West Receiver Back, Upper 8	Receiver	Type K						
RSA-TE65	West Receiver Back, Upper 9	Receiver	Type K						
RSA-TE66	West Receiver Back, Upper 10	Receiver	Type K						
RSA-TE67	West Receiver Back, Upper 11	Receiver	Type K						
RSA-TE68	West Receiver Back, Upper 12	Receiver	Type K						
RSA-TE69	West Receiver Back, Middle 1	Receiver	Type K						
RSA-TE70	West Receiver Back, Middle 2	Receiver	Type K						
RSA-TE71	West Receiver Back, Middle 3	Receiver	Type K						
RSA-TE72	West Receiver Back, Middle 4	Receiver	Type K						
RSA-TE73	West Receiver Back, Middle 5	Receiver	Type K						
RSA-TE74	West Receiver Back, Middle 6	Receiver	Type K						
RSA-TE75	West Receiver Back, Middle 7	Receiver	Type K						
RSA-TE76	West Receiver Back, Middle 8	Receiver	Type K						
RSA-TE77	West Receiver Back, Middle 9	Receiver	Type K						
RSA-TE78	West Receiver Back, Middle 10	Receiver	Type K						
RSA-TE79	West Receiver Back, Middle 11	Receiver	Type K						
RSA-TE80	West Receiver Back, Middle 12	Receiver	Type K						
RSA-TE81	West Receiver Back, Lower 1	Receiver	Type K						
RSA-TE82	West Receiver Back, Lower 2	Receiver	Type K						
RSA-TE83	West Receiver Back, Lower 3	Receiver	Type K						
RSA-TE84	West Receiver Back, Lower 4	Receiver	Type K						
RSA-TE85	West Receiver Back, Lower 5	Receiver	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-TE86	West Receiver Back, Lower 6	Receiver	Type K						
RSA-TE87	West Receiver Back, Lower 7	Receiver	Type K						
RSA-TE88	West Receiver Back, Lower 8	Receiver	Type K						
RSA-TE89	West Receiver Back, Lower 9	Receiver	Type K						
RSA-TE90	West Receiver Back, Lower 10	Receiver	Type K						
RSA-TE91	West Receiver Back, Lower 11	Receiver	Type K						
RSA-TE92	West Receiver Outlet 1	Receiver	Type K						
RSA-TE93	West Receiver Outlet 2	Receiver	Type K						
RSA-TE94	West Receiver Outlet 3	Receiver	Type K						
RSA-TE95	Hot Surge Tank Temp	Receiver	Type K						
RSA-TE96	Cold Surge Tank Temp	Receiver	Type K						
RSA-TE132	West Zone Vent Temp	Receiver	Type K						
RSA-TE133	East Zone Vent Temp	Receiver	Type K						
RSA-TE134	Recirc Pump Outlet Temp	Receiver	Type K						
RSA-ZS97	Recirc Pump Valve Open	Receiver	Micro						
RSA-ZS98	Recirc Pump Valve Closed	Receiver	Micro						
RSA-ZS99	East Zone Fill Valves Open	Receiver	Micro						
RSA-ZS100	East Zone Fill Valves Closed	Receiver	Micro						
RSA-ZS101	East Vent Valve 1 Open	Receiver	Micro						
RSA-ZS102	East Vent Valve 1 Closed	Receiver	Micro						
RSA-ZS103	East Vent Valve 2 Open	Receiver	Micro						
RSA-ZS104	East Vent Valve 2 Closed	Receiver	Micro						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-ZS105	East Vent Valve 3 Open	Receiver	Micro						
RSA-ZS106	East Vent Valve 3 Closed	Receiver	Micro						
RSA-ZS107	East Vent Valve 4 Open	Receiver	Micro						
RSA-ZS108	East Vent Valve 4 Closed	Receiver	Micro						
RSA-ZS109	East Vent Valve 5 Open	Receiver	Micro						
RSA-ZS110	East Vent Valve 5 Closed	Receiver	Micro						
RSA-ZS111	East Vent Valve 6 Open	Receiver	Micro						
RSA-ZS112	East Vent Valve 6 Closed	Receiver	Micro						
RSA-ZS113	West Zone Fill Valves Open	Receiver	Micro						
RSA-ZS114	West Zone Fill Valves Closed	Receiver	Micro						
RSA-ZS115	West Vent Valve 1 Open	Receiver	Micro						
RSA-ZS116	West Vent Valve 1 Closed	Receiver	Micro						
RSA-ZS117	West Vent Valve 2 Open	Receiver	Micro						
RSA-ZS118	West Vent Valve 2 Closed	Receiver	Micro						
RSA-ZS119	West Vent Valve 3 Open	Receiver	Micro						
RSA-ZS120	West Vent Valve 3 Closed	Receiver	Micro						
RSA-ZS121	West Vent Valve 4 Open	Receiver	Micro						
RSA-ZS122	West Vent Valve 4 Closed	Receiver	Micro						
RSA-ZS123	West Vent Valve 5 Open	Receiver	Micro						
RSA-ZS124	West Vent Valve 5 Closed	Receiver	Micro						
RSA-ZS125	West Vent Valve 6 Open	Receiver	Micro						
RSA-ZS126	West Vent Valve 6 Closed	Receiver	Micro						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-ZT127	RSA-CV3 Position	Receiver	4-20 MA						
RSA-ZT128	RSA-CV4 Position	Receiver	4-20 MA						
RSA-ZT129	RSA-CV5 Position	Receiver	4-20 MA						
RSA-ZT130	RSA-CV6 Position	Receiver	4-20 MA						
	Recirc Pump Start	Receiver	Micro						
	Recirc Pump Stop	Receiver	Micro						
	Door Open	Receiver	Micro						
	Door Closed	Receiver	Micro						
	Cold Surge Tank Air Valve Open	Receiver	Micro						
	Cold Surge Tank Air Valve Closed	Receiver	Micro						
	Air Compressor Start	Receiver	Micro						
	Air Compressor Stop	Receiver	Micro						
RSC-FT1	Cold Salt Header Flow	Thermal Storage	4-20 MA						
RSC-FT2	Cold Salt Header Flow	Thermal Storage	4-20 MA						
RSC-FT3	Cold Salt Header Flow	Thermal Storage	4-20 MA						
RSC-FT4	Cold Salt Pump A Flow	Thermal Storage	4-20 MA						
RSC-FT5	Cold Salt Pump B Flow	Thermal Storage	4-20 MA						
RSC-FT6	Cold Salt Pump C Flow	Thermal Storage	4-20 MA						
RSC-TE7	Hot Salt Downcomer Temp	Thermal Storage	Type K						
RSC-TE8	Hot Salt Bypass to Cold Salt Tank	Thermal Storage	Type K						
RSC-ZS9	RSC-TV1 Open	Thermal Storage	Micro						
RSC-ZS10	RSC-TV1 Closed	Thermal Storage	Micro						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSC-ZS11	RSC-WV3 Open	Thermal Storage	Micro						
RSC-ZS12	RSC-WV3 Closed	Thermal Storage	Micro						
RSC-ZS13	RSC-TV4 Open	Thermal Storage	Micro						
RSC-ZS14	RSC-TV4 Closed	Thermal Storage	Micro						
RSC-ZS15	RSC-WV6 Open	Thermal Storage	Micro						
RSC-ZS16	RSC-WV6 Closed	Thermal Storage	Micro						
RSC-ZS17	RSC-TV7 Open	Thermal Storage	Micro						
RSC-ZS18	RSC-TV7 Closed	Thermal Storage	Micro						
RSC-ZS19	RSC-WV9 Open	Thermal Storage	Micro						
RSC-ZS20	RSC-WV9 Closed	Thermal Storage	Micro						
RSC-ZS21	RSC-TV21 Open	Thermal Storage	Micro						
RSC-ZS22	RSC-TV21 Closed	Thermal Storage	Micro						
RSC-ZS23	RSC-TV22 Open	Thermal Storage	Micro						
RSC-ZS24	RSC-TV22 Closed	Thermal Storage	Micro						
RSC-ZS25	RSC-TV23 Closed	Thermal Storage	Micro						
RSC-ZS26	RSC-TV23 Open	Thermal Storage	Micro						
RSC-ZS27	RSC-TV24 Open	Thermal Storage	Micro						
RSC-ZS28	RSC-TV24 Closed	Thermal Storage	Micro						
RSC-ZS29	RSC-WV25 Open	Thermal Storage	Micro						
RSC-ZS30	RSC-WV25 Closed	Thermal Storage	Micro						
RSC-ZS31	RSC-TV61 Open	Thermal Storage	Micro						
RSC-ZS32	RSC-TV61 Closed	Thermal Storage	Micro						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSC-ZS33	RSC-TV38 Open	Thermal Storage	Micro						
RSC-ZS34	RSC-TV38 Closed	Thermal Storage	Micro						
RSC-ZS35	RSC-TV39 Open	Thermal Storage	Micro						
RSC-ZS36	RSC-TV39 Closed	Thermal Storage	Micro						
RSC-ZS37	RSC-TV40 Open	Thermal Storage	Micro						
RSC-ZS38	RSC-TV40 Closed	Thermal Storage	Micro						
RSC-ZS39	RSC-TV43 Open	Receiver	Micro						
RSC-ZS40	RSC-TV43 Closed	Receiver	Micro						
RSC-ZS41	RSC-TV47 Open	Receiver	Micro						
RSC-ZS42	RSC-TV47 Closed	Receiver	Micro						
RSC-ZS43	RSCZV49 to Hot Salt Tank	Receiver	Micro						
RSC-ZS44	RSCZV49 to Cold Salt Tank	Receiver	Micro						
RSC-ZS45	RSC-TV50 Open	Thermal Storage	Micro						
RSC-ZS46	RSC-TV50 Closed	Thermal Storage	Micro						
RSC-ZS47	RSC-TV62 Open	Thermal Storage	Micro						
RSC-ZS48	RSC-TV62 Closed	Thermal Storage	Micro						
RSC-ZT49	RSC-CV12 Position	Thermal Storage	4-20 MA						
RSC-ZT50	RSC-CV16 Position	Thermal Storage	4-20 MA						
RSC-ZT51	RSC-CV20 Position	Thermal Storage	4-20 MA						
RSC-ZT52	RSC-CV42 Hst Level Cont. Valve Position	Receiver	4-20 MA						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSC-ZT53	RSC-CV46 Hst Level Cont. Valve Position	Receiver	4-20 MA						
			Output						
	Cold Salt Pump A Start	Thermal Storage	Micro						
	Cold Salt Pump A Stop	Thermal Storage	Micro						
	Cold Salt Pump B Start	Thermal Storage	Micro						
	Cold Salt Pump B Stop	Thermal Storage	Micro						
	Cold Salt Pump C Start	Thermal Storage	Micro						
	Cold Salt Pump C Stop	Thermal Storage	Micro						
	Cold Salt Pump A Speed	Thermal Storage	4-20 MA						
	Cold Salt Pump B Speed	Thermal Storage	4-20 MA						
	Cold Salt Pump C Speed	Thermal Storage	4-20 MA						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
Heat Trace Thermocouples:									
RSA-TEH228	East Vent Valve 1	Receiver	Type K						
RSA-TEH229	East Vent Valve 2	Receiver	Type K						
RSA-TEH230	East Vent Valve 3	Receiver	Type K						
RSA-TEH231	East Vent Valve 4	Receiver	Type K						
RSA-TEH135	East Vent Valve 5	Receiver	Type K						
RSA-TEH136	East Vent Valve 6	Receiver	Type K						
RSA-TEH137	West Vent Valve 1	Receiver	Type K						
RSA-TEH138	West Vent Valve 2	Receiver	Type K						
RSA-TEH139	West Vent Valve 3	Receiver	Type K						
RSA-TEH140	West Vent Valve 4	Receiver	Type K						
RSA-TEH141	West Vent Valve 5	Receiver	Type K						
RSA-TEH142	West Vent Valve 6	Receiver	Type K						
RSA-TEH143	East Fill Valve 1	Receiver	Type K						
RSA-TEH144	East Fill Valve 2	Receiver	Type K						
RSA-TEH145	East Fill Valve 3	Receiver	Type K						
RSA-TEH146	East Fill Valve 4	Receiver	Type K						
RSA-TEH147	East Fill Valve 5	Receiver	Type K						
RSA-TEH148	East Fill Valve 6	Receiver	Type K						
RSA-TEH149	East Fill Valve 7	Receiver	Type K						
RSA-TEH150	West Fill Valve 1	Receiver	Type K						
RSA-TEH151	West Fill Valve 2	Receiver	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-TEH152	West Fill Valve 3	Receiver	Type K						
RSA-TEH153	West Fill Valve 4	Receiver	Type K						
RSA-TEH154	West Fill Valve 5	Receiver	Type K						
RSA-TEH155	West Fill Valve 6	Receiver	Type K						
RSA-TEH156	West Fill Valve 7	Receiver	Type K						
RSA-TEH157	East Vent Line 1	Receiver	Type K						
RSA-TEH158	East Vent Line 2	Receiver	Type K						
RSA-TEH159	West Vent Line 1	Receiver	Type K						
RSA-TEH160	West Vent Line 2	Receiver	Type K						
RSA-TEH161	East Fill Line 1	Receiver	Type K						
RSA-TEH162	East Fill Line 2	Receiver	Type K						
RSA-TEH163	West Fill Line 1	Receiver	Type K						
RSA-TEH164	West Fill Line 2	Receiver	Type K						
RSA-TEH165	Riser 1	Receiver	Type K						
RSA-TEH166	Riser 2	Receiver	Type K						
RSA-TEH167	Riser 3	Receiver	Type K						
RSA-TEH168	Riser 4	Receiver	Type K						
RSA-TEH169	Riser 5	Receiver	Type K						
RSA-TEH170	Riser 6	Receiver	Type K						
RSA-TEH171	Riser 7	Receiver	Type K						
RSA-TEH172	Riser 8	Receiver	Type K						
RSA-TEH173	Riser 9	Receiver	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-TEH174	Riser 10	Receiver	Type K						
RSA-TEH175	Downcomer 1	Receiver	Type K						
RSA-TEH176	Downcomer 2	Receiver	Type K						
RSA-TEH177	Downcomer 3	Receiver	Type K						
RSA-TEH178	Downcomer 4	Receiver	Type K						
RSA-TEH179	Downcomer 5	Receiver	Type K						
RSA-TEH180	Downcomer 6	Receiver	Type K						
RSA-TEH181	Downcomer 7	Receiver	Type K						
RSA-TEH182	Downcomer 8	Receiver	Type K						
RSA-TEH183	East Receiver Inlet 1	Receiver	Type K						
RSA-TEH184	East Receiver Inlet 2	Receiver	Type K						
RSA-TEH185	West Receiver Inlet 1	Receiver	Type K						
RSA-TEH186	West Receiver Inlet 2	Receiver	Type K						
RSA-TEH187	Cold Surge Tank Inlet	Receiver	Type K						
RSA-TEH188	Hot Surge Tank Outlet	Receiver	Type K						
RSA-TEH189	Drain Line 1	Receiver	Type K						
RSA-TEH190	Drain Line 2	Receiver	Type K						
RSA-TEH191	Drain Line 3	Receiver	Type K						
RSA-TEH192	Drain Line 4	Receiver	Type K						
RSA-TEH193	Cold Surge Tank Inlet	Receiver	Type K						
RSA-TEH194	East Receiver Outlet	Receiver	Type K						
RSA-TEH195	East Receiver Outlet	Receiver	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-TEH196	West Receiver Outlet	Receiver	Type K						
RSA-TEH197	West Receiver Outlet	Receiver	Type K						
RSA-TEH198	Purge Line - Line S	Receiver	Type K						
RSA-TEH199	Purge Line - Line S	Receiver	Type K						
RSA-TEH200	East FCV-1 - Line Q	Receiver	Type K						
RSA-TEH201	East FCV-2 - Line Q	Receiver	Type K						
RSA-TEH202	West FCV-1 - Line Q	Receiver	Type K						
RSA-TEH203	West FCV-2 - Line Q	Receiver	Type K						
RSA-TEH204	Cold Surge - Line V	Receiver	Type K						
RSA-TEH205	Cold Surge - Line V	Receiver	Type K						
RSA-TEH206	Hot Surge - Line U	Receiver	Type K						
RSA-TEH207	Hot Surge - Line U	Receiver	Type K						
RSA-TEH208	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH209	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH210	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH211	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH212	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH213	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH214	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH215	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH216	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH217	(Misc. Trace Heater Circuit Temp -20)								

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
RSA-TEH218	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH219	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH220	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH221	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH222	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH223	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH224	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH225	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH226	(Misc. Trace Heater Circuit Temp -20)								
RSA-TEH227	(Misc. Trace Heater Circuit Temp -20)								

Identifier	Description	Equip. Location	Output Signal
ESC-TV1	Sump to Hot Salt Tank-Valve	Thermal Storage	On/Off
ESC-TV2	Sump to Cold Salt Tank-Valve	Thermal Storage	On/Off
ESD-TV7	Salt Make-Up Pump Disch Valve	Thermal Storage	On/Off
ESD-TV10	Cold Salt to Salt Melter-Valve	Thermal Storage	On/Off
ESD-TV11	Hot Salt to Salt Melter-Valve	Thermal Storage	On/Off
	Sump Pump A Start	Thermal Storage	On/Off
	Sump Pump A Stop	Thermal Storage	On/Off
	Sump Pump B Start	Thermal Storage	On/Off
	Sump Pump B Stop	Thermal Storage	On/Off
	Sump Drainage Pump Start	Thermal Storage	On/Off
	Sump Drainage Pump Stop	Thermal Storage	On/Off
	Sump A Agitator Start	Thermal Storage	On/Off
	Sump A Agitator Stop	Thermal Storage	On/Off
	Sump B Agitator Start	Thermal Storage	On/Off
	Sump B Agitator Stop	Thermal Storage	On/Off

Identifier	Description	Equip. Location	Output Signal
	Salt Make-Up Pump Start	Thermal Storage	On/Off
	Salt Make-Up Pump Stop	Thermal Storage	On/Off
	Foundation Cooling Pump A Start	Thermal Storage	On/Off
	Foundation Cooling Pump A Stop	Thermal Storage	On/Off
	Foundation Cooling Pump B Start	Thermal Storage	On/Off
	Foundation Cooling Pump B Stop	Thermal Storage	On/Off
	Heat Trace Relay	Thermal Storage	On/Off
	Heat Trace Relay	Thermal Storage	On/Off
	Heat Trace Relay	Thermal Storage	On/Off
	Heat Trace Relay	Thermal Storage	On/Off

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
ESA-LT1	Hot Salt Storage Tank Level	Thermal Storage	4-20 MA						
ESA-LT2	Hot Salt Storage Tank Level	Thermal Storage	4-20 MA						
ESB-LT1	Cold Salt Storage Tank Level	Thermal Storage	4-20 MA						
ESC-LT1	Molten Salt Drainage Sump A Level	Thermal Storage	4-20 MA						
ESC-LT4	Molten Salt Drainage Sump B Level	Thermal Storage	4-20 MA						
ESC-TE7	Molten Salt Sump Pumps Disch Temp	Thermal Storage	Type K						
ESC-TE10	Attemperator Pump Bearing	Thermal Storage	Type K						
ESC-TE15	Cold Tank Coolant In	Thermal Storage	Type K						
ESC-TE16	Cold Tank Coolant Out	Thermal Storage	Type K						
ESC-TE20	Hot Tank Coolant In	Thermal Storage	Type K						
ESC-TE21	Hot Tank Coolant Out	Thermal Storage	Micro						
ESC-ZS22	ESC-TV1 Open	Thermal Storage	Micro						
ESC-ZS23	ESC-TV1 Closed	Thermal Storage	Micro						
ESC-ZS24	ESC-TV2 Open	Thermal Storage	Micro						
ESC-ZS25	ESC-TV2 Closed	Thermal Storage	Micro						
ESD-ZS3	ESD-TV7 Open	Thermal Storage	Micro						
ESD-ZS4	ESD-TV7 Closed	Thermal Storage	Micro						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels				Sampling Period (Seconds)
					High/High	High	Low	Low/Low	
ESD-ZS5	ESD-TV10 Open	Thermal Storage	Micro						
ESD-ZS6	ESD-TV10 Closed	Thermal Storage	Micro						
ESD-ZS7	ESD-TV11 Open	Thermal Storage	Micro						
ESD-ZS8	ESD-TV11 Closed	Thermal Storage	Micro						
Heat Trace Thermocouples:									
ESB-TEH74	- Line	Thermal Storage	Type K						
ESB-TEH75	- Line	Thermal Storage	Type K						
ESB-TEH76	- Line	Thermal Storage	Type K						
ESB-TEH77	- Line	Thermal Storage	Type K						
ESB-TEH78	- Line	Thermal Storage	Type K						
ESB-TEH79	- Line	Thermal Storage	Type K						
ESB-TEH80	- Line	Thermal Storage	Type K						
ESB-TEH81	- Line	Thermal Storage	Type K						
ESB-TEH82	Cold Tank Inlet - Line	Thermal Storage	Type K						
ESB-TEH83	Cold Tank Bypass - Line	Thermal Storage	Type K						
ESB-TEH84	Riser - Storage End - Line	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
ESB-TEH85	Downcomer - Storage - Line	Thermal Storage	Type K						
ESA-TEH96	Hot Tank #1	Thermal Storage	Type K						
ESA-TEH97	Hot Tank #2	Thermal Storage	Type K						
ESA-TEH98	Hot Tank #3	Thermal Storage	Type K						
ESA-TEH99	V, Line	Thermal Storage	Type K						
ESA-TEH100	Cold/Hot Tank Bypass, Line	Thermal Storage	Type K						
ESA-TEH101	Hot Tank Outlet	Thermal Storage	Type K						
ESA-TEH102		Thermal Storage	Type K						
ESA-TEH103		Thermal Storage	Type K						
ESA-TEH104		Thermal Storage	Type K						
ESA-TEH105		Thermal Storage	Type K						
ESD-TEH9	Salt Melter	Thermal Storage	Type K						
ESD-TEH10	Salt Melter	Thermal Storage	Type K						
ESD-TEH11	V	Thermal Storage	Type K						
TEH	Cold Tank Outlet	Thermal Storage	Type K						
TEH	Cold Tank #1, CT-1 thru 7	Thermal Storage	Type K						
TEH	Cold Tank #2, CT-1 thru 7	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels				Sampling Period (Seconds)
					High/High	High	Low	Low/Low	
TEH	Cold Tank #3, CT-1 thru 7	Thermal Storage	Type K						
TEH	Cold/Hot Tank Bypass, Line	Thermal Storage	Type K						
ESD-TEH12	V	Thermal Storage	Type K						
ESD-TEH13	V	Thermal Storage	Type K						
TEH	Salt Melter Outlet	Thermal Storage	Type K						
TEH	V, Line	Thermal Storage	Type K						
TEH	V, Line	Thermal Storage	Type K						
ESA-TE3	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE4	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE5	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE6	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE7	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE8	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE9	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE10	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE11	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE12	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
ESA-TE13	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE14	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE15	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE16	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE17	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE18	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE19	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE20	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE21	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE22	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE23	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE24	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE25	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE26	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE27	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE28	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE29	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels				Sampling Period (Seconds)
					High/High	High	Low	Low/Low	
ESA-TE30	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE31	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE32	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE33	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE34	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE35	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE36	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE37	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE38	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE39	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE40	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE41	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE42	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE43	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE44	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE45	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE46	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds).
ESA-TE47	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE48	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE49	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE50	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE51	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE52	Hot Salt Tank, Liner Temp	Thermal Storage	Type K						
ESA-TE53	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE54	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE55	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE56	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE57	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE58	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE59	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE60	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE61	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE62	Hot Tank Rake (Outer)	Thermal Storage	Type K						
ESA-TE63	Hot Tank Rake (Inner)	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
ESA-TE64	Hot Tank Rake (Inner)	Thermal Storage	Type K						
ESA-TE65	Hot Tank Rake (Inner)	Thermal Storage	Type K						
ESA-TE66	Hot Tank Rake (Inner)	Thermal Storage	Type K						
ESA-TE67	Hot Tank Rake (Inner)	Thermal Storage	Type K						
ESA-TE68	Hot Tank Rake (Inner)	Thermal Storage	Type K						
ESA-TE69	Hot Tank Rake (Inner)	Thermal Storage	Type K						
ESA-TE70	Hot Tank Rake (Inner)	Thermal Storage	Type K						
ESA-TE71	Hot Tank Rake (Inner)	Thermal Storage	Type K						
ESA-TE72	Hot Tank Rake (Inner)	Thermal Storage	Type K						
ESA-PT73	Hot Tank Ullage Pressure	Thermal Storage	4-20 MA						
ESA-PT74	Hot Tank Attic Pressure	Thermal Storage	4-20 MA						
ESA-DPC75	Hot Tank Differential Pressure	Thermal Storage	4-20-MA						
ESA-LDT76	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT77	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT78	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT79	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT80	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
ESA-LDT81	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT82	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT83	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT84	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT85	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT86	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT87	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT88	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT89	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT90	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT91	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT92	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT93	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT94	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESA-LDT95	Hot Tank Leak Detectors	Thermal Storage	4-20-MA						
ESB-TE3	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE4	Cold Salt Tank Shell Temp	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels				Sampling Period (Seconds)
					High/High	High	Low	Low/Low	
ESB-TE5	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE6	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE7	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE8	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE9	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE10	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE11	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE12	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE13	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE14	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE15	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE16	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE17	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE18	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE19	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE20	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE21	Cold Salt Tank Shell Temp	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
ESB-TE22	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE23	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE24	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE25	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE26	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE27	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE28	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE29	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE30	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE31	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE32	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE33	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE34	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE35	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE36	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE37	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE38	Cold Salt Tank Shell Temp	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
ESB-TE39	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE40	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE41	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE42	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE43	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE44	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE45	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE46	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE47	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE48	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE49	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE50	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE51	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE52	Cold Salt Tank Shell Temp	Thermal Storage	Type K						
ESB-TE53	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						
ESB-TE54	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						
ESB-TE55	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
ESB-TE56	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						
ESB-TE57	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						
ESB-TE58	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						
ESB-TE59	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						
ESB-TE60	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						
ESB-TE61	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						
ESB-TE62	Cold Salt Tank Rake (Outer)	Thermal Storage	Type K						
ESB-TE63	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-TE64	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-TE65	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-TE66	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-TE67	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-TE68	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-TE69	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-TE70	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-TE71	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-TE72	Cold Salt Tank Rake (Inner)	Thermal Storage	Type K						
ESB-DPT73	Cold Salt Tank Differential Pressure	Thermal Storage	Type K						

Identifier	Description	Equip. Location	Output Signal
SBE-CV26	Desuperheater Control Valve	SSG	4-20 MA
RSC-CV30	Attemperation Pump Recirc Valve	Thermal Storage	4-20 MA
RSC-CV34	Attemperation Pump Bypass Valve	Thermal Storage	4-20 MA
RSC-TV26	Attemp Pump Discharge Valve	Thermal Storage	On/Off
TSC-TV32	Attemp Pump Drain Valve	Thermal Storage	On/Off
RSC-TV35	Attemp Pump Recirc. Isolation Valve	Thermal Storage	On/Off
RSC-TV59	Attemp Pump Disch to Drain Sump	Thermal Storage	On/Off
RSC-TV60	Attemp Pump Disch Vent Valve	Thermal Storage	On/Off
RSC-WV54	Attemp Pump Suction Valve	Thermal Storage	On/Off
SBA-CV1	Feedwater Temp Control Valve	SSG	4-20 MA
SBA-CV40	Evaporator Salt Temp Control Valve	SSG	4-20 MA
SBA-TV35	Preheater Vent Valve	SSG	On/Off
SBA-TV36	Superheater to Drain Sump Valve	SSG	On/Off
SBA-TV37	Evaporater to Drain Sump Valve	SSG	On/Off
SBB-TV1	Valve-Steam Drum to Blowdown Sep	SSG	On/Off
SBC-CV12	Hot Salt Pump A Recirc Valve	Thermal Storage	4-20 MA
SBC-CV16	Hot Salt Pump B Recirc Valve	Thermal Storage	4-20 MA
SBC-CV19	Hot Salt Pump C Recirc Valve	Thermal Storage	4-20 MA
SBC-CV31	Superheater Salt Temp Control Valve	SSG	4-20 MA
SBC-TV1	Hot Salt Pump A Disch. Valve	Thermal Storage	On/Off
SBC-TV4	Hot Salt Pump B Disch. Valve	Thermal Storage	On/Off
SBC-TV7	Hot Salt Pump C Disch. Valve	Thermal Storage	On/Off
SBC-TV20	Hot Salt Pump A Drain Valve	Thermal Storage	On/Off
SBC-TV21	Hot Salt Pump B Drain Valve	Thermal Storage	On/Off

Identifier	Description	Equip. Location	Output Signal
SBC-TV22	Hot Salt Pump C Drain Valve	Thermal Storage	On/Off
SBC-TV23	Hot Salt Header Valve	Thermal Storage	On/Off
SBC-TV24	Hot Salt Bypass Valve	Thermal Storage	On/Off
SBC-TV26	Hot Salt to Drain Sump Valve	Thermal Storage	On/Off
SBC-TV27	SSG to Drain Sump	Thermal Storage	On/Off
SBC-TV29	Hot Salt to Superheater Valve	SSG	On/Off
SBC-TV38	Salt Return Blocking Valve	Thermal Storage	On/Off
SBC-TV39	Supreheater Salt Vent Valve	SSG	On/Off
SBC-TV40	Hot Salt to Drain Sump	Thermal Storage	On/Off
SBC-TV41	Evap. Salt Vent Valve	SSG	On/OFF
SBC-TV44	SSG to Drain Sump	SSG	On/Off
SBC-TV45	Preheater Salt Vent Valve	SSG	On/Off
SBC-WV25	Hot Salt Pump Inlet Valve	Thermal Storage	On/Off
SBD-TV1	Solar Steam to Turbine	SSG	On/Off
SBD-TV3	Solar Steam to Condenser	SSG	On/Off
SBD-ZV2	Solar Steam to Turbine-Stop Check	SSG	On/Off
SBD-ZV4	Solar Steam to Condenser-Stop Check	SSG	On/Off
SBE-CV3	Steam Drum Level Cont. Valve	SSG	4-20 MA
FWA-CV16	Warmup Steam Desuperheater Valve	SSG	4-20 MA
SGG-CV16	Startup Steam Control Valve	SSG	4-20 MA
SGG-TV2	Fossil Steam to Turbine	SSG	On/Off
SGG-TV4	Fossil Steam to Turbine	SSG	On/Off
		SSG	On/Off
SGG-TV9	Fossil Steam to Condenser	SSG	On/Off

Identifier	Description	Equip. Location	Output Signal
SGG-TV13	Fossil Steam for Solar Startup		
SGG-ZV1	Fossil Steam to Turbine-Stop Check	SSG	On/Off
SGG-ZV3	Fossil Steam to Turbine-Stop Check	SSG	On/Off
SGG-ZV10	Fossil Steam to Condenser-Stop Check	SSG	On/Off
SGG-ZV14	Solar Startup-Stop Check		
	Evap. Recirc Pump A Start	SSG	On/Off
	Evap. Recirc Pump A Stop	SSG	On/Off
	Evap. Recirc Pump B Start	SSG	On/Off
	Evap. Recirc Pump B Stop	SSG	On/Off
	Prehtr. Recirc. Pump Start	SSG	On/Off
	Prehtr. Recirc. Pump Stop	SSG	On/Off
	Attemperation Pump Start	Thermal Storage	On/Off
	Attemperation Pump Stop	Thermal Storage	On/Off
	Hot Salt Pump A Speed Control	Thermal Storage	4-20 MA
	Hot Salt Pump A Start	Thermal Storage	On/Off
	Hot Salt Pump A Stop	Thermal Storage	On/Off
	Hot Salt Pump B Speed Control	Thermal Storage	4-20 MA
	Hot Salt Pump B Start	Thermal Storage	On/Off
	Hot Salt Pump B Stop	Thermal Storage	On/Off
	Hot Salt Pump C Speed Control	Thermal Storage	4-20 MA
	Hot Salt Pump C Start	Thermal Storage	On/Off
	Hot Salt Pump C Stop	Thermal Storage	On/Off
	Heat Trace Relay	SSG	On/Off
	Heat Trace Relay	SSG	On/Off

Identifier	Description	Equip. Location	Output Signal
	Heat Trace Relay	SSG	On/Off
	Heat Trace Relay	SSG	On/Off
	Heat Trace Relay	SSG	On/Off
	Heat Trace Relay	SSG	On/Off
	Heat Trace Relay	SSG	On/Off
	Heat Trace Relay	SSG	On/Off
	Heat Trace Relay	SSG	On/Off
	Heat Trace Relay	SSG	On/Off

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
FWA-ZT 1	FWA-CV16 Position	SSG	4-20 MA						
SBE 7	FWC-CV3 Position	SSG	4-20 MA						
RSC-ZS 1	RSC-TV26 Open	Thermal Storage	Micro						
RSC-ZS 2	RSC-TV26 Closed	Thermal Storage	Micro						
RSC-ZS 3	RSC-WV54 Open	Thermal Storage	Micro						
RSC-ZS 4	RSC-WV54 Closed	Thermal Storage	Micro						
RSC-ZS 5	RSC-TV35 Open	Thermal Storage	Micro						
RSC-ZS 6	RSC-TV35 Closed	Thermal Storage	Micro						
RSC-ZS 7	RSC-TV32 Open	Thermal Storage	Micro						
RSC-ZS 8	RSC-TV32 Closed	Thermal Storage	Micro						
RSC-ZT 54	RSC-CV30 Position	Thermal Storage	4-20 MA						
RSC-ZT 55	RSC-CV34 Position	Thermal Storage	4-20 MA						
SBA-LT 1	Steam Drum Level	SSG	4-20 MA						
SBA-LT 2	Steam Drum Level	SSG	4-20 MA						
SBA-LT 3	Steam Drum Level	SSG	4-20 MA						
SBA-PT 4	Steam Drum Press	SSG	4-20 MA						
SBA-TE 5	Steam Leaving Superheater Temp	SSG	Type K						
SBA-TE 6	Steam Leaving Superheater Temp	SSG	Type K						
SBA-TE 7	Steam Leaving Superheater Temp	SSG	Type K						
SBA-TE 8	Steam Entering Superheater Temp	SSG	Type K						
RSC-ZT56	RSC-TV60 Open	Thermal Storage	Micro						
RSC-ZT57	RSC-TV60 Closed	Thermal Storage	Micro						
SBA-TE9	Feedwater to Preheater Temp	SSG	Type K						

Appendix D - Steam Generator Control & Instrument List

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
SBA-TE10	Feedwater to Preheater Temp	SSG	Type K						
SBA-TE11	Feedwater to Preheater Temp	SSG	Type K						
SBA-TE12	Preheater Outlet Temp	SSG	Type K						
SBA-TE13	Evap. Recirc Pump A Inlet Temp	SSG	Type K						
SBA-TE14	Evap. Recirc Pump B Inlet Temp	SSG	Type K						
SBA-TE16	Startup Warming Desuperheater Outlet Temp	SSG	Type K						
SBA-ZS17	SBA-TV1 Open	SSG	Micro						
SBA-ZS18	SBA-TV1 Closed	SSG	Micro						
SBA-ZS19	SBA-TV36 Open	SSG	Micro						
SBA-ZS20	SBA-TV36 Closed	SSG	Micro						
SBA-ZS21	SBA-TV37 Open	SSG	Micro						
SBA-ZS22	SBA-TV37 Closed	SSG	Micro						
SBA-ZT23	Feedwater Temp Control Valve Position	SSG	4-20 MA						
SBA-ZT24	SBA-CV6 Position	SSG	4-20 MA						
SBB-ZS1	SBB-TV1 Open	SSG	Micro						
SBB-ZS2	SBB-TV1 Closed	SSG	Micro						
SBC-FT1	Hot Salt Pump A Flow	Thermal Storage	4-20 MA						
SBC-FT2	Hot Salt Pump B Flow	Thermal Storage	4-20 MA						
SBC-FT3	Hot Salt Pump C Flow	Thermal Storage	4-20 MA						
SBC-FT4	Hot Salt Header Flow	Thermal Storage	4-20 MA						
SBC-FT5	Hot Salt Header Flow	Thermal Storage	4-20 MA						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
SBC-FT6	Hot Salt Header Flow	Thermal Storage	4-20 MA						
SBC-FT7	Attemp Pump Discharge Flow	Thermal Storage	4-20 MA						
SBC-FT8	Attemp Pump Header Flow	Thermal Storage	4-20 MA						
SBC-PT9	Hot Salt Header Press.	Thermal Storage	4-20 MA						
SBC-PT10	Attemp Pump Header Press.	Thermal Storage	4-20 MA						
SBC-TE11	Hot Salt Header Temp	Thermal Storage	Type K						
SBC-TE12	Hot Salt to Superheater Temp	SSG	Type K						
SBC-TE13	Hot Salt to Superheater Temp	SSG	Type K						
SBC-TE14	Hot Salt to Superheater Temp	SSG	Type K						
SBC-TE15	Hot Salt to Evaporator Temp	SSG	Type K						
SBC-TE16	Hot Salt to Evaporator Temp	SSG	Type K						
SBC-TE17	Hot Salt to Evaporator Temp	SSG	Type K						
SBC-TE18	Hot Salt to Preheater Temp	SSG	Type K						
SBC-TE19	Cold Salt Attemp Header Temp	Thermal Storage	Type K						
SBC-ZS 20	SBC-TV24 Open	Thermal Storage	Micro						
SBC-ZS 21	SBC-TV24 Closed	Thermal Storage	Micro						
SBC-ZS 22	SBC-TV29 Open	SSG	Micro						
SBC-ZS 23	SBC-TV29 Closed	SSG	Micro						
SBC-ZS 24	SBC-TV1 Open	Thermal Storage	Micro						
SBC-ZS 25	SBC-TV1 Closed	Thermal Storage	Micro						
SBC-ZS 26	SBC-TV4 Open	Thermal Storage	Micro						
SBC-ZS 27	SBC-TV4 Closed	Thermal Storage	Micro						
SBC-ZS 28	SBC-TV7 Open	Thermal Storage	Micro						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
SBC-ZS 29	SBC-TV7 Closed	Thermal Storage	Micro						
SBC-ZS 30	SBC-WV25 Open	Thermal Storage	Micro						
SBC-ZS 31	SBC-WV25 Closed	Thermal Storage	Micro						
SBC-ZS 32	SBC-TV23 Open	Thermal Storage	Micro						
SBC-ZS 33	SBC-TV23 Closed	Thermal Storage	Micro						
SBC-ZS 34	SBC-TV27 Open	Thermal Storage	Micro						
SBC-ZS 35	SBC-TV27 Closed	Thermal Storage	Micro						
SBC-ZS 36	SBC-TV38 Open	Thermal Storage	Micro						
SBC-ZS 37	SBC-TV38 Closed	Thermal Storage	Micro						
SBC-ZS 38	SBC-TV26 Open	Thermal Storage	Micro						
SBC-ZS 39	SBC-TV26 Closed	Thermal Storage	Micro						
SBC-ZS 40	SBC-TV20 Open	Thermal Storage	Micro						
SBC-ZS 41	SBC-TV20 Closed	Thermal Storage	Micro						
SBC-ZS 42	SBC-TV21 Open	Thermal Storage	Micro						
SBC-ZS 43	SBC-TV21 Closed	Thermal Storage	Micro						
SBC-ZS 44	SBC-TV22 Open	Thermal Storage	Micro						
SBC-ZS 45	SBC-TV22 Closed	Thermal Storage	Micro						
SBC-ZT 46	SBC-CV16 Position	Thermal Storage	4-20 MA						
SBC-ZT 47	SBC-CV19 Position	Thermal Storage	4-20 MA						
SBC-ZT 48	SBC-CV31 Position	SSG	4-20 MA						
SBC-ZT 49	SBC-CV12 Position	Thermal Storage	4-20 MA						
SBD-FT 1	Superheated Steam Flow	SSG	4-20 MA						
SBD-FT 2	Superheated Steam Flow	SSG	4-20 MA						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels				Sampling Period (Seconds)
					High/High	High	Low	Low/Low	
SBD-FT 3	Superheated Steam Flow	SSG	4-20 MA						
SBD-LS 4	Condensate Drip Leg Level SW	SSG	Micro						
SBD-LS 5	Condensate Drip Leg Level SW	SSG	Micro						
SBD-LS 6	Condensate Drip Leg Level SW	SSG	Micro						
SBD-PT 7	Throttle Steam Press	SSG	4-20 MA						
SBD-PT 17	Throttle Steam Press	SSG	4-20 MA						
SBD-PT 18	Throttle Steam Press	SSG	4-20 MA						
SBD-TE 8	Startup Bypass to Condenser Temp	SSG	Type K						
SBD-ZS 9	SBD-TV1 Open	SSG	Micro						
SBD-ZS 10	SBD-TV1 Closed	SSG	Micro						
SBD-ZS 11	SBD-TV3 Open	SSG	Micro						
SBD-ZS 12	SBD-TV3 Closed	SSG	Micro						
SBD-ZS 13	SBD-ZV2 Open	SSG	Micro						
SBD-ZS 14	SBD-ZV2 Closed	SSG	Micro						
SBD-ZS 15	SBD-ZV4 Open	SSG	Micro						
SBD-ZS 16	SBD-ZV4 Closed	SSG	Micro						
SBE-FT 1	Feedwater Flow	SSG	4-20 MA						
SBE-FT 2	Feedwater Flow	SSG	4-20 MA						
SBE-FT 3	Feedwater Flow	SSG	4-20 MA						
SBE-PT 4	Feedwater Pressure	SSG	4-20 MA						
SBC-ZT152	SBC-TV-39 Open	SSG	Micro						
SBC-ZT153	SBC-TV-39 Closed	SSG	Micro						
SBC-ZT154	SBC-TV-39 Open	SSG	Micro						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
SBC-ZT155	SBC-TV-39 Closed	SSG	Micro						
SBC-ZT156	SBC-TV-39 Open	SSG	Micro						
SBC-ZT157	SBC-TV-39 Closed	SSG	Micro						
SBE-TE 5	Feedwater Temp	SSG	Type K						
SBE-ZT 6	SBE-CV3 Position	SSG	4-20 MA						
SGG-ZS 1	SGG-TV4 Open	SSG	Micro						
SGG-ZS 2	SGG-TV4 Closed	SSG	Micro						
SGG-ZS 3	GSS-TV5 Open	SSG	Micro						
SGG-ZS 4	SGG-TV5 Closed	SSG	Micro						
SGG-ZS 5	SGG-TV9 Open	SGG	Micro						
SGG-ZS 6	SGG-TV9 Closed	SSG	Micro						
SGG-ZS 7	SGG-ZV1 Open	SSG	Micro						
SGG-ZS 8	SGG-ZV1 Closed	SSG	Micro						
SGG-ZS 9	SGG-TV2 Open	SSG	Micro						
SGG-ZS 10	SGG-TV2 Closed	SSG	Micro						
SGG-ZS 11	SGG-ZV3 Open	SSG	Micro						
SGG-ZS 12	SGG-ZV3 Closed	SSG	Micro						
SGG-ZS 13	SGG-ZV6 Open	SSG	Micro						
SGG-ZS 14	SGG-ZV6 Closed	SSG	Micro						
SGG-ZS 15	SGG-ZV10 Open	SSG	Micro						
SGG-ZS 16	SGG-ZV10 Closed	SSG	Micro						
SGG-ZT 17	SGG-CV16 Position	SSG	4-20 MA						
TGA-PT 1	First Stage Turbine Press	SSG	4-20 MA						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
TGA-PT 2	First Stage Turbine Press	SSG	4-20 MA						
TGA-PT 3	First Stage Turbine Press	SSG	4-20 MA						
Hot Salt Pump A Speed		Thermal Storage	4-20 MA						
Hot Salt Pump B Speed		Thermal Storage	4-20 MA						
Hot Salt Pump C Speed		Thermal Storage	4-20 MA						
Attemp Pump Speed		Thermal Storage	4-20 MA						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
-TEH	Heat Trace TC	SSG	Type K						
SBC-TE50	Evaporator Temp	SSG	Type K						
SBC-TE51	Evaporator Temp	SSG	Type K						
SBC-TE52	Evaporator Temp	SSG	Type K						
SBC-TE53	Evaporator Temp	SSG	Type K						
SBC-TE54	Evaporator Temp	SSG	Type K						
SBC-TE55	Evaporator Temp	SSG	Type K						
SBC-TE56	Evaporator Temp	SSG	Type K						
SBC-TE57	Evaporator Temp	SSG	Type K						
SBC-TE58	Evaporator Temp	SSG	Type K						
SBC-TE59	Evaporator Temp	SSG	Type K						
SBC-TE60	Evaporator Temp	SSG	Type K						
SBC-TE61	Evaporator Temp	SSG	Type K						
SBC-TE62	Evaporator Temp	SSG	Type K						
SBC-TE63	Evaporator Temp	SSG	Type K						
SBC-TE64	Evaporator Temp	SSG	Type K						
SBC-TE65	Evaporator Temp	SSG	Type K						
SBC-TE66	Evaporator Temp	SSG	Type K						
SBC-TE67	Evaporator Temp	SSG	Type K						
SBC-TE68	Evaporator Temp	SSG	Type K						
SBC-TE69	Evaporator Temp	SSG	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
SBC-TE70	Evaporator Temp	SSG	Type K						
SBC-TE71	Evaporator Temp	SSG	Type K						
SBC-TE72	Evaporator Temp	SSG	Type K						
SBC-TE73	Evaporator Temp	SSG	Type K						
SBC-TE74	Evaporator Temp	SSG	Type K						
SBC-TE75	Evaporator Temp	SSG	Type K						
SBC-TE76	Evaporator Temp	SSG	Type K						
SBC-TE77	Evaporator Temp	SSG	Type K						
SBC-TE78	Evaporator Temp	SSG	Type K						
SBC-TE79	Evaporator Temp	SSG	Type K						
SBC-TE80	Evaporator Temp	SSG	Type K						
SBC-TE81	Evaporator Temp	SSG	Type K						
SBC-TE82	Evaporator Temp	SSG	Type K						
SBC-TE83	Evaporator Temp	SSG	Type K						
SBC-TE84	Preheater Temp	SSG	Type K						
SBC-TE85	Preheater Temp	SSG	Type K						
SBC-TE86	Preheater Temp	SSG	Type K						
SBC-TE87	Preheater Temp	SSG	Type K						
SBC-TE88	Preheater Temp	SSG	Type K						
SBC-TE89	Preheater Temp	SSG	Type K						
SBC-TE90	Preheater Temp	SSG	Type K						
SBC-TE91	Preheater Temp	SSG	Type K						
SBC-TE92	Preheater Temp	SSG	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
SBC-TE93	Preheater Temp	SSG	Type K						
SBC-TE94	Preheater Temp	SSG	Type K						
SBC-TE95	Preheater Temp	SSG	Type K						
SBC-TE96	Preheater Temp	SSG	Type K						
SBC-TE97	Preheater Temp	SSG	Type K						
SBC-TE98	Preheater Temp	SSG	Type K						
SBC-TE99	Preheater Temp	SSG	Type K						
SBC-TE100	Preheater Temp	SSG	Type K						
SBC-TE101	Preheater Temp	SSG	Type K						
SBC-TE102	Preheater Temp	SSG	Type K						
SBC-TE103	Preheater Temp	SSG	Type K						
SBC-TE104	Preheater Temp	SSG	Type K						
SBC-TE105	Preheater Temp	SSG	Type K						
SBC-TE106	Preheater Temp	SSG	Type K						
SBC-TE107	Preheater Temp	SSG	Type K						
SBC-TE108	Preheater Temp	SSG	Type K						
SBC-TE109	Preheater Temp	SSG	Type K						
SBC-TE110	Preheater Temp	SSG	Type K						
SBC-TE111	Preheater Temp	SSG	Type K						
SBC-TE112	Preheater Temp	SSG	Type K						
SBC-TE113	Preheater Temp	SSG	Type K						
SBC-TE114	Preheater Temp	SSG	Type K						
SBC-TE115	Preheater Temp	SSG	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
SBC-TE116	Preheater Temp	SSG	Type K						
SBC-TE117	Preheater Temp	SSG	Type K						
SBC-TE118	Superheater Temp	SSG	Type K						
SBC-TE119	Superheater Temp	SSG	Type K						
SBC-TE120	Superheater Temp	SSG	Type K						
SBC-TE121	Superheater Temp	SSG	Type K						
SBC-TE122	Superheater Temp	SSG	Type K						
SBC-TE123	Superheater Temp	SSG	Type K						
SBC-TE124	Superheater Temp	SSG	Type K						
SBC-TE125	Superheater Temp	SSG	Type K						
SBC-TE126	Superheater Temp	SSG	Type K						
SBC-TE127	Superheater Temp	SSG	Type K						
SBC-TE128	Superheater Temp	SSG	Type K						
SBC-TE129	Superheater Temp	SSG	Type K						
SBC-TE130	Superheater Temp	SSG	Type K						
SBC-TE131	Superheater Temp	SSG	Type K						
SBC-TE132	Superheater Temp	SSG	Type K						
SBC-TE133	Superheater Temp	SSG	Type K						
SBC-TE134	Superheater Temp	SSG	Type K						
SBC-TE135	Superheater Temp	SSG	Type K						
SBC-TE136	Superheater Temp	SSG	Type K						
SBC-TE137	Superheater Temp	SSG	Type K						
SBC-TE138	Superheater Temp	SSG	Type K						

Identifier	Description	Equip. Location	Input Signal	Range	Alarm Levels High/High	High	Low	Low/Low	Sampling Period (Seconds)
SBC-TE139	Superheater Temp	SSG	Type K						
SBC-TE140	Superheater Temp	SSG	Type K						
SBC-TE141	Superheater Temp	SSG	Type K						
SBC-TE142	Superheater Temp	SSG	Type K						
SBC-TE143	Superheater Temp	SSG	Type K						
SBC-TE144	Superheater Temp	SSG	Type K						
SBC-TE145	Superheater Temp	SSG	Type K						
SBC-TE146	Superheater Temp	SSG	Type K						
SBC-TE147	Superheater Temp	SSG	Type K						
SBC-TE148	Superheater Temp	SSG	Type K						
SBC-TE149	Superheater Temp	SSG	Type K						
SBC-TE150	Superheater Temp	SSG	Type K						
SBC-TE151	Superheater Temp	SSG	Type K						