FWC/FWDC/TR-83/14

FOSTER WHEELER SOLAR DEVELOPMENT CORPORATION

FWC/FWDC/TR-83/14

OPERATING AND MAINTENANCE MANUAL

FOR

MODULAR INDUSTRIAL SOLAR RETROFIT SYSTEM

Prepared for

Sandia National Laboratories
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FOSTER WHEELER SOLAR DEVELOPMENT CORPORATION
12 Peach Tree Hill Road, Livingston, New Jersey 07039

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MISR SYSTEM DESCRIPTION

Section 1

MISR SYSTEM DESCRIPTION

1.1 INTRODUCTION

This Modular Industrial Solar Retrofit (MISR) system is designed to be retrofitted to an existing industrial facility. When insolation is sufficient, it will generate saturated steam in a safe and reliable manner with a minimum of operator intervention.

The MISR system utilizes a heat-transfer loop to deliver hot, pressurized water from the solar collectors to the heat exchanger (SG-101). The water is then recirculated through the accumulator tank (TK-101) to the collectors via a centrifugal pump (P-101), as illustrated in Figure 1.1. In the heat exchanger (SG-101), feedwater from the condenser is converted into saturated steam up to 250 lb/in^{2}g. The accumulator tank (TK-101) accommodates the thermal expansion of water and ensures that boiling is prevented within the heat-transfer loop. During normal operation the plant is controlled by automatic analog controllers.

1.2 DUTY OF PLANT

The plant is designed to convert boiler feedwater (BFW) to saturated steam at 250 lb/in^{2}g. At peak insolation, 5500 lb/h steam will be produced.

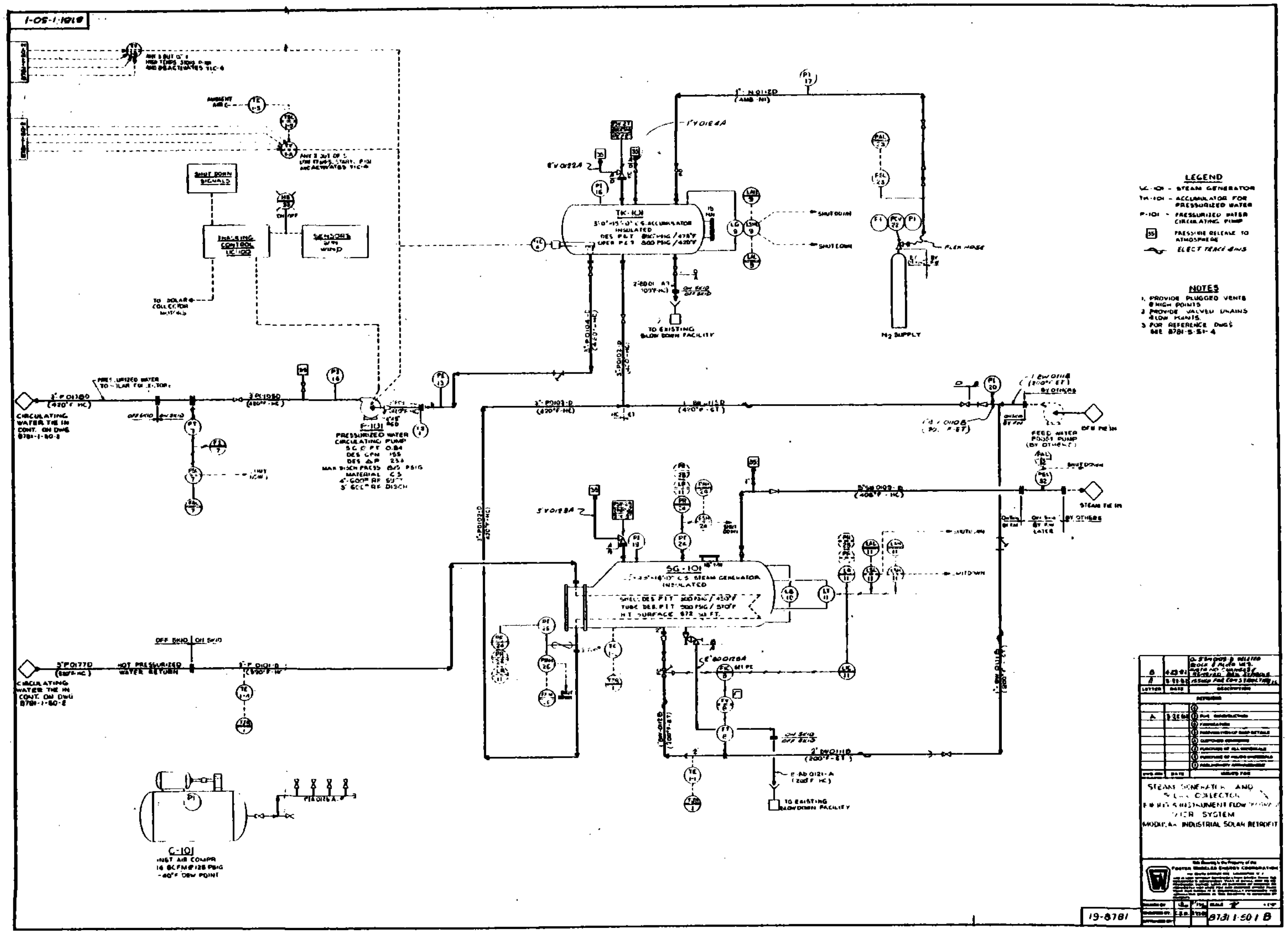

Figure 1.1 Piping, Instrument, and Design Temperature and Pressure Diagram for MISR System

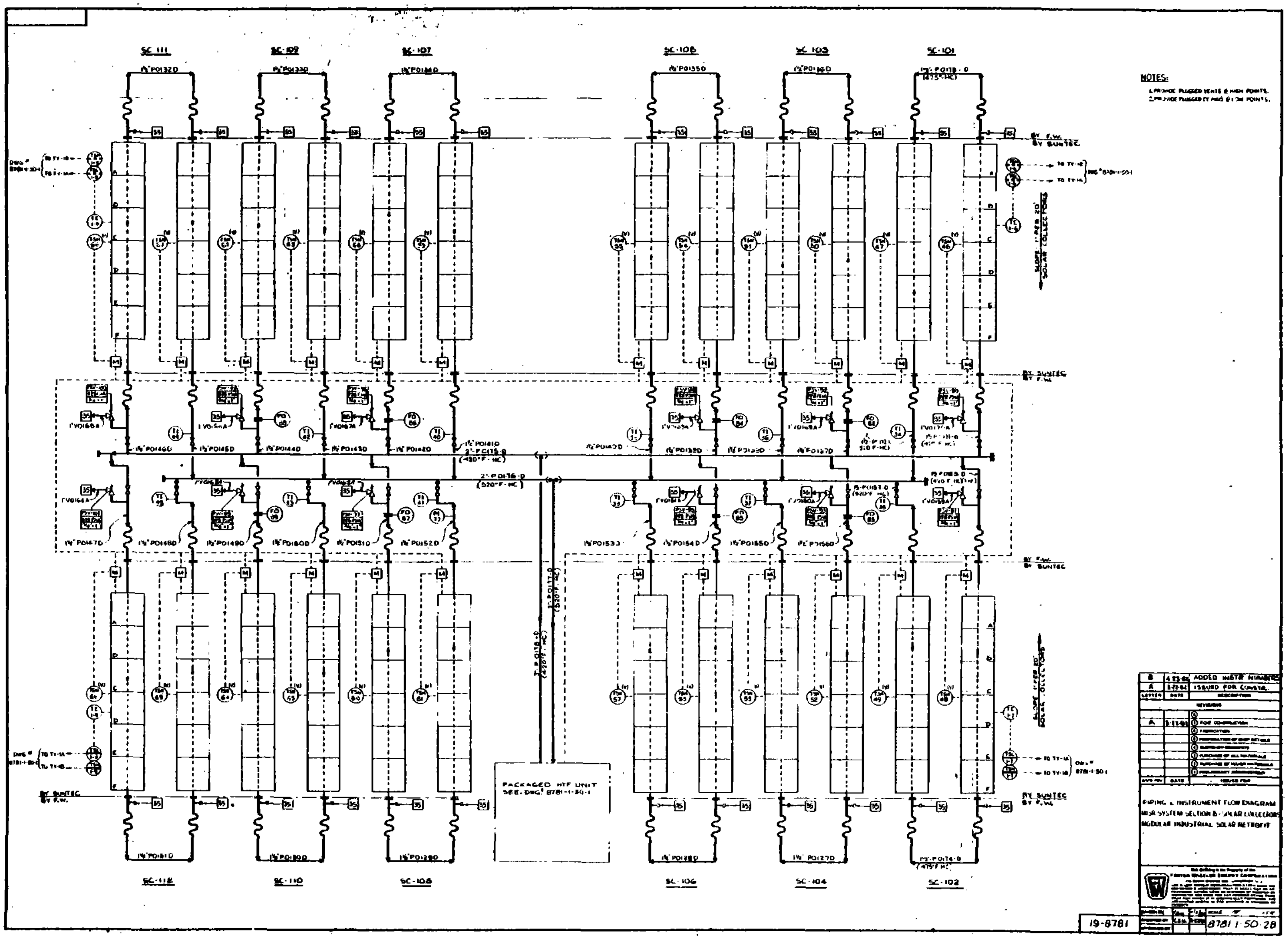

Figure 1.1 Piping, Instrument, and Design Temperature and Pressure Diagram for MISR System (Cont)

1.3 DESIGN BASIS

The basic parameters utilized for design of the plant are as follows:

- Maximum energy delivery during peak insolation of 6.07 x 10^6 Btu/h
- Boiler feedwater from the condenser at 200°F and 300 lb/in²g
- Saturated steam from the solar plant delivered at 250 lb/in²g
- Water temperature from the collectors at 500°F and to the collectors at 420°F.

1.4 PLANT FACILITIES

- Solar Collectors are manufactured by Suntec Systems, Inc.; they are single-axis, parabolic-trough, line-focusing type; sun-hour tracking; 12 rows each 120 ft long; nominal 20-ft collector spacing; 27840 ft² total collector aperture area; smooth absorber tube.

  The control system for the collectors is provided by Honeywell, Inc. This Flux Line Sun Tracker control system comprises a master controller, local controllers on each collector, and sun and wind sensors.

  Each collector is driven by a direct drive assembly powered by a battery-powered, 24-Vdc motor. The motors are hard-wired to the remotely located and environmentally protected battery pack. The batteries are maintained by an on-line 110-Vac trickle charger.

- Heat Exchanger (SG-101) generates steam on the shell side and is designed for a maximum heat absorption rate of 6.07 x 10^6 Btu/h. At this heat absorption rate, the unit will generate 5500 lb/h of 250 lb/in²g steam. SG-101 is a kettle-type exchanger in which a 20-in.-dia removable bundle of 188 U-tubes is inserted into a 48-in.-dia shell. To maintain a satisfactory inside film convective heat-transfer coefficient, 3/4-in. O.D. x 0.083-in. wall thickness x 16-ft long tubes are used and arranged in four passes.

  Boiler feedwater at 200°F enters the shell side and is vaporized to produce 250 lb/in²g saturated steam. Sufficient disengaging space is left above the tube bundle to minimize liquid carryover in the product steam.

- Accumulator Tank (TK-101) has two basis functions:
  - To accommodate the thermal expansion of water
  - To maintain the system pressure passively so that boiling within the water heat-transfer loop is prevented.

  The tank is 3 ft in diameter and 15 ft long and has a volume of 113 ft^3. The volume of water in the tank will vary between 50 ft^3 at 60°F and to 80 ft^3 at the maximum designed operating temperature (420°F). This variable level ensures adequate vapor space at all times should venting through the relief valve or pressure-control valve be required.

  Boiling of water in the closed, heat-transfer loop is prevented by maintaining sufficient pressure within the accumulator vapor space. This pressure is provided by the partial pressures of the nitrogen blanket and water vapor within the vapor space. At 200°F, the pressure within the tank should be 216 lb/in^2a.

- Water Circulation Pump (P-101). At a pump inlet temperature of 420°F, the normal pumping rate is 151 gal/min.

- Air Compressor (C-101). A skid-mounted instrument air system delivers 14 sft^3/min at 125 lb/in^2g with a 40°F dew point. This air system is complete with a receiver, dryer, and control panel. The compressor is piston driven and oil free.

- Piping. A piping list is provided (Table 1.1). Piping is of carbon steel, of Schedule 80 if the I.D. of the pipe exceeds 1-1/2 in. (Schedule 40 if less), insulated with up to 3 in. of double-layer calcium silicate insulation.

Table 1.1 Line Classification List

FOSTER WHEELER SPEC, INC.
LIVINGSTON, NEW JERSEY

CONTRACT: 5-21-8781
SECTION: MISR

LINE CLASSIFICATION LIST

FLOW SHEET NUMBER & REVISION: 8781-1-50-1/2B

PAGE 1 OF

REVISION	ORIGINAL	1	2	3	4	5	6	7	8	9	10	11
DATE	3-22-82	4-22-82										

LINE NUMBER SIZE	SERIAL		SPEC	LINE EXTREMITIES FROM	TO	OPERATING TEMP °F	OPERATING PRESS PSIG	DESIGN TEMP °F	DESIGN PRESS PSIG	INSULATION TYPE	INSULATION THK	PLAN OR ISOMETRIC DRAWING NO.	PIPE WALL THK	FLU CAT.	REMARKS
1"	BW	0110	B	BW0111	BW0115	200	350	225	400	Calcium Silicate	3"				
1"	BW	0111	B	FW PUMP DISCH.	2" TEST SEC	200	350	225	400						
2"	BW	0111	B	2" TEST SECTION		200	350	225	400						
1"	BW	0112	B	2" TEST SEC	ST GEN	200	350	225	400						
3"	P	0104	D	TK-101	P-101 INLET	420	800	470	880						
3"	P	0105	D	P-101 DISCH	EDGE OF SKID	420	820	470	880						
3"	P	0178	D	SKID	COLL. INLET MANIFOLD	420	820	470	880						
2"	P	0175	D	P0178	INLET MANIFOLD	420	820	470	880						
1½"	P	0137	D	INLET MANIFOLD	FLEX HOSE	420	820	470	880						REPLICATED FOR ALL COLLECTOR STRINGS
1½"	P	0173	D	MID PT AT STRING		465	820	525	880						"
1½"	P	0172	D	FLEX HOSE	OUTLET MANIFOLD	500	820	575	880						"
2"	P	0176	D	OUTLET MANIFOLD		500	820	575	880						
2"	P	0177	D	OUTLET MANIFOLD	SKID	500	820	575	880						
3"	P	0101	D	SKID EDGE	SG-101	500	820	575	880						
3"	P	0102	D	SG-101	TK-101	420	800	"70	880						
3"	SM	0109	B	SG-101 (STM DISCH.)	STEAM TIE IN	406	265	445	290						
1"	N	0112	D	N_2 SUPPLY	TK-101	UP TO 420	UP TO 800								
1"	BW	0115	D	BW0110	TK-101 TIE IN	420	800	470	880						
2"	V	0122	A	PSV 27 FROM TK-101		420	ATM	475	25						
3"	V	0123	A	PSV 28 FROM SG-101		400	ATM	450	25						
1"	V	0124	A	PV 21A FROM TK-101		420	ATM	475	25						
2"	BD	0125	A	SG-101	BD PIT	400	ATM	450	25						
2"	BD	0122	D/A	TK-101	BD PIT	200	20	225	25						
1"	IA	0126	A	C-101	IA HEADER	120	125	140	150						
(5) ← SEE NOTES – LINE CLASSIFICATION LIST INDEX →						(1)	(1)	(1)	(1)	(2)			(3)		(4)

SECTION 2

OPERATING CONDITIONS AND CONTROLS

Section 2

OPERATING CONDITIONS AND CONTROLS

2.1 GENERAL OPERATING CONDITIONS

The plant is designed to operate automatically upon activation of the control mechanism. Operation commences when the sun sensor, a photocell mounted on the equipment skid, signals the master controller that adequate insolation is available. The master controller, in turn, sends a command to the pump (P-101) control for pump start-up if:

- Demand switch HS-33 is "ON"
- Wind speed is below 30 mi/h
- Heat exchanger (SG-101) and accumulator tank (TK-101) water level are within bounds.

The pump (P-101) establishes water circulation in the heat-transfer fluid loop. A flow switch (FSL-7) detects flow and, when an affirmative signal is sent to the master controller, it activates the module controls to drive collectors from the stowed position and begin tracking. When the sun's image is centered on the tracking head and therefore upon the receiver, a feedback signal is sent to the module controls and tracking begins. Tracking ensures that the sun's image is always focused upon the receiver tube.

As water flows through the solar collector receiver tubes, it absorbs heat and delivers it to the tube side of the heat exchanger (SG-101), vaporizing boiler feedwater on the shell side to produce 250 lb/in²g saturated steam.

The steam produced by the plant discharges into the steam header. The water level in SG-101 is automatically controlled to keep the heating coils submerged and to maintain sufficient disengagement space to minimize water carry-over. To ensure the smooth flow of boiler feedwater, cascaded control is exerted over the flow through level and flow controllers.

When the insolation (solar intensity) falls below a preset value (at nightfall or when clouds cover the sun), the master controller signals the local controllers to stow the collectors after a predetermined time delay. During this time delay, the collectors are held in position. If the insolation should rise above the preset value within this period, normal operation resumes. If adequate insolation is not restored, the collectors are stowed and the pump is stopped. Normal operation of the system resumes when insolation again reaches the required value.

The design operating conditions of the system are:

Heat-Transfer Fluid (Water)	
Inlet temperature to heat exchanger	500°F
Outlet temperature from heat exchanger	420°F
Flow rate	151 gal/min
Pressure	810 lb/in^{2}g
Feedwater	
Inlet temperature	200°F
Inlet pressure	300 lb/in^{2}g
Saturated Steam	
Temperature	406°F
Pressure	250 lb/in^{2}g
Peak flow rate	5500 lb/h

Should insolation be lower than the maximum value anticipated in the design, the water heat-transfer loop operates at a lower temperature. No control whatsoever is exerted over the temperatures within the water heat-transfer loop other than the requirement that the steam generated be at 406°F.

2.2 FREEZE PROTECTION

The following automatic protection prevents freezing within the pipes, receiver tubes, and vessels:

- The boiler feedwater line is electrically heat traced. Heating of the line begins when the ambient temperature reaches 40°F.
- When two of the three devices measuring the temperatures on the two receiver tubes and the ambient temperature indicate temperatures below 40°F, the pump is started to circulate warm water through the heat-transfer loop. When the temperature in both receiver tubes exceeds 110°F, the pump is stopped.

Freeze protection is initially provided by circulating the hot water stored within the accumulator and drawing from the heat stored within the heat exchanger. As the temperature within the accumulator falls if the MISR system is operating in the freeze protection mode, the thermostatically controlled electric heater in the accumulator operates so as to maintain a temperature of 100°F in the accumulator (TK-101).

It should be noted that should insolation be adequate and the other usual conditions be met, normal operation will resume and operation in the freeze protection mode will cease (e.g., pump shutdown will no longer occur when the temperature in both receiver tubes exceeds 100°F etc.).

2.3 MISCELLANEOUS OPERATING CONTROLS AND PROCEDURES

- Collector Row. When a collector row fails, that row must be stowed. The master controller cannot remotely stow a row; this action must be initiated manually.

- Reduced Steam Production. At times it may be desirable to operate the MISR system at reduced steam production rates. Such reduction can be achieved by stowing one or more of the collectors.

- Manual Valves Normally Open During Operation

Size (in.)	Line No.	Location
1	BW0111-B	Upstream of FT-8
1	BW0112-B	Between SG-101 and FCV-8
3	SM0109-B	Between SG-101 and vent to atmosphere
3	P0102-D	Between SG-101 and TK-101
3	P0104-D	Between TK-101 and P-101
3	P0105-D	Between P-101 and FT-7
1-1/2		Inlet and outlet to collector strings

- Manual Valves Normally Closed During Operation

Size (in.)	Line No.	Location
2	BD0122-A	Blowdown line from TK-101
1	BW0115-D	Between check valve and 3-in. P0102-D
2	BD0125-A	Blowdown line from SG-101 (Yarway tandem blowdown)

- Water Quality (SG-101). Samples of water from SG-101 should be taken periodically and analyzed; blowdown should reflect the results of these tests.

  The addition of a phosphate solution in the shell side of SG-101 is not planned at this time, but can be incorporated at a later date if necessary.

- Water Quality (Heat-Transfer Loop). A sample of water should be taken periodically from the drain plug on the 1-1/2 in. P0113-D line and examined visually for contamination. This sample should be taken only when the system is cold.

- Loss of Electricity for Freeze Protection. Should electrical power be lost at a time when freeze protection is required, the system should be drained by opening all blowdown and drain valves. Should the heater in the accumulator fail, circulation of the water will probably suffice to prevent freezing--if the water temperature does not fall below 26°F. Below this temperature the system should be drained.

SECTION 3

DESCRIPTION OF EMERGENCY EQUIPMENT

Section 3

DESCRIPTION OF EMERGENCY EQUIPMENT

3.1 SAFETY VALVES

Safety valves for the MISR system are described in Table 3.1.

Table 3.1 Safety Valves

Item No.	Service	Set Pressure (lb/in^2g)	Size (in.)	Relieves To
PSV-90 to 101	On ΔT loop, water	910	3/4 x 1	Atmosphere
PSV-28	SG-101 steam generator, water	280	2 x 3	Atmosphere
PSV-27	TK-101, water	880	1-1/2 x 2	Atmosphere

3.2 ALARMS

Table 3.2 lists alarms provided for the MISR system.

3.3 EMERGENCY SHUTDOWN

Table 3.3 lists the conditions that will cause the system to shut down and the collectors to stow.

Table 3.2 Alarms

Description	Item No.	Service	Set Point	Remarks
Temperature alarms				None
High-flow alarms				None
Low-flow alarms	FAL-7	3-in. P0105-D water from P-101	75 percent of normal flow	
High-level alarms	LAH-9	TK-101 accumulator	30 in.	
	LAH-11	SG-101 heat exchanger	36 in.	
Low-level alarms	LAL-9	TK-101 accumulator tank	18 in.	
	LAL-11	SG-101 heat exchanger	18 in.	
High-pressure alarms	PAHH-26	3 in. P0102-D water line from SG-101	840 lb/in^2g	
	PAH-24	SG-101 heat exchanger	265 lb/in^2g	
Low-pressure alarms	PAL-23	Nitrogen supply pressure	350 lb/in^2g	

Table 3.3 Emergency Shutdown

Condition	Cause	Switch	Set Point	Remarks
Overall shutdown	Power loss in any phase			
High-pressure shutdown	High pressure in heat-transfer loop	PSHH-26	840 lb/in²g	
	High pressure in steam generator	PSH-24	265 lb/in²g	
Low-pressure shutdown				None
High-level shutdown	High level in SG-101	LSH-11	36 in.	
	High level in TK-101	LSH-9	30 in.	
Low-level shutdown	Low level in SG-101	LSL-11	18 in.	
	Low level in TK-101	LSL-9	18 in.	
Low-flow shutdown	Low water flow in heat transfer loop	FSL-7	75 percent of normal flow	
High wind speed			30 mi/h	Collectors are stowed if wind speed exceeds 30 mi/h for 30 sec

In addition to the conditions listed in the table, individual collectors are stowed if their receiver temperature exceeds 525°F.

Master Controller. The normal operation of the plant, including cyclical start-up and shutdown, is controled by a Honeywell Master Controller. In addition, the Master Controller is designed to execute an automatic shutdown of the plant in the event of an emergency. The Controller system incorporates an uninterruptable power source (UPS) in case of electric power failure. Master Controller specifications are shown in Table 3.4.

Table 3.4 Master Controller Specifications

Characteristic	Specification
<u>Power Requirements</u>	
Master controller	24 Vdc ±5V at 1 amp (nominal)
Sun sensor	Powered from the master controller
Wind sensor	Powered from the master controller
<u>Operating Temperature</u>	-20°F to ±150°F ambient
<u>Input Signals</u>	
Wind speed	0.7.6 Vac corresponds to 0-100 mi/h
Solar intensity	0-10 Vdc corresponds to 0-1000 W/m²
AC power loss	Contacts open = AC power off Contacts closd = AC power on
Demand	Contacts open = Demand off Contacts closed = Demand on
No flow	Contacts open = No flow Contacts closed = Flow
<u>Output Signals</u>	
Pump control signal	+24 Vdc turns pump on 0 Vdc turns pump off
Authorization signal	+24 Vdc up to 5 amps = Authorization on 0 Vdc = Authorization off
<u>Trip Points and Time Delays</u>	
AC power loss	30-sec delay
AC power recovery	3-min delay
Wind speed above trip point	30-sec delay
Wind speed below trip point	2-min delay Wind speed trip point is manually adjustable. Factory set at 30 mi/h

Table 3.4 Master Controller Specifications (Cont)

Characteristic	Specification
Trip Points and Time Delays (Cont)	
Solar intensity above trip point	3-min delay
Solar intensity below trip point	20-min delay Solar intensity level trip point is manually adjustable. Factory set at 315 W/m^2 (100 Btu/ft^2h)
Front Panel Status Lamps	28 Vdc incandescent GE #387
Program running	Green
AC power loss	Red
High wind	Red
Miscellaneous fault	Red
Demand on	Green
Sun level above TP	Green
Sun timer activated	Yellow
Pump signal on	Green
No-flow	Red
Authorization signal on	Green
Front Panel Switches	
Program reset	Momentary push button
Lamp test	Momentary push button
Power switch	2-position toggle: on-off
Pump switch	2-position toggle: on-auto
Authorization switch	3-position toggle: on-off-auto
Rain wash switch	2-position toggle: on-off
On Board Switches	
Sun simulation	2-position toggle: on-off
Cabinet	Type NEMA 12
Hoffman A-1412 CHNF	14 x 12 x 6 in. Mounting holes: 5/16-in. dia 10 x 14-3/4 in. on center

SECTION 4

PREPARATION FOR INITIAL START-UP

Section 4

PREPARATION FOR INITIAL START-UP

4.1 GENERAL

Before initial start-up of the plant, all facilities must be checked for proper installation, cleaned, tested, and made ready for operation. The procedures outlined in this section are provided as a guide for execution of these activities. These procedures are carried out as a whole only once, at the completion of construction and before initial operation of the unit. However, appropriate portions of these procedures should be repeated after any major repair, alteration, or replacement during subsequent shutdowns. This plant preparation must be carried out systematically and thoroughly so that the actual plant start-up of the plant can be completed without unnecessary delays.

A checklist should be used to ensure that all activities involved are actually done.

During the preparation period, the operators should familiarize themselves with the physical layout of the plant.

4.2 EQUIPMENT INSTALLATION CHECKOUT

All lines and valves should be checked to ensure that their installation conforms to design specifications and related drawings. Specifically, the following should be checked:

- Automatic Control Valve Installations--for proper direction of flow and control function

- Block Valves and Check Valves--for proper direction of flow and control function
- Pressure-Relief Valves--by tag number for proper location
- Flanged Connections--for gaskets and loose bolts
- All Equipment--for proper installation and adequacy of drains and vents.

4.3 PIPELINE AND EQUIPMENT CLEANING

4.3.1 Pipelines

The piping system should be cleaned by flushing it with water or blowing it out. Before such cleaning, the instruments, relief valves, and vessels should be isolated or removed. The piping system must then be pressure tested.

4.3.2 Accumulator Tank TK-101

The inside of TK-101 should be visually inspected through the manway and flushed clean with high-pressure water from a hose through the manway. The water should be discharged through the drain line.

4.3.3 Heat Exchanger SG-101

A visual inspection should be made to ensure that the shell side of the heat exchanger is clean. If necessary, the shell side should be cleaned with high-pressure water.

The tube bundle should not be flushed in conjunction with testing and cleaning of the piping system. The tube bundle must be checked; all tubes in the bundle must be open so that water flows freely during operation.

Care must be taken to ensure that all connections to SG-101 that were broken for inspection and tests are restored to their original state and do not leak.

4.4 ELECTRICAL EQUIPMENT

All electrical equipment must be commissioned by qualified electrical personnel. All motors should be run uncoupled to test them and the control circuitry. At this stage the motor rotation should be checked to ensure that its direction is correct for the driven equipment before the two are coupled.

4.5 INSTRUMENT PREPARATION

The following steps should be taken to ensure that instruments are in working order:

- Safety Valves--tested before installation for correct lift-off and sealing, be adjusted for proper pressure, and be car seal locked
- Orifice Plates--checked for correct size and specified gaskets
- Control Valves
  - Stroked over full operating range to ensure freedom of movement
  - Checked with manual loading station signals
  - Checked for correct action on motive failure
- Instruments--compared with design data for correct location and range of measurement
- Instrument Piping and Tubing--cleaned and tested in accordance with procedures
- Instrument Loops
  - Checked for correct installation (i.e., location of transmitter relative to line sizing and layout of lead lines, insulation and tracing, and seal fluid in lead lines where required)
- Transmitters--calibrated and checked in place
- Receivers--checked with output signals from transmitters
- Alarm and trip settings checked
- Each trip actuator checked to be sure it initiates the specified trip function

- Valves Associated With Trip System--checked for correct operation
- Alarm and Automatic Safety Switches--tested.

4.6 PUMPS

4.6.1 General

Pumps should be broken in following manufacturer's recommendations. The following general procedures should be followed in conjunction with breaking in the pumps:

- Rotate pumps to check for ease of rotation, by hand (if possible) with both suction and discharge valves open.
- Provide cooling water at all required points (stuffing boxes, gears, seals, etc.) and water flow begin before starting pumps.
- Ensure that all lubrication requirements conform with manufacturer's specifications.
- Install a temporary strainer at the pump suction (to be removed after break-in period).
- Prime pumps, with suction valves fully open, by opening all top vents to expel air. Start pumps with suction valves fully open and discharge valves closed. As soon as pump is started, check that discharge pressure gauge indicates correct pump pressure.
- Slowly open discharge valve partially to give a flow adequate for testing the pump. Check:
  - Full load amp rating
  - Motor/pump rev/min
  - Bearings for signs of overheating
  - Gland packing boxes for overheating.

4.6.2 Circulating Pump, P-101

Water for the break-in of P-101 can be charged into Accumulator Tank TK-101 by opening the valve in the line. The tank should be vented to the atmosphere during water charging, and all discharge valves from TK-101 should be closed until pump run-in is actually started. Valves, simulator, and Solar Collectors (on 2-in. P0104-B1) must be closed before starting pump break-in.

As many as possible of the instruments on the pump discharge line should be checked during pump break-in. After pump break-in is complete, all water should be drained from the break-in system.

4.7 AIR COMPRESSOR

The air compressor should be checked for:

- Leaks and proper pressure buildup
- Proper operation of the pressure switch and controls
- Proper operation of the air drier, including cycling between the two dessicant chambers.

4.8 SOLAR COLLECTORS

Operation of the solar collectors should be checked under the guidance of the manufacturer's representative to ensure that all mechanical aspects of the system function properly.

SECTION 5

INITIAL START-UP

Section 5

INITIAL START-UP

5.1 GENERAL

Before proceeding with actual start-up operations, a final check should be made that all prestart-up preparations were completed. These preparations include the following checks:

- Pressure testing, inspection, and cleaning of the piping system, vessels, instrument lines, etc.
- Operation of air compressor
- Proper operation of instruments
- Pumps run-in and operating characteristics
- Electrical system
- Operation of solar collectors.

Availability of the following items should be confirmed:

- Boiler feedwater
- Sufficient water to fill the system plus an operating reserve
- Electric power
- Nitrogen.

All valves in boiler feedwater service, water heat-transfer loop, steam and nitrogen services should be closed when start-up begins to ensure that each fluid in the system goes where intended when appropriate valves are opened and flow is begun.

5.2 CHARGING HEAT EXCHANGER SG-101 WITH BOILER FEEDWATER

- Notify the appropriate boiler room operators that the Heat Exchanger SG-101 is to be charged with boiler feedwater and that the boiler feedwater pump is to be started
- Open the following valves:
  - 1 in. downstream of FV-8.
- Activate boiler feedwater controls on skid and check FV-8
- Fill heat exchanger SG-101 until the tube bundle is entirely covered, leaving the top zone free for vapors to escape.

5.3 FILLING HEAT-TRANSFER LOOP

Important Note: Water can be charged to Accumulator Tank TK-101 only when the temperature of the tank is 200°F or below and pressure is less than 220 lb/in²g. No attempt should be made to charge the accumulator at higher temperatures and pressures because reverse flow might occur through the feed pump. If venting of the receiver tubes is required to remove gases when the system is being filled, the collectors must be stowed, both to protect personnel from reflected solar radiation and to allow positive ventilation in filling, because vent valves on the receiver tubes of the solar collectors must be in a vertical position for positive venting during filling.

For the initial fill of the accumulator system, the following steps should be taken:

- Open vent valve in 2 in. V0122A.
- Open the valve in line 1-in. BW0115-D to allow water to flow slowly into the accumulator, displacing air through the vent valve.
- When Accumulator Tank TK-101 is nearly full, open the valves in 3-in. P0102-D and 3-in. P0104-D and vent pump P-101. Allow the flooding of as much of the piping as possible under gravity.

- Start the pump P-101 and regulate the flow of fresh boiler feedwater into the accumulator tank TK-101 so as to maintain the high level. The circulating water should be sufficient to sweep the air from the system. To confirm this, once the escape of air from the accumulator tank TK-101 ceases, the solar receiver tubes should be manually positioned above the mirrors using the rainwash capability and the taps opened. The taps should be closed once the venting of air ceases.

  CAUTION: If this last step is performed in sunshine, personnel must wear welding goggles, Shade No. 4.

- Stop pump P-101.

- Close the valve in the water feed line 1-in. BW0115-D.

- Open valves in the nitrogen line in N0112D to maintain a pressure of 10 lb/in²g in the accumulator. The small vapor space above the water in the accumulator will then be purged with nitrogen.

- After purging for ten minutes, close the accumulator vent valve.

- Close the valve in the nitrogen line when the pressure in the accumulator is 100 lb/in²g.

- Open the valve in the accumulator blowdown line 2-in. BD211-A and adjust the level in the accumulator tank TK-101 to L (Figure 5.1).

- Read the temperature in the accumulator (TIC-4). This temperature is T_1.

- Using the accumulator vent valve and the nitrogen feed valves, adjust the pressure in the accumulator to P_1 corresponding to T_1 (Figure 5.1).

- Once the pressure in the tank has steadied (observe PI16), close the nitrogen feed and accumulator vent valves.

The water heat-transfer loop is now filled and ready for operation.

5.4 START-UP OF PLANT

Since the operation of the plant, after filling all systems is automatic, actual start-up is accomplished as follows:

- Open block valves in steam line 3-in. SM0109-B

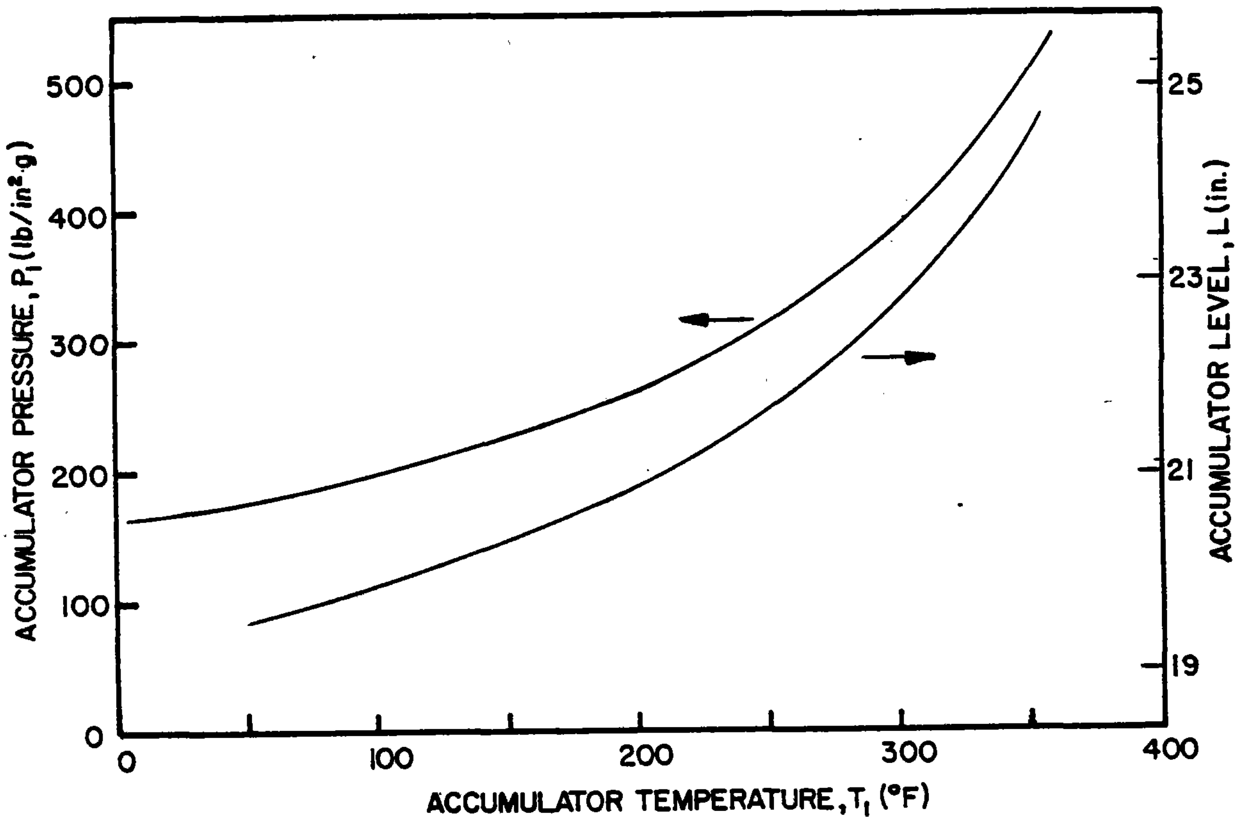

Figure 5.1 Appropriate Accumulator Pressure

- Commission all control instruments that have not yet been activated
- Turn demand switch HS-33 to "ON" position.

When the sun rises, the solar intensity increases, and the master controller receives an affirmative signal. It then sends a command to Circulating Pump P-101 to start up if:

- Wind speed is below 30 mi/h
- Boiler feedwater level in heat exchanger SG-101 is adequate.

Flow switch FSL-7 detects flow and sends a signal to the master controller which, in turn, sends signals to the module controls to drive the solar collectors out of stow position. Tracking begins when the tracking head sends a feedback signal to the module controls.

The flow rate through the collectors should be checked and adjusted to meet specifications. This check is made by ensuring that the temperatures of the water leaving each of the collector strings are identical. Small adjustments to the flow rate can be made by adjusting a valve at the inlet or outlet of the string. Gross adjustments should be made by replacing the restriction orifice.

During the initial system warm-up, verify that proper thermal expansion is occurring in the collectors as the operating temperature is approached and that no heating problems occur. Each collector row should be visually inspected at collector outlet temperatures of 200, 250, and 300°F. The specific items to be examined are:

- The receiver glass and bellows--there should be no cracks.
- The receiver housing--there should be no bending, wrinkling or other deformation caused by thermal expansion. (Note: the receiver pylons will bend to accommodate thermal expansion.)
- The receiver pipes and valving--there should be no evidence of leaks.

The receiver expansions expected are listed in Table 5.1.

Table 5.1 Receiver Pipe Linear Expansion

Temperature Change (°F)	Expansion at Receiver Ends (in.)*
100	15/32
200	15/16
300	1-7/16
400	1-15/16
500	2-1/2
600	3-1/16

*Receiver pipe is fixed in the middle of the row; expansion listed is observed at both ends of the tube.

Should a fault occur, defocus the collector and repair it. If the fault should be in the receiver tube the system should be shut down, and the receiver tubes should be isolated after allowing them to cool. After repair, the following steps should be taken during system warm-up:

- Focus each faulty collector row.
- Monitor system and collector loop outlet temperatures.

- During warm-up to 200°F, perform all visual inspections listed earlier.
- At 200°F defocus the collector field and carefully complete examination. Ensure receiver tubing expansion is as described.
- Refocus collector and repeat the last two steps, but increase outlet temperature to 300°F.
- Repair any pipe leaks.
- If proper thermal expansion is not experienced, call the collector manufacturer, Suntec Systems, Inc.

SECTION 6

NORMAL SHUTDOWN

Section 6

NORMAL SHUTDOWN

6.1 NORMAL CYCLICAL SHUTDOWN

When the sun sets and solar insolation falls below a preset limit (set-point is adjustable from 300 to 800 W/m^2), the master controller signals the module controls to stow the collectors. At the same time, another signal, to stop water circulation in the loop, is transmitted to pump P-101 by the master controller.

Boiler feedwater supply to SG-101 is automatically controlled and will stop when the remainder of the plant is shut down.

6.2 SELF-PROTECTION MODES

The master controller, utilizing data from control sensors, protects the system from potential damage resulting from operating conditions that exceed plant design criteria. Defensive action is automatically initiated for the following:

- High Winds. The wind transmitter signals the master controller when wind speed is excessive; collectors are shut down automatically if an average wind speed of 30 mi/h exists for more than 30 seconds.
- High Temperatures. Each collector has an individual high-temperature switch for stowing itself if the temperature rises above the present upper limit.
- Low Insolation. When the sun is obstructed by a cloud or otherwise blocked, the collectors are locked in a fixed position for 3 to 10 minutes (adjustable). If the sun reappears within this set time, normal operation will continue; otherwise, the master controller causes collectors to stow.

SECTION 7

EMERGENCY SHUTDOWN

Section 7

EMERGENCY SHUTDOWN

7.1 GENERAL

Mechanical failures that may cause an emergency shutdown of a plant are usually preceded by unusual, but easily recognizable conditions, such as:

- Increased noise
- Excessive vibration
- Increased operating temperature
- Liquid or vapor leaks.

Early detection of such conditions will often permit corrective action and eliminate the need for an emergency shutdown, or shorten its duration.

The operation of the MISR system is highly automatic and incorporates shutdown provisions to cover most emergency conditions. In this section, we will identify the shutdown action that will occur in an emergency. In addition, manual actions necessary in shutdown will also be described.

7.2 ELECTRIC POWER FAILURE

7.2.1 Solar Collectors

In the event of electric power failure (the loss of any or all phases), the master controller will continue to operate on the uninterruptable power source (UPS). UPS capacity is sufficient to rotate solar collectors to the protect position and shut down the system.

7.2.2 Circulating Pump P-101

Circulating pump P-101 will stop upon loss of electric power and the system will be shutdown. The solar collectors will be stowed automatically.

7.3 MECHANICAL FAILURES

Physical damage to any one of the solar collectors, collector panels, or piping system may require shutdown of the MISR system. To protect maintenance personnel the collectors should be stowed.

Should repairs to the piping or receiver tubes be necessary:

- Isolate the receiver pipe by closing block valves at the inlet and discharge line to the solar collector loop
- Block the accumulator tank closing valves in both 3-in. P0104-D and 3-in. P0102-D.

NOTE: Safety glasses with welding lenses should be worn whenever work is done on solar collectors between sunrise and sunset if the collector under repair and the adjacent collectors are not stowed facing downward.

Should substantial air be introduced into the heat-transfer loop in the course of maintenance, the vapor space in TK-101 (accumulator tank) should be purged when the pump is next started. Purging can be performed as follows:

- Read the temperature in the accumulator tank (TIC-4). This temperature is T_1.
- Examine Figure 5.1 to identify the pressure (P_1) appropriate for the accumulator temperature (T_1).
- Open the valves in the nitrogen line to raise the accumulator's pressure. Leave the valve cracked open (P_1 + 50) lb/in²g.

- Slowly open the accumulator vent valve to achieve and maintain a pressure of P_1. By this means, the accumulator can be purged of oxygen without causing the water to boil.

- After purging for 10 minutes, close the vent valve and then the valves in the nitrogen feed line.

7.4 LOSS OF NITROGEN SUPPLY

A low nitrogen pressure will activate an alarm. As the MISR system normally operates without continual requirements for additional nitrogen, this is not an emergency situation. However fresh nitrogen cylinders should be connected as soon as possible.

7.5 LOSS OF BOILER FEEDWATER

Loss of boiler feedwater will cause the level in heat exchanger SG-101 to drop to the low limit, and a signal from LSL-11 will automatically result in the complete shutdown of the plant.

7.6 ABNORMAL OPERATING CONDITIONS

Abnormal conditions that will cause the emergency shutdown of the MISR system are described in Section 3.

SECTION 8

GENERAL SAFETY

Section 8

GENERAL SAFETY

8.1 GENERAL

The safe operaton of this MISR system is the responsibility of the owner/operator. All established safetly rules, regulations, and practices should be followed at all times. The information provided in subsequent portions of this section is intended to supplement existing safety requirements and guides. Therefore, emphasis is placed on safety considerations associated with those aspects of the operation that may be unfamiliar to the personnel involved.

In addition to specifically defined rules and practices, the exercise of good judgment by every person involved is essential to safe operation. An operator should be alert for any situation that might present a hazard to personnel. Each person familiar with the plant should be responsible for warning other workers entering the plant of possible hazards they could encounter.

8.2 HAZARDS TO PERSONNEL

This system poses three potential safety hazards to personnel:

- Exposure to concentrated solar radiation
- Physical contact with hot surfaces
- Exposure to pressurized hot water accidentally released.

8.2.1 Exposure of Personnel to Concentrated Solar Radiation

In general, personnel should stay 10 ft away from the solar collectors and perform maintenance upon them only at night or when the sun is not shining.

Should work be performed upon collectors in daylight hours, however, safety-type sun glasses with welding lenses (Shade No. 4) should be worn. Gloves and long-sleeve clothing should also be worn and synthetic fabrics avoided.

To avoid possible injury caused by concentrated solar radiation, personnel should particularly avoid standing close to the ends of the tracking collectors because, except at midday, focused radiation will spill off the end of the collectors.

8.2.2 Physical Contact With Hot Surfaces

Operating temperatures throughout the MISR system are such that thermal burns will result upon physical contact with uninsulated surfaces. Gloves and protective clothing should be worn when contact with hot surfaces is possible.

8.2.3 Accidental Release of Pressurized Hot Water

Because water circulates through the MISR system at high temperatures and pressures, it is imperative that uncontrolled discharges of this water not take place. In particular:

- The blowdown valve on the accumulator tank TK-101 must not be opened except when the temperature in the tank has fallen to 200°F.
- If maintenance is to be performed upon the receiver tubes or piping, the following steps should be taken:
  - The accumulator tank should be isolated with the valves on lines 3-in. P0102-D and 3-in. P0104-D closed
  - The piece of equipment under repair should be isolated where possible
  - The equipment should be allowed to cool for several hours before it is opened.

SECTION 9

SUMMARY OF MAJOR EQUIPMENT

Section 9

SUMMARY OF MAJOR EQUIPMENT

9.1 SOLAR COLLECTORS

9.1.1 General Description

The Suntec Systems, Inc., Parabolic Trough Solar Collector is a concentrating-type collector capable of high-temperature heat collection. A collector row consists of a movable parabolic-shaped reflector with receiver, supporting structure, and automatic tracking controls. Each row is 120 ft long.

The entire row rotates around its long axis by means of the motor drive. The motor is controlled by the collector control, which keeps the sun's energy focused on the receiver tube. When the collector is not in use, the reflector panels and receiver, connected to the torque tube, are rotated to a stowed position with the reflector panels and receiver facing downward.

9.1.2 Reflector Panels

The reflector panels consist of a second-surface silvered glass mirror backed with copper and Kraton®. The reflected and concentrated sunlight is directed toward the receiver by the reflector panels. The parabolic shape results in a 40:1 concentration ratio. This concentrated energy can result in operating temperatures as high as 600°F.

9.1.3 Receiver

The receiver is a single-pass, selectively coated, steel pipe within an insulated housing located at the focal line of the collector. The receiver and reflector panels rotate as a unit, thus maintaining the proper optical relationship. Because of the moving receiver, a rotating union is required at both ends of each row to connect the receiver to the field piping. Water entering one end of the collector row is progressively heated as it passes through the illuminated receiver pipe, exits the opposite end, and enters the field piping.

> WARNING: Maintenance work on the receiver should only be done when the collector is defocussed or when the operator is wearing safety glasses with welding lenses. Exposure to concentrated sunlight is hazardous both to the eyes and exposed skin.

9.1.4 Support Structure

The collector is supported by structural steel support members. The support stanchions (single pedestal, bolted to a single foundation) are bolted to customer-furnished single foundations. Wind loads generated by wind that passes over the collector are passed through the support structure to the foundations.

Atop the stanchions are bolted bearings which allow the collector to turn freely and track the sun. The collector is rotated by the drive mechanism and serves to support and align the reflector panels and the receiver.

9.1.5 Drive Mechanism

The Suntec collector is driven by an electrical motor (dc) connected to a gearbox for torque multiplication, which enables the force of the motor to resist wind loads and drive the collector to an accurate focus rotational position. The motors are powered by a lead acid battery as an emergency power source. The batteries provide sufficient surge current to operate the collectors and are maintained on a trickle charge to be ready at any time.

9.1.6 Controls

Suntec uses microprocessor-based electronic collector controls. They provide the collector tracking and safety functions and control interface with the customer energy system. The use of a microprocessor allows the freedom to change collector control to update for more efficient energy collection and for customer needs.

Basically, the controls analyze the input parameters such as solar intensity, ac power, fluid flow, wind, and the demand for heat. If these are met, the controls authorize the collectors to search for the sun and commence tracking. The controls maintain constant checks to ensure safe collector operation. If any unsafe condition is detected, the collectors are unauthorized (commanded to stow). When sufficient time has elapsed after insufficient sunlight is detected (nightfall or cloud cover), the collectors are commanded to stow.

9.2 COLLECTOR CONTROL PACKAGE

9.2.1 Solar Field Master Controller

The Honeywell Solar Field Master Controller features microprocessor-based logic which provides automatic and manual control of solar collector fields equipped with Honeywell Flux-Line Sun Trackers.

Field protection functions are provided for loss of flow, high winds, and loss of ac power. Signals are output for pump control and track authorization. Solar intensity is continuously monitored using a Honeywell Solar Wake-Up Sensor. Detailed specifications are listed in Table 3.1 of Section 3.

9.2.2 Local Collector Controller

The local controller is microprocessor based, providing a means to detect a concentrated flux-line (light beam). The local controller monitors rotational limits (the maximum forward and stowed positions), detects collector hazards, and reacts to the authorization-to-operate signal. It features a 24-Vdc motor drive and 20-mA to 2-A solid-state relay control outputs (forward and reverse). It can be operated either automatically or manually. Specifications are listed in Table 9.1.

9.3 HEAT EXCHANGER

The kettle-type heat exchanger is certified according to the ASME Boiler and Pressure Vessel Code, Section 8, 1980. It consists of a 16-in. removable tube bundle in a 48-in.-dia shell. Tubes are 3/4-in. O.D. x 0.083-in. thick x 16 ft long, arranged in four passes.

Conditions	Shell Side	Tube Side
Design Pressure (lb/in^2g)	300	900
Design Temperature (°F)	400	570
Test Pressure (lb/in^2g)	450	1350
Design Fluid	Water	Water

Table 9.1 Local Controller Specifications

Characteristic	Specification
Electronics Power Requirements	24 Vdc ±5V 200 mA (nominal)
Operating Temperature	-20°F to ±150°F ambient
Interface Signal (Inputs)	
Authorization	24 Vdc - 12 mA
Temperature	Normally closed switch
Maximum forward limit	Normally closed switch
Stow limit	Normally closed switch
Overtravel	Normally closed switch
Cabinet door	Normally open switch
Indicator Signal (Outputs)	
Program running	Green LED
Manual mode	Green LED
Overtemperature/manual mode	Red LED
Overtemperature/auto mode	Red LED
Motor overcurrent	Red LED
Forward and reverse drive	Green LEDS
Drive Output	±24 Vdc 19 amps (Current limited to 21 amps for approximately 2 sec)
Manual Controls	
Program reset	Push button switch
Mode select	3-position toggle switch: manual/auto/not used
Manual motor drive	3-position toggle switch: reverse/off/forward (spring-loaded to the off position)
Local authorization	2-position toggle switch: remote/local
Tracking Error	0.125 degree RMS
Physical	10-3/4 x 12-3/4 x 2-1/2 in. with pre-drilled holes to directly mount in a standard NEMA 4 (12 x 14 x 6 in.) enclosures with weld nut spacing of 10-1/4 x 12-1/4 in.

9.4 ACCUMULATOR TANK, TK-101

This tank is a pressure vessel certified according to the ASME Code. It is 3 ft in diameter x 15 ft long with a total volume of 113 ft^3.

Conditions	Shell Side
Design pressure (lb/in^2g)	880
Design temperature (°F)	475

9.5 CIRCULATING PUMP, P-101

Specifications	
Centrifugal type - 12 percent chromium carbon steel	
Sp Gr at P.T.	0.84
Design GPM at P.T.	155
Design differential (lb/in^2)	23.3
Maximum discharge pressure (lb/in^2g)	825

SECTION 10

MAINTENANCE

Section 10

MAINTENANCE

10.1 GENERAL

Except for the solar collectors and master controller package, there is little in the MISR system that would not be found in most other plants. Maintenance on vessels, pumps, and piping systems will therefore not differ from normal programs. Detailed maintenance procedures are described in the companion mechanical catalog. In this section some of these procedures will simply be described.

10.2 FAILURE REPORTING FORM

Every time a failure in a component of the MISR system is identified and repairs are undertaken, a Failure Reporting Form (Figure 10.1) should be filled out.

10.3 CLEANING OF SOLAR COLLECTORS

Routine and scheduled maintenance will ensure long life and maximum performance for the solar collectors. Site conditions and environmental factors will determine the frequency of maintenance. Basic maintenance is reflector surface cleaning in conformance with manufacturer's instructions, visual inspection, periodic lubrication, and receiver glass cleaning.

Reflector Surface Cleaning. Following are procedures to be followed when cleaning the collectors:

- Time of Day. Cleaning should be scheduled when the solar energy system could not otherwise by operating (e.g., during cloudy weather or at night). For convenience, cleaning may be scheduled during the first hour after sunrise for several days in a row, when there is

Failure Reporting Form

RECENT PLANT OPERATING HISTORY:

Date of last shutdown: ____________________

Has recent operation been typical of previous operation? ____Yes ____No

If no, describe differences from normal operation: ____________________

____

FAILURE INFORMATION: Failure Date: __________ Time: __________

Failed item: ____________________

(viz. collector drive, valve, control relay, etc.)

Item function: ____________________

Hours in service prior to failure: _____ Mfr. and ID No.: __________

Mfr's descriptive name for item: ____________________

How was failure detected? ____________________

How did item fail? ____________________

Was a detailed diagnosis made of the failure cause? ____Yes ____No

Cause of failure (if known): ____________________

Date of last maintenance on failed item: ____________________

Nature of maintenance: ____________________

Was failed item in continuous use? ____Yes ____No

If item was not used continuously, how often was it used? __________

Average length of each use. (Estimate, if necessary.) __________

Were there other items that failed as a result of or concurrent with the above failure? ____Yes ____No. If yes, what were they? ____________________

ITEM OPERATING ENVIRONMENT:

Typical external operating conditions for failed item:

Temperature ____________________°F Pressure ____________________

Special characteristics ____________________

REPAIR INFORMATION: Was item repaired? __________ Replaced? __________

Manhours necessary to repair/replace failed item: ____________________

Number of people required to perform repair/replacement: __________

Total hours plant down as a result of failure: ____________________

Portion of total hours actually spent on repair/replacement: __________

MISCELLANEOUS:

Person preparing this report: ____________________

Title: ____________________

Phone number: (   ) __________ Date report prepared: __________

Figure 10.1 MISR Failure Reporting Form

adequate light for cleaning but not enough to operate the solar energy system. Furthermore, the receiver tube should be cool in the morning, so that breaking of the glass receiver tube covers as a result of thermal shock should not be a problem.

- Subfreezing Temperatures. We do not recommend washing when ambient temperatures are below freezing. We base this advice on the assumption that a period of above-freezing temperatures will eventually occur, and the energy lost by waiting is not worth the difficulties and costs that would result from washing in subfreezing weather.

- Cleaning Techniques. The vendor of the pressure washing equipment should provide information on effective washing techniques; but as experience is gained, new and more efficient procedures should be developed by experimentation at the site. A few suggestions based on experience at solar energy sites may be helpful:

  - When there is a well-defined wind direction, start cleaning on the upwind side of the field, and move downwind so that cleaned collectors will not be soiled by blowing.

  - Avoid allowing the detergent mixture to dry on the reflector surface; it can be difficult to remove. In dry climates, possibly only one or two minutes can pass between wash and rinse.

  - Avoid getting water in sun sensors (windows in such devices should be cleaned by hand).

- Contact Cleaning. The need may occasionally arise to contact clean reflector surfaces. Prior to contact cleaning, it is important to remove loose grit by spray washing before using any mops, brushes, or squeegees. Damage to the mirror should not occur if standard glass-cleaning techniques are used.

- Damage to Collectors. Glancing angles near the edges of the mirrors should be avoided, and the pressure should not be set too high (600 lb/in^2 or less should be sufficient).

- Hazards to Personnel. The system should not be washed during operation or when high-temperature fluid is flowing in the system, because heat transfer fluid leaks can pose a hazard to personnel. If the sun is shining, the collectors should face away from the sun during washing to avoid the hazards of concentrated sunlight. Very hot or very high-pressure spray can cause injury to personnel. Workers should be well briefed on safe operating procedures for the pressure washing equipment. They should be safe from electrical shock if long extension cords are used to power the pump. Finally, in cold weather, protective (e.g., waterproof) clothing should be considered.

Receiver Tube Cover Cleaning. There are several differences in the nature of the cleaning problem for glass receiver tube covers compared with reflector surfaces.

- There is much less surface area to clean
- Performance of the system is less affected by dirt (and scratches) on the reflector surface.

Glass receiver tube covers are susceptible to breaking, and care must be taken not to hit them inadvertently with the spray wand when cleaning the collectors. A padded sleeve on the wand may help prevent this. Another potential cause of shattering a receiver tube cover is thermal shock when cool water hits a hot receiver tube cover. Cleaning should not be attempted until the system has cooled sufficiently.

10.4 MISR MAINTENANCE

Little routine maintenance is required of the MISR system. This maintenance is summarized in Table 10.1. In addition, periodic inspection and cleaning of the steam generator will be required if fouling occurs.

Both routine and nonroutine maintenance should be performed as described by the manufacturer in the accompanying mechanical catalog.

10.5 CORRECTIVE MAINTENANCE

It is not possible to provide an all-inclusive malfunction troubleshooting guide for the MISR system. However, the following symptom/probable cause/remedy chart (Table 10.2) is provided to help diagnose malfunctions. It should be used in conjunction with the alarm descriptions provided in Section 3.2 to help identify the causes of and remedies for problems.

Table 10.1 Required Maintenance

Item	Daily	Weekly	Monthly	Quarterly	Semiannually	Annually	Biannually
Steam Generator			Analyze water for dissolved solids--blowdown as necessary.				
Pump	Visual inspection. Check oil level and refill as necessary.				Clean motor windings. Check phase voltage, frequency and power.	Change oil.	
Air Compressor	Visual inspection. Check crankcase oil pressure and compressor discharge pressure.	Drain moisture from accumulator points. Clean cooling surfaces on compressor and intercooler. Check operating conditions and operating cycle.	Check belts for correct tension. Inspect and clean filter velts on control pilot valve and crankcase hydraulic loader.	Blowdown relief valve. Check outlet dew point.	Inspect valve assemblies. Lubricate motor bearings. Change oil. Inspect dessicant and replace as necessary. Remove and clean/replace pilot air filter. Inspect and clean orifice in check valves and blowdown limiter valve.	Inspect motor starter contact points. Inspect and clean check valves. Inspect and clean pilot-operated valves and replace packings if worn. Inspect and clean solenoid valves.	Change dessicant.
Collectors		Check battery electrolyte level. Add water as necessary.	Check and readjust tracking heads as necessary.	Check nuts and bolts which attach torque tubes to pylon offset plates.			

Table 10.1 Required Maintenance (Cont)

Item	Daily	Weekly	Monthly	Quarterly	Semiannually	Annually	Biannually
Collectors (Cont)		Check battery terminals for corrosion. Clean with a baking soda solution and coat lightly with a corrosion inhibitor as necessary. Check battery charger for proper operation and battery condition indicator.	Check mirrors for corrosion, cracks, misalignment, etc. Adjust as necessary. Inspect entire structure for scratches or corrosion. Remove by sanding. Paint and refinish using Rustoleum primer and paint on structural members, 3M on absorber tubes.	Tighten to 20 ft lbs torque if loose. Check that all mirrors are firmly attached to mirror mounting tabs and no shoulder screws are loose or broken. Replace and tighten screws to 30 in. lbs torque. Check for cracked/broken receiver glass, replacing receiver sections as necessary. Inspect for leaks in receiver absorber tubes.			

Table 10.2 Malfunction Troubleshooting Guide

Symptom	Probable Cause	Remedy
1. Circulating pump (P-101) will not start	1.1 Inadequate insolation/excessive wind speed	None.
	1.2 Steam demand switch off/failed	Ensure demand switch is on. Ensure circuit breakers in correct position. Repair defective components.
	1.3 Failure of sun-sensor or anenometer--false high readings of wind speed or insolation given	Repair defective components.
	1.4 Failure of master controller to allow operation to commence	Repair defective controller.
	1.5 Loss of electric power	Restore power. Ensure circuit breakers are in correct position.
	1.6 Pump defective	Repair pump/pump motor. Ensure pump is isolated or the system is cooled if it is to be opened.
2. Circulating pump stops	2.1 Loss of power	See 1.5.
	2.2 Pump failure	See 1.6.
	2.3 Defective low flow time-delay relay: prematurely shut down of the system	Repair defective relay.
3. Inadequate water flow	3.1 Lines blocked/valves closed	Check positions of all valves, correcting these as necessary. Check strainers. Clean lines.
4. Both collectors fail to unstow	4.1 Inadequate water circulation	See 2.3/1.1-6.
	4.2 Batteries removed/discharged	Check on batteries. Repair defective components.
	4.3 Loss of power to batteries	Check on circuit breakers. Repair defective wiring.
	4.4 Defective master controller	Repair defective controller.
	4.5 Simultaneous failure of local controllers/motors, etc.	Repair defective components.
5. Single collector fails to unstow	5.1 Failure in collector motor/drive gear/local controller	Repair defective components.
	5.2 High temperature stow switch misset/acts prematurely	Repair/reset defective switch.

Table 10.2 Malfunction Troubleshooting Guide (Cont)

Symptom	Probable Cause	Remedy
6. Collector fails to track accurately	6.1 Collectors follow a bright object	Remove image of bright object.
	6.2 Defective local controller/ sun sensors	Repair defective components.
	6.3 Failure in collector motor or drive gear	Repair defective components.
7. Single collector fails to stow	7.1 Defective local controller/ motor/drive gear	Repair defective components.
8. All collectors fail to stow	8.1 Defective master controller	Repair defective controller.
	8.2 Batteries removed/discharged	See 4.2.
	8.3 Simultaneous failures in individual collector local controllers/motors/drive gears	Repair defective components. Defocus collectors by hand, if necessary.
9. Overtemperature in collector	9.1 Inadequate flow through collectors	Ensure collectors stowed. Check on the position of valves controlling the flow of water to the collectors and adjust as necessary. Clean lines.
	9.2 Defective/misset high temperature switch	Repair/reset defective switch.
	9.3 Unstowed collectors isolated	Stow/defocus collectors.
10. Overtemperature/ overpressure in heat transfer loop	10.1 Spurious alarm/trip	Repair/reset defective switches, transmitters or relays.
11. Overpressure in accumulator	11.1 Spurious alarm or trip	Repair/reset defective switches, transmitters or relays.
	11.2 Valve in nitrogen supply line fails open	Valve off nitrogen supply. Make repairs.

Table 10.2 Malfunction Troubleshooting Guide (Cont)

Symptom	Probable Cause	Remedy
11. Overpressure in accumulator (Cont)	11.3 Too high an initial nitrogen pressure/water level in accumulator	Carefully vent accumulator.
	11.4 Too high a temperature in accumulator--excessively hot water empties	Ensure an adequate water level is maintained in the heat exchanger. Ensure the pressure on the steam side of the heat exchanger is not too high. Clean tube bundle.
12. Low water level in accumulator	12.1 Spurious low level alarm or trip	Repair/reset defective transmitters, switches or relays.
	12.2 Leak at gasket, etc.	Repair. If leak cannot be isolated, ensure a low system pressure is achieved prior to opening lines.
13. High water level in accumulator	13.1 Spurious high level alarm or trip	Repair/reset defective transmitters, switches or relays.
	13.2 Initial water level too high	Lower water level when system is cool.
14. Overpressure on steam side of heat exchanger	14.1 Valve in steam line closed	Ensure all lines open.
	14.2 No steam demand	None.
15. Heat exchanger overtemperature	15.1 Overpressure	See 14.
	15.2 Low water level	See 16.2-5.
	15.3 Tubes fouled	Clean tubes.
16. Low water level in heat exchanger	16.1 Spurious low level alarm or trip	Repair/reset defective transmitters, switches or relays.
	16.2 Feedwater pump failure	Repair pump.
	16.3 Feedwater line blocked/valve closed	Check valve position and correct as necessary.
	16.4 Failure in level and flow control loops: defective operator, controller or transmitters; loss of instrument air	Repair defective component or adjust set points.
	16.5 Leak at gaskets, etc.	Check for leaks and effect repairs.

Table 10.2 Malfunction Troubleshooting Guide (Cont)

Symptom	Probable Cause	Remedy
17. High water level in heat exchanger	17.1 Spurious high level alarm or trip	Repair/reset defective transmitters, switches or relays.
	17.2 Failure in level and flow control loops: defective operator, controller or transmitters	See 16.4.
18. Collector freeze protection fails	18.1 Failures in temperature transmitters and switches--freeze protection not initiated	Initiate freeze protection. Repair/reset defective components. Drain system if outage prolonged.
	18.2 Power failure	Drain system if outage prolonged.
	18.3 Accumulator heater failure	See 18.2.
19. Electric heat tracing fails	20.1 Power failure	Check power supply and circuit breaker position. Drain affected lines as necessary.
	20.2 Defective wiring or controller	Repair defective components. Drain affected lines if necessary.
	20.3 Set point for heat tracing too low	Adjust set point.
20. Loss of instrument air	21.1 Failure of air compressor	Repair compressor.
	21.2 Lines frozen	Thaw lines. Repair/regenerate drier.
	21.3 Lines plugged	Unblock lines. Install new filters.
	21.4 Air leaks	Repair leaks.

FOSTER WHEELER SOLAR DEVELOPMENT CORPORATION

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