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Safety Analysis Report MISR Qualification Test System and Test Site (Modular Industrial Solar Retrofit Project)

Robert L. Alvis

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
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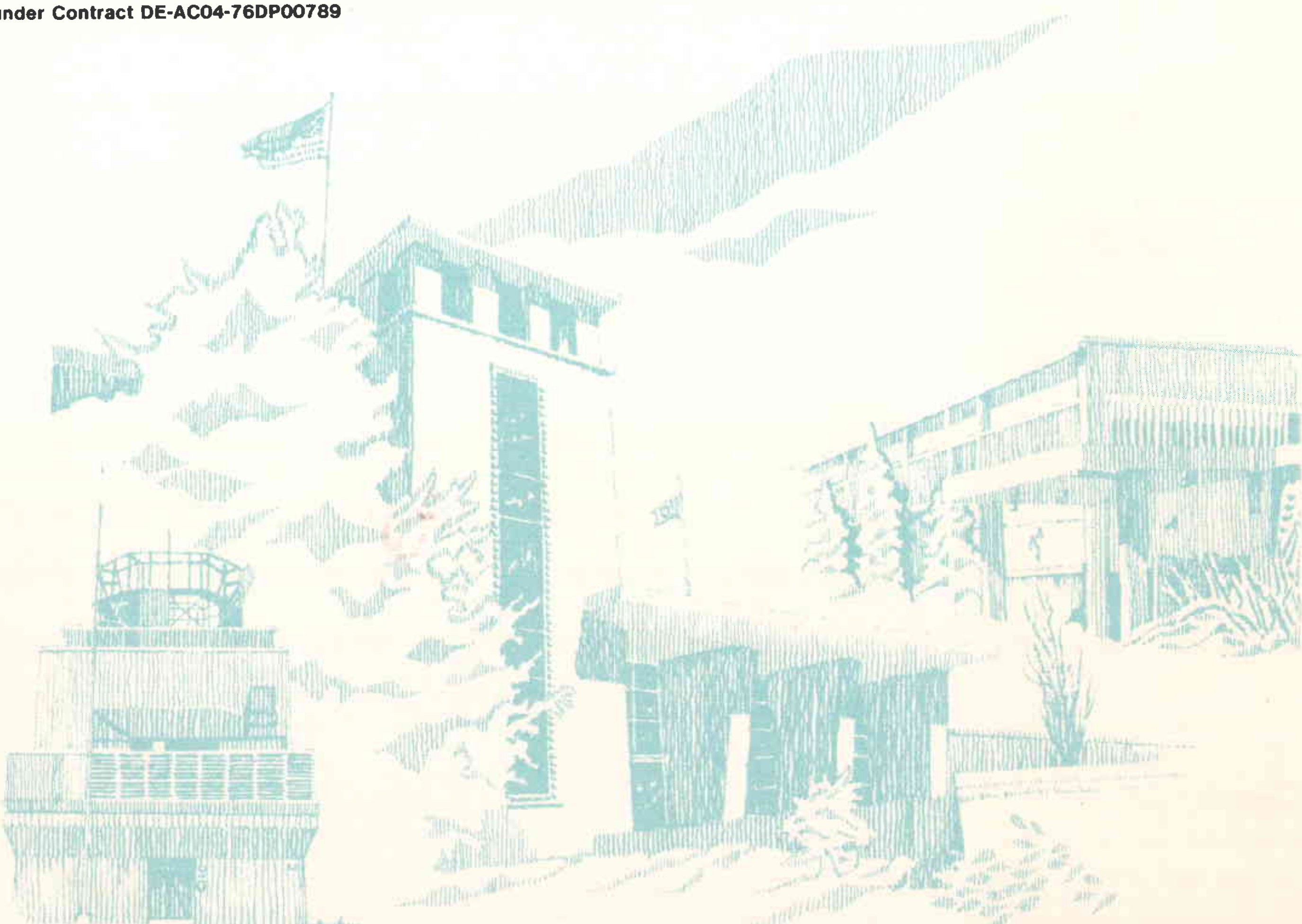

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Abstract

MISR is a US Department of Energy solar thermal energy system project. Sandia National Laboratories (SNLA) has been assigned the responsibility for assisting industry to develop MISR system designs and for conducting qualification tests on systems representing these designs. This report concerns the safety of the systems during the qualification tests to be conducted at SNLA.

Contents

Figures

Safety Analysis Report
MISR Qualification Test System and Test Site (Modular Industrial Solar Retrofit Project)

Introduction

Purpose

The purpose of this safety analysis is to address (1) the potential hazards to the health and safety of the public and Laboratory personnel, and (2) the adequateness of the protection provided to both environment, personnel, and property resulting from the operation and testing of the Modular Industrial Solar Retrofit (MISR) qualification test systems (QTS). The contents of this report will be used, in part, by the Department of Energy (DOE) and Sandia National Laboratories (SNLA) to assess the risks associated with operating the MISR systems during design qualification testing. It is the responsibility of both DOE and SNLA to ascertain that the risks involved are acceptably small.

Basic Principle

The basic principle of this document is to assess all potential hazards of the MISR systems not routinely encountered and/or accepted by the general public. Only the reflected and concentrated solar energy used in these systems is really new to the public. However, because the test site is adjacent to the Central Receiver Test Facility and some operators may not be familiar with conventional processes, other potentially hazardous areas will be addressed in this report.

The QTS systems to be tested are generically the same. For expediency reasons, only those areas of the system designs that are significantly different from the others will be addressed independently.

This document will be reviewed periodically for completeness and accuracy and modified and updated as required.

Description of a MISR System

As described in *DOE's MISR Multiyear Project Plan*, the basic MISR system has only thermal energy output, incorporates only line-focus type solar collectors, is modular in design, and is capable of operating in an unattended mode. The modularity of design extends from the system level, through the subsystem level, to the component level. At the system level, the basic system size has been established to be approximately 2,500 m^2 of collector aperture area. Multiple systems may be operated in parallel where more energy production is desired. The energy output of these systems will be in the form of saturated steam and with pressures up to 1.7 MPa (250 psia). An artist's concept of a MISR system is shown in Figure 1.

The modularity of design at the subsystem level is directed at obtaining factory manufactured equipment that is assembled and tested before it reaches the installation site. For MISR, this approach should result in truck-transportable, skid-mounted equipment requiring only interface connection assembly at the site.

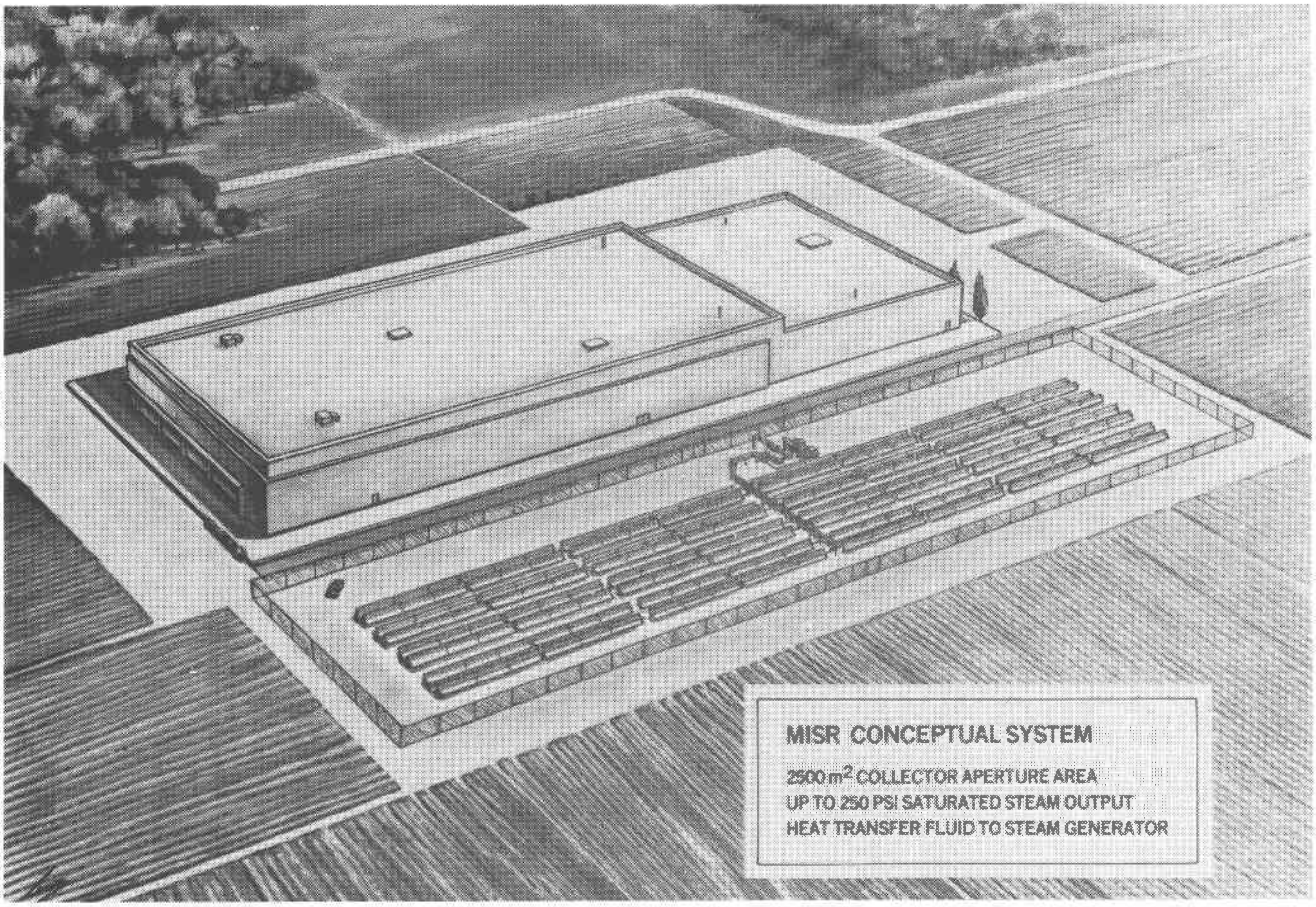


Figure 1. MISR Conceptual System

The modularity of design at the component level is directed at improving reliability of operation and reducing system cost. Reliability can be improved through the use of proven designs and fewer component models. Cost reduction results from quantity price breaks and the fewer number of spares required.

To gain the greatest benefits from a modular system design, the operation and installation of the system shall be independent of collector field orientation and environment.

The MISR QTS will consist of the minimum hardware that is representative of the modular design. For the QTS, this will include one delta-temperature solar collector loop, manifolding, control system, and full-size equipment skid. The QTS will be instrumented by SNLA, independent of the system's conventional instruments for control, for the purpose of obtaining operational and performance data. Interface connections will be made to the QTS as would be done in an actual installation, except that an additional interface will be used to simulate the output of the balance of the solar collector field.

Site Description

The MISR QTS test site, consisting of about four acres, is located adjacent to the Central Receiver Test Facility (CRTF) at SNLA. A photograph of the CRTF is shown in Figure 2 with an artist's concept of the QTS inlayed. (The QTS site is on the west side of the CRTF and the collector rows are oriented in an east-west direction.)

The site definition consists of SNLA Plant Engineering drawing No. 96639. The site has been graded, vehicle paths have been graveled, and a protective fence constructed on the perimeter. Office trailers are located on the east side of the site for contractor offices and data acquisition equipment. Propane tanks are located at the extreme north side of the site both for remoteness and ease of refilling.

The virgin site was on an arid plateau gently sloping westward from the base of the Manzano Mountains to the Rio Grande. The plateau is actually a broad alluvial plain consisting primarily of unconsolidated sand, gravel, and silt derived from granite and metamorphic rocks of pre-Cambrian age.

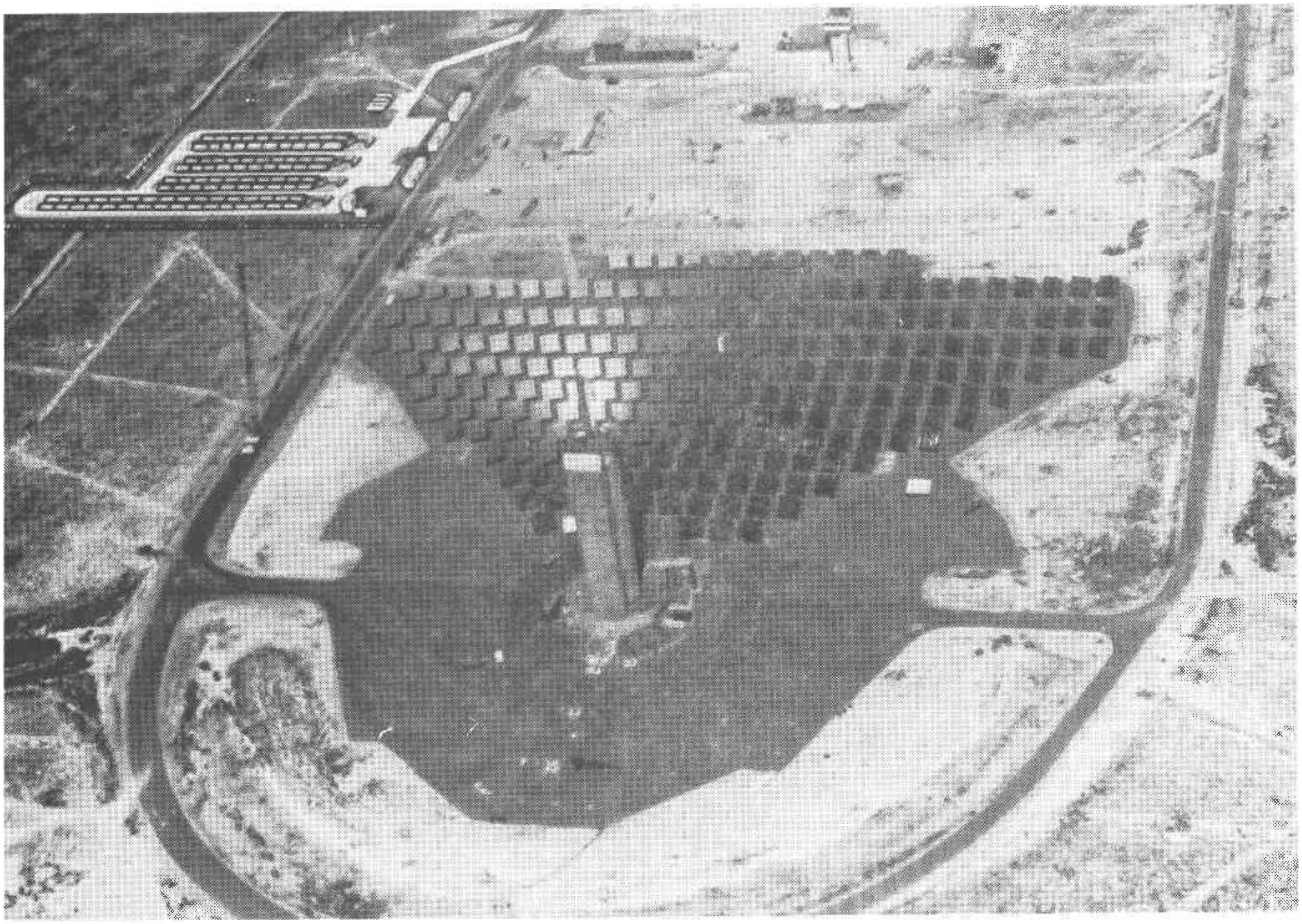


Figure 2. CRTF and MISR QTS Sites

Underlying the alluvium are rocks of Permian, Pennsylvanian, and pre-Cambrian age which are the major constituents of the Sandia and Manzano mountains to the east of the site. Seismic activity for the area is frequent, but low in Richter scale magnitude. Facilities in the area are designed for Zone 2 quakes.

Meteorologically, the average wind at the site is less than 9 mph. On an average of 46 days during the year, the maximum wind velocity will be 32 mph. A 90-mph wind gust lasting at least 1 to 5 s is expected to occur once in 60 yr. Every 2 yr a 60-mph wind of 1-min duration is expected. The average annual precipitation is about 8 in.—usually occurring in late afternoon or evening as brief, often intense, thundershowers. Annual average snowfall is about 10 in. Temperatures can range from a high of 38°C (100°F) to a low of −24°C (−10°F).

The natural grade of the site permits satisfactory drainage toward the west-southwesterly direction and eventually into the Rio Grande 10 mi to the west. The drainage at the site consists of sheet flow into small, shallow arroyos. There are no natural lakes in the area and all drainage flows are intermittent, occurring only during periods of significant precipitation.

Vegetation at the site consists of sparsely growing native grass interlaced with weeds. The weeds are mainly Russian thistles and sunflowers. All of these plants have demonstrated their ability to reestablish themselves naturally when the land is not being actively used.

Potential Hazards Associatd With the QTS Site

Test System and Hardware

A schematic of a generic MISR QTS is shown in Figure 3. It consists of one delta-temperature (ΔT) collector loop; a full-size equipment skid containing the steam generator, circulation pumps, etc; and the interconnecting manifolds and control systems. The interface between the QTS and the test site equipment is shown by the double intersecting lines in Figure 3.

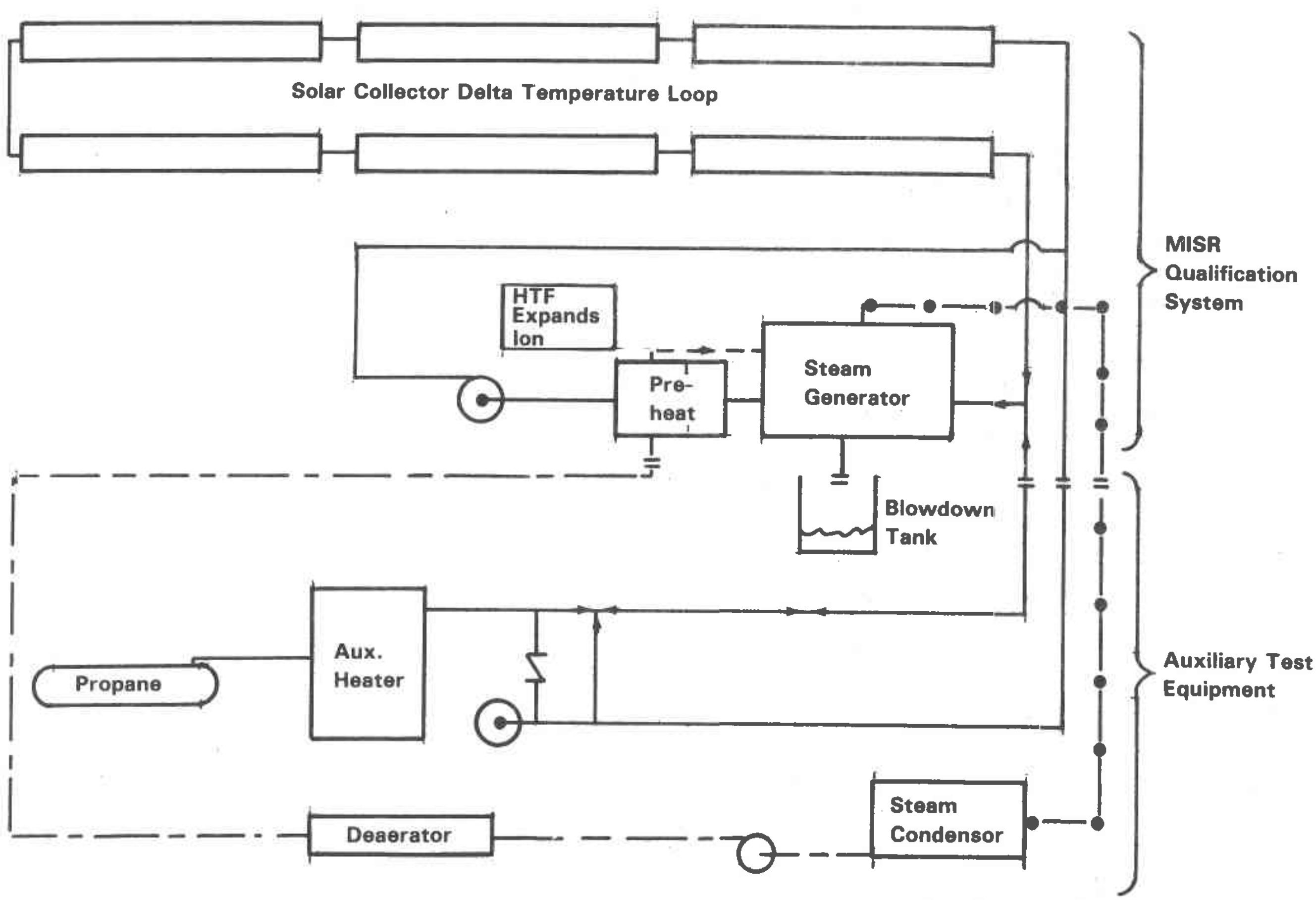


Figure 3. Typical MISR Qualification Test System

The test site equipment consists of a steam-condensing unit, a deaerator, feedwater pump, propane-fired heaters, and a heat transfer fluid circulation/pump system for the propane-fired heaters. The test site heater system will supply approximately seven-eighths of the energy that a full-size MISR system would supply. It, in essence, duplicates the remaining field by following the temperature output of the one ΔT loop. The condenser represents an industry load for the solar system and will accept the generated steam at the solar system design pressure and return the condensate as feedwater.

Potential Hazards at the Site

Several common hazards exist. These include 440-V electrical power, hot surfaces, rotating machinery, and hot fluids. Some not so common potential hazards include concentrated sunlight at the MISR solar collectors, the possibility of the heat transfer fluid igniting if a break occurs in the fluid loop, the possible escape at 250 psi steam if a break occurs in the steam system, and the possibility of an over-temperature condition at the heater or a flame-out at the heater resulting in a propane leak.

In addition to the MISR test site hazards, the adjacent CRTF can generate high-intensity light as a result of reflected light from items under test. Hazards similar to the MISR site exist at the CRTF, but MISR test personnel are aware of them and MISR visitors will be segregated from the CRTF by a fence.

Visitor Access

Visitors will be encouraged to visit the site and to witness the operation of the MISR QTS systems. However, visitor access will be controlled, and unauthorizd people will not be permitted into the area.

Authorized visitors will be logged in and briefed by site personnel on the potential dangers at the site. They will be advised to wear shaded glasses for protection from concentrated light. Visitors will be escorted while they are at the site to reduce the possibility of accidents. No escorted visitors will be allowed within hazardous areas.

Considerations of Potential Hazards

Fire Prevention and Control

Potential sources of fires are the heat transfer fluid (HTF) and an uncontrolled propane leak.

Fire prevention is accomplished by the incorporation of out-of-limit detectors and annunciators in the QTS and auxiliary equipment. The normal operating conditions are well below the autoignition temperatures of the HTFs that will be used. If an out-of-limit condition is detected, the system will automatically shut down. Only after a thorough investigation and correction of the problem will the operator be authorized to restart the system. Some HTFs have demonstrated the capacity for spontaneous combustion at temperatures lower than the autoignition temperature. This is usually the result of HTF getting into and soaking the fibrous insulation. To prevent this, the QTS systems will incorporate closed-cell insulation at points of potential HTF leaks. Also, only HTFs with high autoignition temperatures will be used.

The propane pipes will be constructed per standard practice and will be leak-tested before use. Both the propane vaporizer and HTF heater will have safety shutoff valves in case the burners go out. The main line from the tanks to the vaporizer will carry liquid propane and will contain excess flow valves. Any leaks in this line can be visually detected by onsite operating personnel. Any leaks of propane vapor can be detected by an odor. Upon the detection of any potentially hazardous leak, the site operator will close the main valves at the propane tanks.

Should a fire occur, strategically located fire extinguishers will be available for use. A telephone will be located in the data acquisition trailer to summon Kirtland Air Force Fire Department, and a water source that can supply water at 2350 gpm at 55 psi is available at the site.

A major portion of the site will be designated a nonsmoking area. Finally, in the event of any large propane spill, fire, or severe storm, the site will be shut down and the personnel evacuated. Any site test personnel may initiate such an evacuation.

Hot Surfaces and Hot HTF Hazard Potential

The very purpose of the MISR QTS system requires the existence of hot surfaces and hot HTF. Under normal operating conditions, some of the hottest surfaces can reach 600°F. It is also the purpose of the solar system designers that the system operate thermally efficient. To accomplish this, all possible hot surfaces are well insulated, and OSHA guidelines dictate that the insulation surfaces be below 120°F during normal ambient conditions.

By necessity, the collector receiver tubes, temperature probes, and some pressure probes will be at an elevated temperature. Visitors will be kept away by rope barricades and staff escort. Operators will be made knowledgeable of the location of hot surfaces by training and experience and by specially prepared system operation and maintenance procedures.

Hot HTF or steam can come in contact with a person only if a failure occurs in the fluid circuits during system operation. To minimize the probability of this occurring, proper national design code and associated safety margins have been used. Preoperational pressure and leak tests will have been conducted. The QTS systems have out-of-limit operation monitors and an automatic shutdown command will be initiated if any out-of-limit condition is detected. During a period when an out-of-limits condition exists, all personnel will be directed to stand clear and no maintenance on the system is to be attempted.

Maintenance or repair of the fluid circuits shall not be attempted as long as the system is above 66°C (150°F). This restriction should minimize the possibility of accidentally breaking into a hot fluid line and receiving burns as a result. This temperature will be confirmed by the system operator before repair is authorized.

If an HTF spill does occur, the HTF is expected to cool rapidly and the site grading is such that any flow will be directed to a catch basin at the west side of the site. Although the caught fluid is nontoxic, it will be recovered from the area as soon as practical. Division 3442 shall be notified of any spill greater than 160 L (40 gal).

Optical Hazards

There are two potential optical hazards at the QTS site. These are the reflected-concentrated light from the system collectors being tested and the reflected light from items under test at the CRTF.

The potential optical hazard resulting from the QTS collectors presents only a local hazard. It is conservatively estimated that if a person is 3 m or further away, the reflected light is equivalent to only one sun. A one sun light is damaging only if one looks at it for a period of time, but this is a common hazard. To prevent high intensity damage, all site personnel and visitors within this optical hazard zone will be required to wear shade No. 4 sunglasses. These glasses have been used by SNLA for previous solar applications.

At distances closer than 3 m to the collector, the reflected light increases in intensity until the focal point is reached. At this point, skin burns and clothing ignition can occur. All visitors and site personnel will be warned of these hazards. All visitors will be isolated from these areas by rope barriers.

The potential optical hazard resulting from tests being conducted at the adjacent CRTF depends upon the type of test being conducted. The worst-case, full reflection, could result in approximately 200 suns reflected light. At the MISR test site, due to the diffused reflected sunlight, the intensity is much less.

This potential hazard, which is common at the CRTF, will be minimized by maintaining close coordination with the CRTF personnel. The No. 4 sunglasses have proven to provide sufficient safety from this hazard. When the CRTF is operating at a level that could pose a hazard to MISR site personnel, the MISR site will follow the safety procedures for optical hazards as approved for the CRTF. The CRTF controls allow the focus of the heliostats to drift east of the tower during a CRTF failure. This drift is away from the MISR QTS site and should present no hazard to the QTS facility.* The CRTF reflection problem has been addressed.**

Rotating Machinery Hazards

There are two types of rotating machines at the QTS site: solar collectors and pumps. The solar collectors rotate very slowly (180° in 5 min) and may not appear to represent a potential hazard, but they have rotating torque capability of greater than 3390 N-m (2500 ft-lb) per drive unit. The pumps consist of high speed, centrifugal HTF circulation pumps, a feedwater pump, and an air compressor.

Collector Rotation

The collector rotates about one axis up to approximately 270°. This is a slow rotation and any danger from it appears remote. However, due to this slow and silent movement, it does represent a potential hazard. To minimize this hazard, each drive system will contain a local/remote control. If test personnel are to work on or near the collector, the control switch must be set in local. Before the collectors are to be rotated from the remote master control, the operator shall verify that the field is clear of both personnel and any obstructions for the safe operation of the system. Again, rope barricades and staff escort will be used to keep visitors at a safe distance.

High Speed Rotating Equipment

All of these components and pumps shall have safety guards in place before system operation is allowed. When the shields are removed for maintenance purposes, the circuit breaker for that component shall be opened and locked open. The system operators will verify that this condition has been satisfied.

Safe Operating Procedures

Up to four separate QTS designs will be evaluated simultaneously at the site. Each of the four system suppliers will, under contract, supply an Operation and Maintenance Manual for their QTS. In addition, each supplier will train designated SNLA personnel in the proper operation of their QTS system. The SNLA trained operator and the MISR project leader shall jointly ascertain that the system performs safely and satisfactorily. If it is found that the system does not operate in a safe manner, the acceptance of the hardware by SNLA will be delayed until the problem areas are corrected. The MISR project leader will notify the supplier of SNLA's acceptance, and the supplier will not operate or maintain the system again unless authorized by the MISR project leader.

At this time, the operating and maintenance manuals provided by the system supplier will be used by the SNLA operators to operate the systems. Only those SNLA personnel that have been briefed by the suppliers or by another SNLA employee will be allowed to operate the specified system. These persons will be recognized by their own signature and that of their division supervisor signature in this report. These forms are shown in Tables 1A through 1D, and a duplicate copy shall be posted at the MISR QTS site.

*See Final Safety Analysis Report, 5MW Solar Thermal Test Facility, dated August, 1978.

**See the report by T. D. Brumleve, *Eye Hazard and Glint Evaluation for the 5MW Solar Thermal Test Facility*, SAND76-8022, dated May, 1977.

Table 1A

Approval to Operate Acurex Corporation's QTS

I have received operating instructions and I have read, understand, and will follow the Safe Operating Instructions.

Operator	Date	Supervisor	Date

Table 1B

Approval to Operate BDM Corporation's QTS

I have received operating instructions and I have read, understand, and will follow the Safe Operating Instructions.

Operator	Date	Supervisor	Date

Table 1C

Approval to Operate Custom Engineering Inc.'s QTS

I have received operating instructions and I have read, understand, and will follow the Safe Operating Instructions.

Operator	Date	Supervisor	Date

Table 1D

Approval to Operate Solar Kinetics Inc.'s QTS

I have received operating instructions and I have read, understand, and will follow the Safe Operating Instructions.

Operator	Date	Supervisor	Date

The operation of the site equipment, which includes the QTS to be operated, shall be approved by those shown in Table 2. The operation of this equipment shall then become the responsibility of the site operator. Any potential hazards with this equipment shall also be sufficient reason for shutdown and notification of the project leader by the operator.

Emergency Procedures

Personal Injury

A first aid kit will be available in the data acquisition mobile office. First aid should be rendered and a determination made regarding the seriousness of the accident. If in any way this injury appears life threatening, the ambulance should be called immediately. The telephone is also located in the data acquisition mobile office. If the injury does not appear life threatening, SNLA medical shall be called and instructions obtained on the proper action to follow. Both telephone numbers will be posted by the telephone.

Telephone Numbers	
Ambulance	4-4357 (4-HELP)
SNLA Medical	4-2471 (automatic when you call 4-HELP)

Fire

If a person is endangered, the person shall be attended to first. The person shall be removed from the fire area and the flame on the person smothered. Then personal injury instructions above should be followed.

A safety shower is provided at the site. Site personnel will be instructed in its use both for extinguishing clothing fires and for cooling hot oil spills on individuals. The shower will be operated every two weeks to determine its operational status.

If the fire is site-related and small in size, the available fire extinguisher should be used immediately. If the fire appears to be larger than the extinguisher can handle, the fire department should be called. If the fire appears to be capable of igniting the propane tanks or HTF reservoirs, the fire department should be notified and the site evacuated. No one should return to the site until the fire departmnt has ascertained that it is safe to do so. At no time shall site personnel risk injury in fighting a fire.

Telephone Number
Fire Department – 117

Approaching Storm

If an approaching storm appears to be severe (with strong winds, hail, tornado, or severe lightning), the site will be shut down and all personnel moved to the CRTF control building. The CRTF personnel monitor lightning early warning systems (LEWS) at the CRTF and will warn the QTS personnel of impending storms. One should not try to go to the CRTF building if sufficient time is not available to get there before the storm hits.

Anyone caught at the site during a severe storm should get into the office trailer and stay inside until the storm has subsided.

Large Propane Leak

If a large propane leak occurs (a line breaks, tank pressure safety valve actuates, etc), site personnel should move out of the vapor area at once. Vehicles should not be started or driven out of the area. If the tanks are remote from the point of the leak and are not in the vapor area, site operators should turn off the main valves at the tank and then vacate the site. If the wind is less than 5 mph, the CRTF facility should be immediately notified. Call telephone 844-6871.

The occurrence of a severe leak during a calm wind presents a potentially serious hazard. Personnel should walk quickly to a distance of at least 200 m away from the vapor. If the vapor moves toward an individual, he should move away at a right angle to maintain a safe distance of 200 to 300 m.

General

If a site emergency does occur, D. R. Parker, 3311, and Don Rost, 3442, shall be notified by the MISR project leader. The site shall not be operated again until approval has been obtained from the project leader or Division 9722 or 9727 Supervisor.

MISR System Safety Considerations

The principal purpose of the SNLA QTS site is to evaluate the system design through operation of the hardware. Potential hazards with this hardware such as pressurized steam, hot heat transfer fluid, etc, do exist. These potential hazards have been addressed from a safety standpoint in two ways: (1) standard design practices have been specified in the contracts SNLA awarded for the development of the MISR designs, and (2) each system designer was required to develop a system analyses report. The contract specifications can be found in a report by K. Wally entitled *Modular Industrial Solar Retrofit System Constraints, Specifications, and Guidelines*, SAND81-1300. The contractor system safety analyses are enclosed as Appendices A through D of this report.

All known applicable standard design codes have been requested to be adhered to in the design of the MISR systems. The contractor safety analyses indicate how these have been addressed and indicate the margin of safety that exists in their design.

Conclusions

The safety aspects of the MISR designs and the MISR test site at SNLA have been addressed. The designers' characteristics indicate the systems are compatible with the pertinent national design codes. System operation procedures will be developed and verified by the system suppliers. The MISR project leader and the designated operator will agree that the operation procedures present no hazards to operation before the system is accepted for SNLA operation.

Potential hazards exist at the site during testing. Each potential hazard area has been addressed and risk minimized by operating procedures and visitor control. First-aid procedures to be followed in the case of injuries have been described. These procedures will be posted for easy access during any disruption period.

Attention to the safety guidelines outlined in this report and the adherence by site personnel to safe, conventional operation of equipment will ensure that the risks involved with the MISR qualification tests will be acceptably low.

Table II

Safety Analysis for the SNLA MISR QTS Site Operation.

Approved:	[signature] Division 4727	Date:	5-20-82
Approved:	[signature] Division 4723	Date:	6/7/82
Approved:	[signature] Department 4720	Date:	6-6-82
Approved:	[signature] Division 3311	Date:	[illegible]
Approved:	[signature] Division 3442	Date:	6/4/82

APPENDIX A

Acurex MISR System Safety Considerations

ACUREX Corporation

HAZARD ANALYSIS

☐ SYSTEM ☐ FAILURE MODE & EFFECT ☒ PRELIMINARY ☐ OPERATIONAL

PROGRAM Modular Industrial Solar Retrofit (MISR)

PREPARED BY T. J. Liddy APPROVED BY A. K. Yasuda

DATE 11/30/81 REVISION A SHEET 1 OF 7

DEFINITIONS

Probability of Failure (P)

P is the qualitative rank ordering of the expected frequency of individual component failure. Selection of P is based on the Frequency of Failure (F).

F = 1 — RELIABILITY (R)

P	Frequency of Failure (F)	
	Category	Range
6	Frequent	1 to 10^{-1}
5	Probable	10^{-1} to 10^{-3}
4	Occasional	10^{-3} to 10^{-5}
3	Remote	10^{-5} to 10^{-6}
2	Improbable	10^{-6} to 10^{-8}
1	Impossible	10^{-8} to 0

Hazard Severity (S)

S is the weighting factor for the severity of a hazard resulting from an individual component failure.

S	Hazard	
	Category	Severity
4	I — Catastrophic	May cause death or system loss
3	II — Critical	May cause severe injury, severe occupational illness, or major system damage
2	III — Marginal	May cause minor injury, minor occupational illness, or minor system damage
1	IV — Negligible	Will not result in injury, occupational illness or system damage

Hazard Priority (H_p)

H_p shows the criticality of the hazard and establishes the priority for corrective action.

$$H_p = (P \times S)$$

H_p	Corrective Action
1 to 4	Not required
5 to 8	Recommended but not required
9 to 15	Required to operate without restrictions
16 to 24	Required before operation

ACUREX Corporation

PROGRAM: Modular Industrial Solar Retrofit | SHEET 2 OF 7

SUBSYSTEM: | REV. A

PRELIMINARY HAZARD ANALYSIS

Item No.	Hazardous Component or Condition	Description of Potential Hazard	PROBABILITY/ SEVERITY: Probability (P)	Severity (S)	Priority (PxS)	Recommended Action
1	Heat Transfer Fluid	1a- Autoignition The heat transfer fluid (HTF) to be used is Monsanto's Therminol 60. Typical properties of T-60 published by Monsanto are: Pour point: -90°F (68°C) Flash point, coc: 310°F (154°C) Fire point, coc: 320°F (160°C) Autoignition temp: 835°F (446°C)	1	3	3	1a1- Provide overtemperature detectors at each collector group. Verify that the overtemperature sensor is set at or below 600°F (357°C). 1a2- Include periodic testing of each temperature sensor in maintenance schedules.
		1b- System operation with HTF at or above its flash point. Release of HTF at such temperatures could result in a hazardous oil/ air mixture near the leak or rupture.	6	1	6	1b1- All electrical equipment, within 3 ft of mechanical flanges, joints, valves, flex hoses and field recirculation pump flex hoses which will circulate HTF at temperatures of 300°F (149°C) or higher, should meet NEC Class I, Division 2 requirements. 1b2- The entire collector field and equipment skid be clearly posted as a "NO SMOKING" area. 1b3- Periodic maintenance procedures should warn against allowing debris or weeds to accumulate around collector field piping or the equipment skid which could become saturated with leaking oil and become a potential ignition source. 1b4- Provide thermal heat detectors near the field circulation pump interlocked to: shutdown the pump; desteer the collector field; and activate an automatic dry chemical fire extinguishing system in case of fire. 1b5- Include periodic inspection of circulation pump seals and bearings in maintenance procedures with a warning of the increased fire hazard of operating with oil leaks or worn bearings.

ACUREX Corporation

PROGRAM: Modular Industrial Solar Retrofit SHEET 3 OF 7

PRELIMINARY HAZARD ANALYSIS

SUBSYSTEM: REV. A

Item No.	Hazardous Component or Condition	Description of Potential Hazard	PROBABILITY/ SEVERITY Probability (P)	Severity (S)	Priority (PxS)	Recommended Action
		1c- Spilled or leaking HTF can become a "hazardous waste" or contaminate underground water supplies. Spilled oil is also a slipping hazard.	4	2	8	1c1- Two portable dry chemical fire extinguishers rated at a minimum of 4A:40BC each should be provided on the equipment skid near the system controller and at the steam generator equipment skid. 1c2- Provide a nonslip surface for the equipment skid to prevent personnel from being injured in falls.
		1d- Heat transfer fluid degradation	3	1	3	1d- Periodic analysis of the HTF should be included in maintenance procedures. The analysis should check peformance characteristics as well as safety concerns with changes in flash point and autoignition temperatures.
2	Hot Surfaces	2- OSHA requires all surfaces sufficient to burn tissue on momentary contact, and within 7 ft of the ground, to be guarded against contact.	5	2	10	2a- Provide thermal insulation on all external surfaces which will exceed 130°F (54°C) in surface temperature during operation, OR 2b- Provide a physical barrier, such as a guardrail, around such equipment to prevent persons not familiar with the hot surface hazard from inadvertently making contact with the equipment. 2c- Provide "WARNING - HOT SURFACES" signs around all equipment presenting a burn hazard such that anyone coming near the equipment will be advised of the hazard.
3	Field Circulation Pump-Rotating Shaft	3- Contact with the rotating shaft of the field circulation pump could result in personal injury.	2	2	4	3- Ensure that accidental contact with the rotating shaft of the field circulation pump is not possible. Any guard which is installed to prevent contact must be designed to prevent accumulation of leaking HTF and should not inhibit rapid cooling of any such leaking fluid.
4	HTF Circulation Piping	4a- Pipe rupture at normal operating temperatures and pressures	2	2	4	4a- Specify carbon steel pressure pipe to ASTM A53 Grade B or A106 Grade B or equivalent.

ACUREX Corporation

PROGRAM: Modular Industrial Solar Retrofit — SHEET 4 OF 7

SUBSYSTEM: — REV. A

PRELIMINARY HAZARD ANALYSIS

Item No.	Hazardous Component or Condition	Description of Potential Hazard	Probability (P)	Severity (S)	Priority (PxS)	Recommended Action
		4b- Pipe rupture due to overpressure.	2	2	4	4b- Design the sytem with an atmospheric expansion tank and follow recommendation 4a. This should provide a minimum factor of safety greater than 4 at 265 psig.
		4c- Pipe rupture due to themal expansion stresses.	2	2	4	4c- Design the piping with factor of safety of 2.0 (ultimate) under operating conditions.
5	Structural Failure	5a- The table which follows compares the environmental extremes specified for MISR to the design parameters of the Acurex Model 3011 collector:	3	2	6	5a1- The snow or ice load, and rain ratings, for the Acurex 3011 collector do not meet the MISR specifications. The MISR requirement of an approximate 4-in. ice load seem excessive. These requirements need to be reviewed.

Parameter	MISR Spec	Acurex 3011
Wind Speed (stow)	80 mph	80 mph
Wind Speed (operational)	0 to 25 mph	0 to 25 mph
Temperature (operational)	0^{o}F to +120^{o}F	0^{o}F to +120^{o}F
Hail (stow)	0.75" @ 55 fps	0.75" @ 55 fps
Snow or Ice Load	20 psf	3.9 psf
Dust or Sand	≤150 microns	Not specified
Rain	18"/24 hr	2.5"/24 hr
Seismic		0125g Lat/1.09 vert.

Minimum structural factors of safety for the Acurex reflector modules, receiver tubes, flex hoses, and drive systems are 2.0 (yield) under operational conditions, and 1.2 (yield) and 2.0 (ultimate) under survival conditions.

ACUREX Corporation

PROGRAM: Modular Industrial Solar Retrofit — SHEET 5 OF 7

PRELIMINARY HAZARD ANALYSIS

SUBSYSTEM: — REV. A

Item No.	Hazardous Component or Condition	Description of Potential Hazard	Probability (P)	Severity (S)	Priority (PxS)	Recommended Action
6	Concentrated Sunlight	6a- Eye damage to personnel from reflected concentrated sunlight is a hazard near the collectors.	4	2	8	6a1- All personnel working in the collector field should wear eye protection for glare. Visitors who will be entering the collector field should be issued eye protection and should be required to wear it. 6a2- Signs warning of the concentrated sunlight hazard should be posted around the perimeter of the collector field and at every entrance to the field.
7	Thermal Expansion of Oil in a Closed Delta T Loop	7- Loop isolation valves are provided at the supply and return sides of each delta T loop. If both valves are closed, thermal expansion can result in the loop being pressurized with hot oil, then becoming a hazard to maintenance personnel should they attempt to disassemble the oil piping for any reason.	4	2	8	7a- Provide a bleed valve in every collector delta T loop to enable safe venting of the loop when the isolation valves are closed. 7b- Provide warnings in operational and maintenance manuals describing the hazard of disassembling a pressurized system.
8	Tracking Motor Failure	8- The failure of a tracking motor could result in the inability to automatically position the collector group connected to the failed motor.	3	3	9	8a- Provide instructions for manually positioning collector groups to STOW in O & M manuals. 8b- Make sure the tools required for manually positioning the collectors are available onsite.
9	Steam Generator and Feedwater Preheater	9a- Rupture at normal operating pressure and temperatures.	2	3	6	9a1- ASME certification documents should be forwarded to the customer along with other sytem documentation.
		9b- Rupture due to overpressure. A safety relief system is required by the ASME Pressure Vessel Code for the steam generator.	2	3	6	9b- Maintenance procedures should specify annual testing of all pressure relief valves.

ACUREX Corporation

PRELIMINARY HAZARD ANALYSIS

PROGRAM: Modular Industrial Solar Retrofit SHEET 6 OF 7

SUBSYSTEM: REV. A

Item No.	Hazardous Component or Condition	Description of Potential Hazard	PROBABILITY/ SEVERITY Probability (P)	Severity (S)	Priority (PxS)	Recommended Action
		9c- Personnel contact with hot surfaces.	4	1	3	9c- Steam, hot water, and HTF piping should be insulated to prevent personal injuries from burns. If the pipes are not insulated, other physical methods must be utilized to prevent accidental contact with pipe surfaces which will exceed $130^{\circ}F$ ($54^{\circ}C$).
10	Equipment Skid	10- The equipment skid is constructed of steel. During bad weather, or in case of a leak or spill, the surface of the skid could become very slippery and result in an injury to personnel.	5	2	10	10- Provide an anti-slip surface on the equipment skid.
11	Control Logic	11- Relay logic must be designed "fail safe" such that all control relays are in the safe mode when de-energized. If sensors which detect safety related functions fail without detection, it then becomes possible for an unsafe condition to develop without the system automatically correcting.	3	3	9	11a- Verify all relay logic is of "fail safe" design. 11b- Incorporate periodic functional testing of safety critical detectors into maintenance procedures.
12	Personnel Exposure to Energized Electrical Circuits	12- All electrical equipment is designed to meet the National Electric Code and NEMA requirements, therefore, under normal operation energized circuits will be totally enclosed. During maintenance, however, personnel may need to open the control boxes thereby exposing energized circuits.	4	4	16	12a- Place labels warning of the electrical hazard on all electrical equipment enclosures which may have to be opened while circuits are energized. 12b- Provide warning notes identifying the hazard in maintenance procedures. 12c- Ensure only trained technicians or engineers, familiar with the electrical hazards, are allowed to troubleshoot the electrical equipment.
13	Loss of Electrical Power	13- Electrical power for the control system, field circulation pump, and collector drive systems is normally obtained from the local utility grid. A power failure in that grid would result in automatic switchover to an emergency power generator to enable the collector field to be placed in the stow position.	4	1	4	13a- Verify the control circuitry will accomplish the power switch and drive the collectors to stow. 13b- Provide for periodic testing of the emergency power generator in the maintenance manual.

ACUREX Corporation

PROGRAM: Modular Industrial Solar Retrofit

SHEET 7 OF 7

PRELIMINARY HAZARD ANALYSIS

SUBSYSTEM:

REV. A

Item No.	Hazardous Component or Condition	Description of Potential Hazard	PROBABILITY/SEVERITY Probability (P)	Severity (S)	Priority (PxS)	Recommended Action
14	Extinguishing System Not Pressurized	14- The fire extinguishing system for the equipment skid consists of cylinders of dry chemical and a pressurized cylinder of air or an inert gas such as nitrogen. Should the pressure in the gas cylinder be lost, the system cannot operate.	3	2	6	14- Include periodic inspection of dry chemical tanks to determine satisfactory state of charge.
15	Restart of Fire After System Has Been Discharged	15- Fires in heat transfer fluid can re-ignite if the source of ignition is not removed and the flow of hot oil is not stopped.	3	3	9	15- Interlock the discharge of the dry chemical to shut down the field ciruclation pump and stow the collector field.

APPENDIX B

BDM Corporation MISR System Safety Considerations

MISR - MODULAR INDUSTRIAL SOLAR RETROFIT

PRELIMINARY SAFETY ANALYSIS

November 30, 1981

BDM/A-61-3397

FOREWORD

This document, MISR - Modular Industrial Solar Retrofit Preliminary Safety Analysis report (BDM 61-3397), is submitted by The BDM Corporation, 1801 Randolph Road S.E., Albuquerque, New Mexico 87106. It is prepared for the Sandia National Laboratories, Albuquerque, New Mexico.

TABLE OF CONTENTS

CHAPTER I
INTRODUCTION

Sandia National Laboratories, Albuquerque, has awarded The BDM Corporation a contract to design a Modular Industrial Solar Retrofit (MISR) system.

The MISR will consist of 25,200 square feet of linear parabolic trough solar collectors which will collect thermal energy required to generate a peak of 4275 lbs/hr of steam for an industrial process. A (P&ID) Piping and Instrumentation Diagram, BDM drawing #02F001660, is included with this report.

The Design and Analysis of the MISR requires a preliminary safety analysis of the solar energy system that is contained in this document. Potential hazards of the system will be addressed, including corrective measures.

A description of each of the solar project subsystems is contained in the following chapters. For each subsystem the possible safety hazards are identified and recommendations are made either to eliminate or control the hazards at an acceptable level. Figure I-1 summarizes the subsystems, their safety analysis, and resolution.

HAZARD SOURCE	SAFETY CONCERN	PRECAUTIONARY/PROTECTIVE MEASURES
COLLECTORS	o BURNS FROM RECEIVER TUBE o LIGHT INTENSITY o COLLECTOR MOVEMENT	o WARNING SIGNS o PERSONNEL PROTECTIVE GEAR o WARNING HORNS
HEAT TRANSFER FLUID SUBSYSTEM	o FIRE o CONTACT BURNS o TOXIC VAPORS	o FIRE PROTECTION o PERSONNEL PROTECTIVE GEAR o SHOWER AND EYE WASH
STEAM GENERATOR	o OVER PRESSURE EXPLOSION o STEAM/HOT WATER BURNS	o PRESSURE SWITCH & RELIEF VALVES o PERSONNEL PROTECTIVE GEAR
PUMP	o ELECTRICAL MOTOR OVER TEMPERATURE o ROTATING SHAFT	o FIRE PROTECTION o COUPLING GUARD
ELECTRICAL SYSTEM	o FIRE o BURNS/SHOCK	o EXPLOSION PROFF EQUIPMENT o CIRCUIT BREAKERS o GROUNDING
COMPRESSED GAS (NITROGEN)	o OVER PRESSURE EXPLOSION	o PRESSURE RELIEF VALVE
EXPANSION TANK	o FIRE o OVER PRESSURE	o FIRE PROTECTION o PRESSURE RELIEF VALVE
PIPE INSULATION	o HTF SATURATION	o IMPREGNABLE PROTECTIVE FABRIC o INSTALL VALVE STEMS AT 45° DOWNWARD FROM HORIZONTAL

FIGURE I-1

CHAPTER II
SYSTEM DESCRIPTION

A layout of the MISR is shown in BDM Drawing 02F001658. The inlet and outlet manifolds run along the edge of the collector field, feeding five delta-T loops. The 10 rows of collectors have 18, 20 ft collectors that make the nominal length of the field 500 ft. The rows are equally spaced with 15' center-to-center spacing making the nominal width of the field 200 ft (accounting for side access walkways). The 4" inlet and outlet manifolds connect to the steam generator and the mechanical equipment skid. The generated steam is transported through a 3" steam line where it feeds the plant in parallel with the existing fossil fuel boiler. Feedwater is supplied from the existing condensate System through a 1 1/2" feedwater line. Access to fire and emergency vehicles is provided through crash gates leading to a roadway surrounding the field.

CHAPTER III
MASTER CONTROL SYSTEM (MCS)

The function of the MCS is to ensure the safe, reliable operation of the solar steam generator system under varying insolation and weather conditions. The key to the safe operation of the MISR is the Master Control Subsystem (MSC) which consists of sensors connected to hard-wired relay logic to control valves, pumps, collectors, etc., in response to different operating conditions.

The MCS consists of off-the-shelf sensors, switches, and relay components in which the control logic is hard-wired into the control panel. Advantages to this type of system are:

(1) System control reliability which does not depend on computer software and is not affected by computer inconsistencies, minor voltage surges, and drift in analog signals.

(2) Logic Simplicity allowing plant personnel likely to be familiar with standard industrial controls and component testing requiring simple instrumentation (volt/ohm meter, etc.).

(3) Ease of component repair through the use of off-the-shelf hardware not requiring long lead times.

(4) Continuous monitoring of the status of each sensor input to the control panel as opposed to discrete scanning required in a computer based system.

(5) Automatic operation to allow unattended operation by hard-wiring the solar system to the "on" switch of the fossil fuel boiler. This will not allow the solar system to operate unless the fossil fuel boiler is on, or unless over-ridden manually.

(6) Alarm indications to detect all hazards with manual reset for safety and diagnosis.

An overview of the hazard logic that will ensure safe system operation is shown with details in BDM Drawing No. 02D001664.

CHAPTER IV
SOLAR COLLECTOR SUBSYSTEM

The collector used in this application is a Solar Kinetics (SKI) linear parabolic trough with a 7-foot aperture, designated the T-700. The present generation Solar Kinetics troughs have been evaluated by Sandia Laboratories as one of the best systems available today.

The T-700 is manufactured in 20-foot long sections and constructed with aluminum components using a monocoque design with an aircraft grade aluminum skin. The reflector surface is an acrylic film FEK-244 made by 3M. Weather testing has shown less than 4-percent specular loss over 3 years.

The collector structure is extremely resistant to deflection and damage because of its monocoque design and high grade aluminum skin. Extrapolation of wind tunnel tests show the T-700 able to withstand 90 mph winds in the stowed position and steady 40 mph winds at any focal position. Natural hailstones up to three-quarter-inch diameter have not caused damage to the aluminum skin in the Solar Kinetics test stand in Dallas.

The collectors will not present a safety hazard since maintenance on the array will be conducted mostly on cloudy days or at night after the system has cooled. However, while the system is hot, sensible precautions need to be taken, such as keeping limbs away from the focal point of the parabolic collector and being aware of the high temperature of the receiver tube. Under no circumstances will personnel or repair work be allowed when the collector is under operating conditions. Pressure relief valves will be installed in each collector loop to guard against unintentional focusing and the resulting overpressure of an isolated collector loop. Conspicuous warning signs about temperature, concentrated sunlight, and fire hazards will be posted so that they are visible from any location in the array. All piping and valves will be labeled for easy identification in emergencies.

Pedestrian and vehicle access to the collector field will be provided for emergency operations. Piping has been routed so as not to inhibit access to or egress from these facilities. Maps and procedures will be included in the operations and maintenance manual to be provided.

CHAPTER V
HEAT TRANSFER SYSTEM

The heat transfer fluid selected for the MISR project is Therminol-60 (T-60) manufactured by the Monsanto Chemical Company. T-60 is a synthetic hydrocarbon mixture with chemical properties and temperature range which make it ideal for this kind of operation. There are over one hundred applications currently using T-60.

Monsanto has conducted laboratory experiments to determine the toxicity levels of T-60. Humans and rabbits were subjected to dermal applications of T-60 and rats were exposed to inhalation and ingestion tests. The manager of the Environmental Assessment & Toxicology Department has concluded that T-60 is considered nontoxic by ingestion in single doses and by single dermal applications. Prolonged contact with the fluid can cause eye and skin irritations; therefore, immediate removal of T-60 is necessary. This can be achieved by flushing eyes or skin with plenty of water. Standard industrial precautions should be exercised when handling T-60 to minimize contact. An emergency flood/shower station will be located near the equipment pad if site constraints permit.

Due to its low vapor pressure, T-60 does not present an inhalation hazard at ambient temperatures. Vapor emitted by T-60 heated to elevated temperatures may be mildly irritating and cause discomfort on prolonged exposure. However, in the heat transfer installation, the fluid will be used in a closed system with the expansion tank vent routed to an appropriate discharge area. Consequently, there should be little or no opportunity for workers to come in contact with the vapor. The anticipated life expectancy of T-60 is thirty years, which eliminates periodic fluid changes.

Precautions are being taken to prevent any leaks of the heat transfer fluid in the solar energy system. Leaks constitute a fire hazard and a safety risk. As the temperature of the heat transfer fluid rises, the viscosity drops, thus making ordinary threaded pipe fittings susceptible to leakage. Either butt or socketed joint welds will be used on small valving, pipe joints, reducers, and other connections while large control valves and equipment will be flanged. Certified welders who guarantee their work, will be contracted to install the system. A leak test using a compressed gas and soap suds will be performed prior to the installation of insulation.

The steam generator and pump will be similarly tested to protect against leaks. Pressure testing of the heat transfer subsystem will be done according to ANSI B31.3. All electrical lines from these units will be routed through conduits completely isolated from the fluid system. Even in the event of fluid leakage, no electrical lines will be affected.

In the past, flex hose connected to the collector has been silver-brazed, and has been a source of fluid leakage. To prevent problems, this connection will be welded according to the specifications of the other pipe connections in the system. Solar Kinetics has already adopted this as standard practice in its manufacturing process for the T-700.

Therminol-60, as well as other heat transfer fluids, will eventually oxidize and degrade when exposed to the atmosphere. In an effort to reduce oxidation, the expansion tank will be pressurized with a commercial-grade nitrogen as a blanket over the fluid, preventing outside air from contacting it. Nitrogen was selected because it is inert, inexpensive, readily available, and non-toxic. The pressurized tank will be secured to the equipment skid to prevent any accidental dislodging. The pressure will be used to vent the gas in the case of an over pressure. Pressure for the incoming nitrogen will be kept above ambient pressure to ensure a positive pressure when the system is thermally at a minimum. The tank is plumbed in parallel with the main piping system to prevent pumping losses and heat losses, and to ensure maintenance without affecting the main supply.

At the end of the working day the heat transfer system can be checked for leaks by pressuring the system with nitrogen to 100 psi. If a drop in pressure over and above temperature effects has occurred by the following morning, a leak is probable and a visual search of the system must be conducted. The leak can be isolated by closing off selected collector rows.

The expansion tank will be sized to accommodate the expansion of the heat transfer fluid when it is heated to high temperatures to prevent over-flowing and over-pressure. Thus, the tank will be 25 percent full at ambient temperature and 75 percent full at operating temperature.

The remainder of the heat transfer system includes the piping, insulation and pump. Mild steel was selected for the piping system because of its cost, weldability, availability, and adaptability to valving and couplers. Welded joints increase reliability by minimizing possible leaks.

The piping system will be insulated with a standard high temperature insulation, fiber glass or performed jacketed insulation at valves and connections. To prevent the transfer of leaking oil, there will be gaps in the insulation in areas of potential leaks, i.e., valves.

Valves have been located to permit control and isolation of individual collector and sectors of the main header for repair. These valves will also be insulated. Gloves will be worn to adjust valves. Valve stems will be placed 45° downward from the horizontal to inhibit any fluid leakage from entering the insulation.

The insulation will be jacketed with aluminum to protect against deterioration from weather. A heat transfer analysis shows that this aluminum jacket will reach a maximum temperature of 95°F, which is not hazardous to persons working on the solar array.

Hole at the bottom of the weather proof jacketing will be located in insulation gaps near areas for potential leaks. These holes minimize the amount of insulation contamination by allowing the fluid to drain out and be detected.

The heat transfer fluid pump will be thermally insulated except for its motor, which would overheat if insulated. Signs will be posted to warn employees about the hot surfaces of the motor. The outdoor location of the pumps will lessen the danger of explosions from vapor build-up that could occur with an indoor site. A coupling guard will protect personnel from the rotating pump shaft. A Halon fire extinguishing system will be installed for safety against both electrical and oil hazards in addition to UV detection for both the field and mechanical skid.

CHAPTER VI
FIRE PROTECTION

Many precautions were incorporated in the design of the heat transfer system to prevent the possibility of fire occurring in the solar array. To prevent fluid leaks the system will be build with low carbon steel pipe and will have all tees, couplers and reducers welded. After the heat transfer system is assembled and welded, a leak check using a compressed gas and soapy water will be performed on all welded joints, valves, and fittings to ensure a leak tight system. The only possible place for leaks to occur will then be around the compression type fittings, flanged equipment, and valve seals. The valves will be installed with the stem pointing 45° downward from horizontal so that if a leak does occur the fluid will not saturate the insulation.

The present selected insulation for valves and connections in the solar array is fiber glass. Since there is a possibility of fluid leaking around the fiber glass insulation and saturating the insulation, the following procedure will be followed to minimize this danger. Around every joint, valve, and fitting there will be a 2-inch break between the insulation surrounding the fitting and the insulation surrounding the pipes. A 1/2-inch diameter drain hole will be drilled at the bottom of this gap in the aluminum jacket covering the insulation. This will ensure that the fluid leak will be contained to a very local area. The drain hole will also serve for visual location leaks by their dripping.

Investigation is being made into prefabricated, reusable insulation jackets around potentially high activity areas such as the pump and the inlet and outlet headers. These would consist of contoured "jackets" of fiberglass insulation packaged in an impregnable silicon coated fiber glass material. The benefits of these devices lie in cost savings from reusability (since the probability of the breakage of brittle fiber glass sections are high after several re-installations) and added safety since leaks would not be soaked into the insulation at all.

The selection of Therminol-60 as the heat transport fluid was influenced because of its high auto-ignition temperature of over 800°. This is above the design operating temperature of all components in the system including the receiver tube.

Ultra-violet (UV) detectors will be placed to view key locations on the MISR; the manifold at the collector inlet and outlet, the intra-row connectors, the end loop around, and the mechanical skid. These are the locations of the automatic valves and the collector flex hoses which are the most susceptible to oil leaks and therefore are fire hazards. These devices will trip the Master Control System hazard loop and alarms to warn personnel and activate a packaged Halon extinguishing system as appropriate to protect the mechanical skid.

Halon 1301 will be used as the extinguishing agent on the enclosed mechanical skid. It is a clean agent which will provide positive extinguishment. The system will discharge within 10 seconds from alarm with a recommended concentration of 6 1/2%. The final concentration will be determined after the mechanical skid has been completed.

Halon 1301 is a colorless, odorless, electrically non-conductive gas (bromotrifluoromethane). According to present knowledge, it extinguishes fires by inhibiting the chemical reaction of fuel and oxygen. It is a clean agent that leaves no residue and is non-toxic. The inhalation toxicity of Halon 1301 for animals has been investigated and found to be among those in least toxic categories. It should be noted that the products of decomposition by fire are irritating and normal precautions to ensure good ventilation after the effects of a fire should be taken.

No smoking will be permitted anywhere near the solar energy system.

CHAPTER VII
PERSONNEL PROTECTION

When maintaining the solar array, employees will be protected from hot surfaces by the use of protective clothing and sensible procedures. Employees will be expected to wear high temperature resistant coveralls, gloves, and hard hats.

Employees will be expected to heed warning signs. No one would be permitted to work on the collector or heat transfer system while they are operating or when it is hot. When working on the solar array during daytime hours, sunglasses will be provided to protect employees' eyes from concentrated sunlight.

First aid kits and supplies will be easily accessible to the maintenance workers. A safety shower and eyewash fountain will also be located near the equipment skid.

CHAPTER VIII
LIGHTNING PROTECTION

Lightning protection for the MISR facility will consist of a counterpoise system with a ground plan established by burial of bare copper wire together with the power and central conduit in the field. A mesh covering the entire field will thus be provided.

CHAPTER IX

DOCUMENTATION OF OPERATING PROCEDURES AND SAFETY TRAINING

BDM will provide a complete manual of standard operating procedures, which will be available at the facility at all times. This manual will include:

1. organizations and personnel involved with various subsystems
2. precautions for system operation, service, and repair
3. schedules for equipment safety checks and personnel safety drills
4. equipment drawings
5. electrical schematics
6. piping and instrumentation diagram
7. detailed emergency procedures

All necessary information will be documented for a fifteen year operation of the system. A complete safety and training manual will also be provided for a training program.

APPENDIX C

Custom Engineering, Inc, MISR System Safety Considerations

CUSTOM ENGINEERING INC.
2805 South Tejon Street Englewood, Colorado 80110
(303) 761-7585

MISR

PRELIMINARY SAFETY ANALYSIS

February 9, 1982

The following charts show the safety margins for the critical design elements of the Custom Engineering's MISR design.

MISR
SAFETY ANALYSIS

ITEM NO.	COMPONENT OR SUBSYSTEM	DESIGN ALLOWABLE	OPERATING CONDITION	MARGIN	COMMENTS
1.	STEAM GENERATOR				
	SHELL-STEAM	Pressure 300 psi Temperature 422° F	Pressure 250 psi Temperature 406° F	50 psi (20%) 16° F (4%)	Relief Valve - 300 psi
	TUBES - HTF	Pressure 150 psi Temperature 650° F	Pressure 50 psi Temperature 550° F	100 psi (200%) 100° F (18%)	Relief Valve - 150 psi
	F.W. HEATER SHELL	Pressure 300 psi Temperature 422° F	Pressure 250 psi Temperature 390° F	50 psi (20%) 32° F (8%)	Relief Valve - 300 psi
	F.W. TUBES	Pressure 150 psi Temperature 650° F	Pressure 50 psi Temperature 425° F	100 psi (500%) 225° F (53%)	Relief Valve - 150 psi
2.	PUMP	Pressure 600 psi Temperature 500° F	Pressure 100 psi Temperature 400° F	500 psi (500%) 100° F (25%)	
3.	EXPANSION TANK	Pressure 75 psi Temperature 450° F	Pressure 50 psi Temperature 200° F	25 psi (50%) 250° F (125%)	Relief Valve - 75 psi

MISR
SAFETY ANALYSIS

ITEM NO.	COMPONENT OR SUBSYSTEM	DESIGN ALLOWABLE		OPERATING CONDITION		MARGIN	COMMENTS
4.	N_2 TANK	Pressure Temperature	75 psi 450° F	Pressure Temperature	50 psi 70° F	25 psi (50%) 380° F (543%)	Relief Valve - 75 psi
5.	STRAINER	Pressure Temperature	515 psi 650° F	Pressure Temperature	100 psi 400° F	415 psi (415%) 250° F (63%)	
6.	WASH SYSTEM SOFTNER	Pressure Temperature	100 psi 100° F	Pressure Temperature	60 psi 60° F	40 psi (67%) 40° F (67%)	
7.	FIRE SUPPRESSION SYSTEM TANK	Pressure Temperature	200 psi 100° F	Pressure Temperature	150 psi 60° F	50 psi (33%) 40° F (67%)	Relief Valve - 200 psi

MISR
SAFETY ANALYSIS

ITEM NO.	COMPONENT OR SUBSYSTEM	DESIGN ALLOWABLE	OPERATING CONDITION	MARGIN	COMMENTS
8.	PIPING A106GR.B VALVES A216WCB FITTINGS A105				
	STEAM	Pressure 515 psi Temperature 650° F	Pressure 250 psi Temperature 406° F	265 psi (106%) 244° F (60%)	Protected by the relief valve on the generator shell.
	HTF	Pressure 515 psi Temperature 650° F	Pressure 100 psi Temperature 555° F	415 psi (415%) 95° F (17%)	Protected by the relief valve on the HTF side of the steam generator.
	FEEDWATER	Pressure 515 psi Temperature 650° F	Pressure 300 psi Temperature 230° F	215 psi (72%) 420° F (183%)	Protected by the relief valve on the feedwater heater.

MISR
SAFETY ANALYSIS

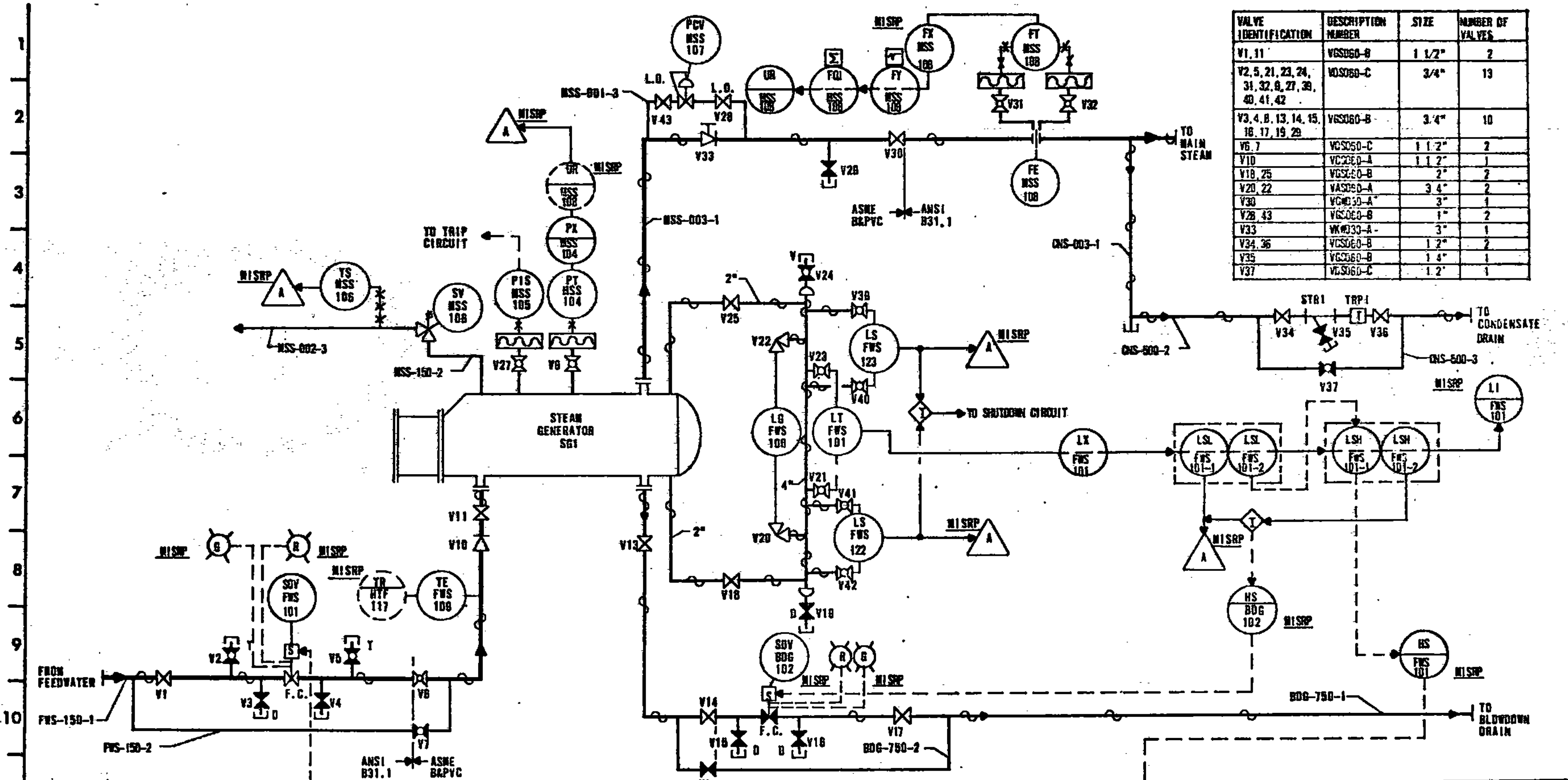
ITEM NO.	COMPONENT OR SUBSYSTEM	DESIGN ALLOWABLE	OPERATING CONDITION	MARGIN	COMMENTS
9.	INSULATION	Fiberglass 650° F Alum. Jacket	Fiberglass 550° F Alum. Jacket - 130°F (Max.)	100° F (18%)	
10.	COLLECTORS				
	STRUCTURE				The collectors and pylons are designed to meet low deflection requirements under operating loads. This results in factors of safety of 10 or more for strength.
	GEARBOX	Torque 69000 in lb.	Torque 61200 in.lb.	7800 in. lb. (13%)	
11.	ELECTRICAL		208 volt service		NEMA enclosures with circuit breaker interlocks. High voltage warning labels will designate electrical panel hazards.
12.	EQUIPMENT SKID			Factor of safety of 2 calculated loads.	To prevent slipping and injury to personnel, an antislip surface will be applied to the skid surface.

MISR
SAFETY ANALYSIS

ITEM NO.	COMPONENT OR SUBSYSTEM	DESIGN ALLOWABLE	OPERATING CONDITION	MARGIN	COMMENTS
13.	FLEX HOSE	Pressure (see comment) Temperature 650° F	Pressure 100 psi Temperature 550° F	100 psi (100%) 100° F (18%)	Proof tested to 200 psi.

APPENDIX D

Solar Kinetics MISR System Safety Considerations



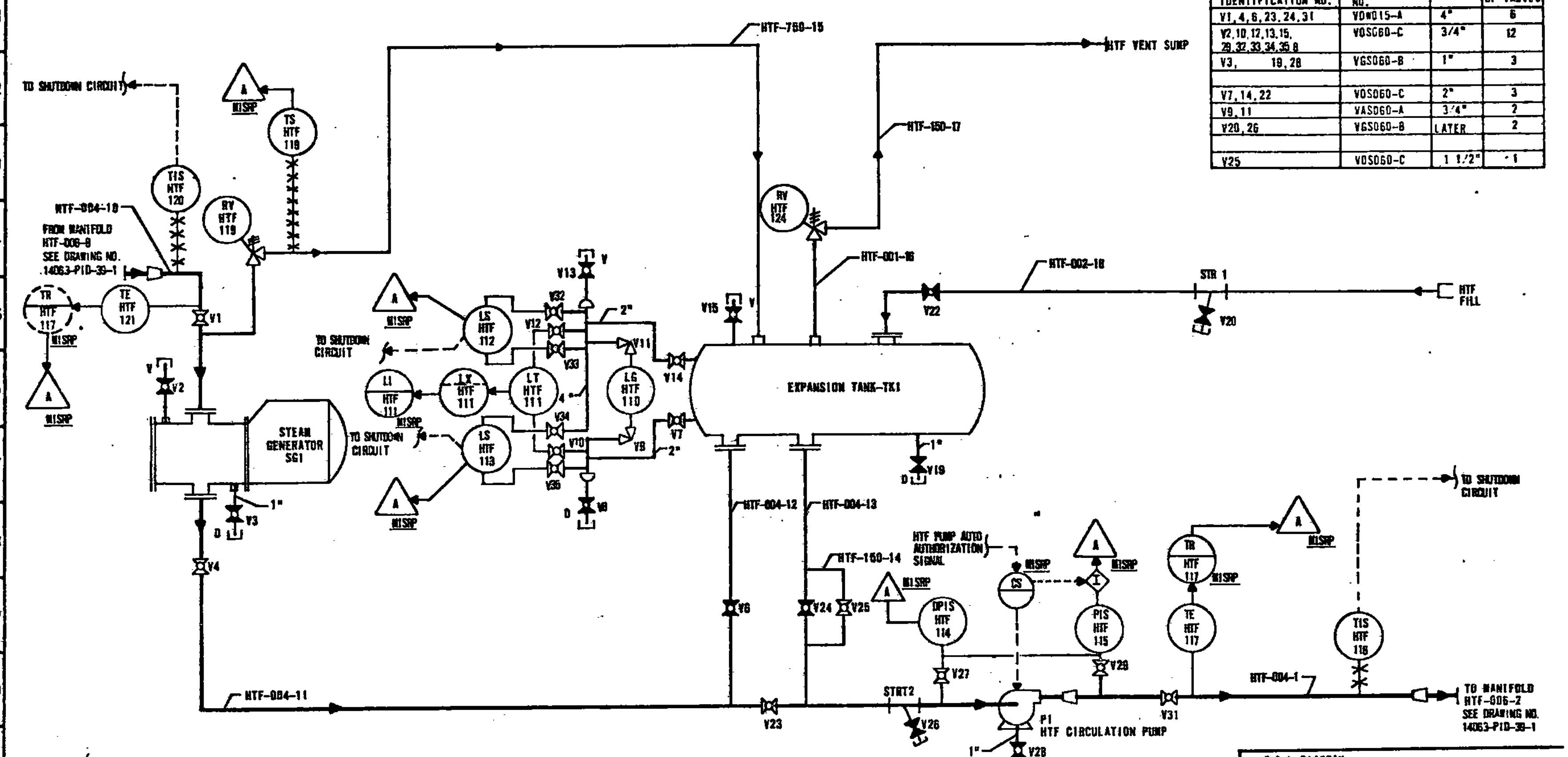
VALVE IDENTIFICATION	DESCRIPTION NUMBER	SIZE	NUMBER OF VALVES
V1, 11	VGS060-B	1 1/2"	2
V2, 5, 21, 23, 24, 31, 32, 9, 27, 39, 40, 41, 42	VDS060-C	3/4"	13
V3, 4, 8, 13, 14, 15, 16, 17, 19, 29	VGS060-B	3/4"	10
V6, 7	VCS050-C	1 1/2"	2
V10	VC2060-A	1 1/2"	1
V18, 25	VGS060-B	2"	2
V20, 22	VAS090-A	3/4"	2
V30	VG#030-A	3"	1
V28, 43	VGS060-B	1"	2
V33	VK#030-A	3"	1
V34, 36	VCS060-B	1/2"	2
V35	VGS060-B	1/4"	1
V37	VDS060-C	1/2"	1

NOTES:

1. "BDG"- BLOWDOWN SUBSYSTEM IDENTIFICATION CODE.
2. "FWS"- FEEDWATER SUBSYSTEM IDENTIFICATION CODE.
3. "MSS"- MAIN STEAM SUBSYSTEM IDENTIFICATION CODE.
4. "CNS"- CONDENSATE SUBSYSTEM IDENTIFICATION CODE.
5. ALL INSTRUMENT, DRAIN, AND VENT CONNECTIONS ARE 3/4".
6. UR-MSS-108 IS A TWO PEN RECORDER MONITORING (1)MAIN STEAM FLOW AND (2)STEAM GENERATOR PRESSURE.

DATE				03/12/82	02/01/82	12/23/81	11/20/81
C	7	6	5	4 RGM	3 RGM	2 RGM	1 RGM
P				BWS	BWG	BWG	BWG
E							

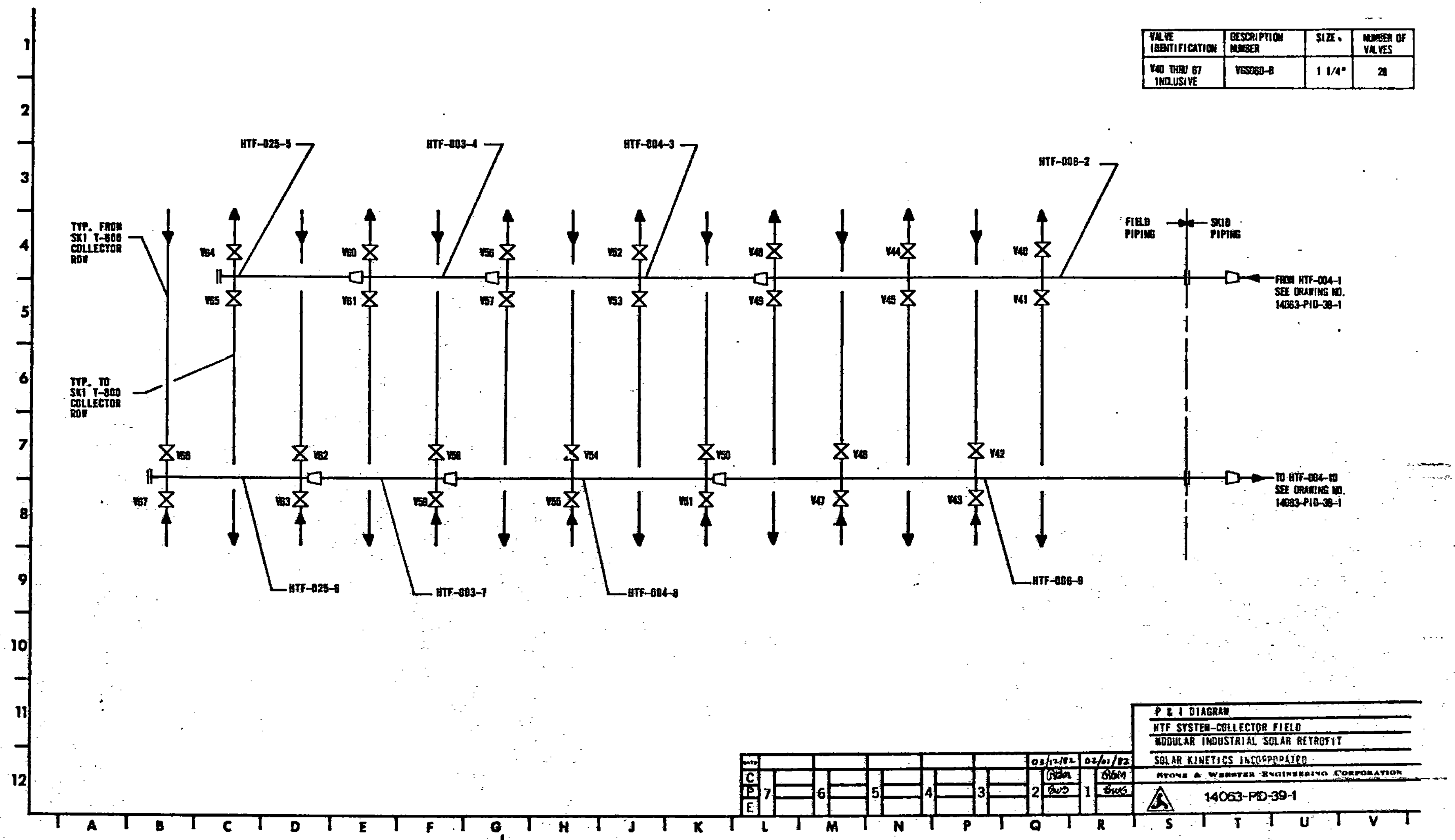
P & I DIAGRAM
WATER-STEAM SYSTEM
MODULAR INDUSTRIAL SOLAR RETROFIT
SOLAR KINETICS INCORPORATED
STONE & WEBSTER ENGINEERING CORPORATION
14063-PID-3-1



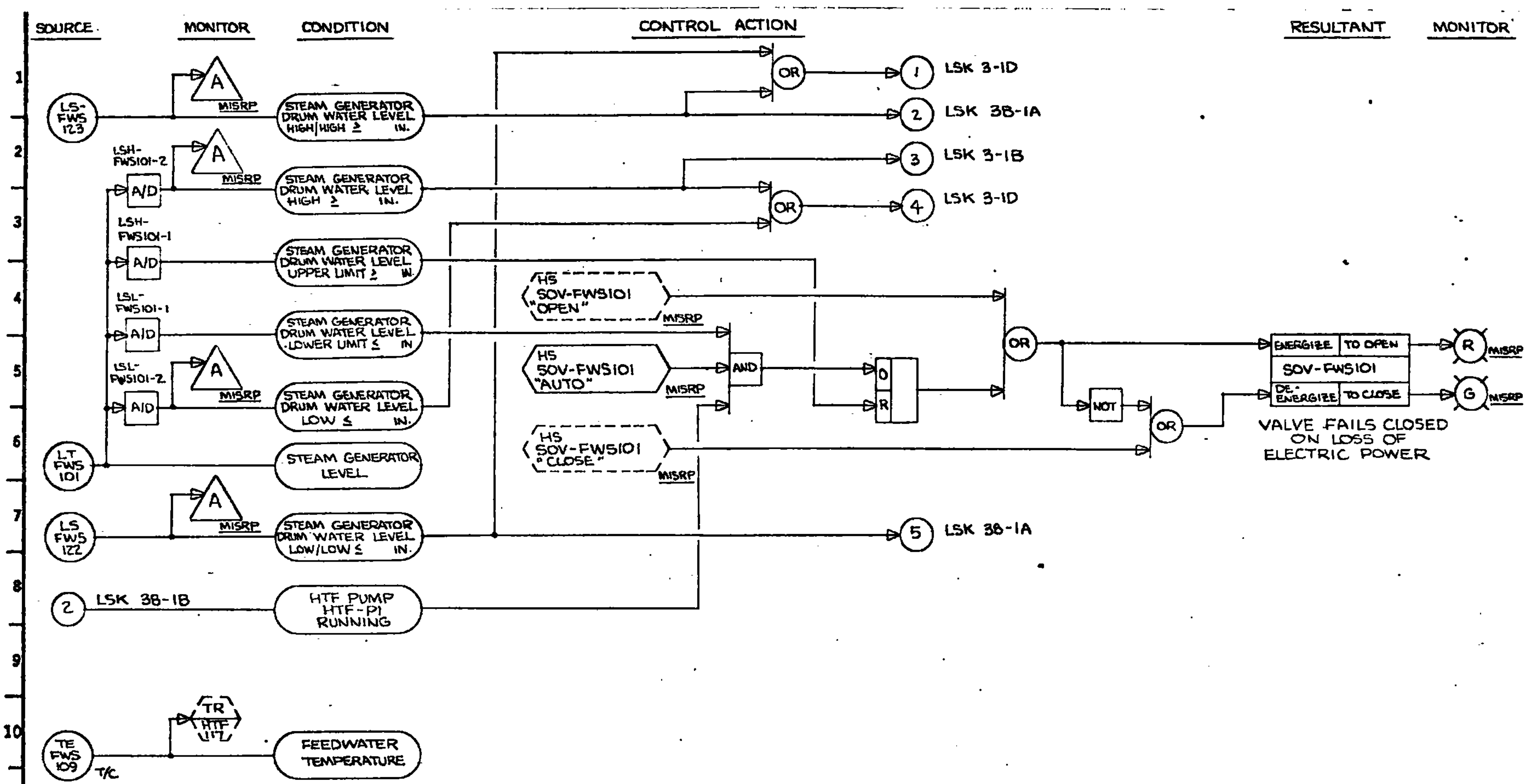
VALVE IDENTIFICATION NO.	DESCRIPTION NO.	SIZE	NUMBER OF VALVES
V1,4,6,23,24,31	VOW015-A	4"	6
V2,10,12,13,15, 29,32,33,34,35 8	VOSG60-C	3/4"	12
V3, 19,28	VGS060-B	1"	3
V7,14,22	VOS060-C	2"	3
V9,11	VAS060-A	3/4"	2
V20,26	VGS060-B	LATER	2
V25	VOS060-C	1 1/2"	1

NOTES:

1. "HTF"- HEAT TRANSFER SYSTEM IDENTIFICATION CODE.
2. TR-HTF117 IS A THREE PEN TEMPERATURE RECORDER MONITORING (1) HEAT TRANSFER FLUID FROM COLLECTOR FIELD,(2) HEAT TRANSFER FLUID TO COLLECTOR FIELD,(3) FEEDWATER INTO STEAM GENERATOR.
3. ALL INSTRUMENT,DRAIN,AND VENT CONNECTIONS ARE 3/4" UNLESS OTHERWISE NOTED.



VALVE IDENTIFICATION	DESCRIPTION NUMBER	SIZE.	NUMBER OF VALVES
V40 THRU 67 INCLUSIVE	VGS060-B	1 1/4"	28

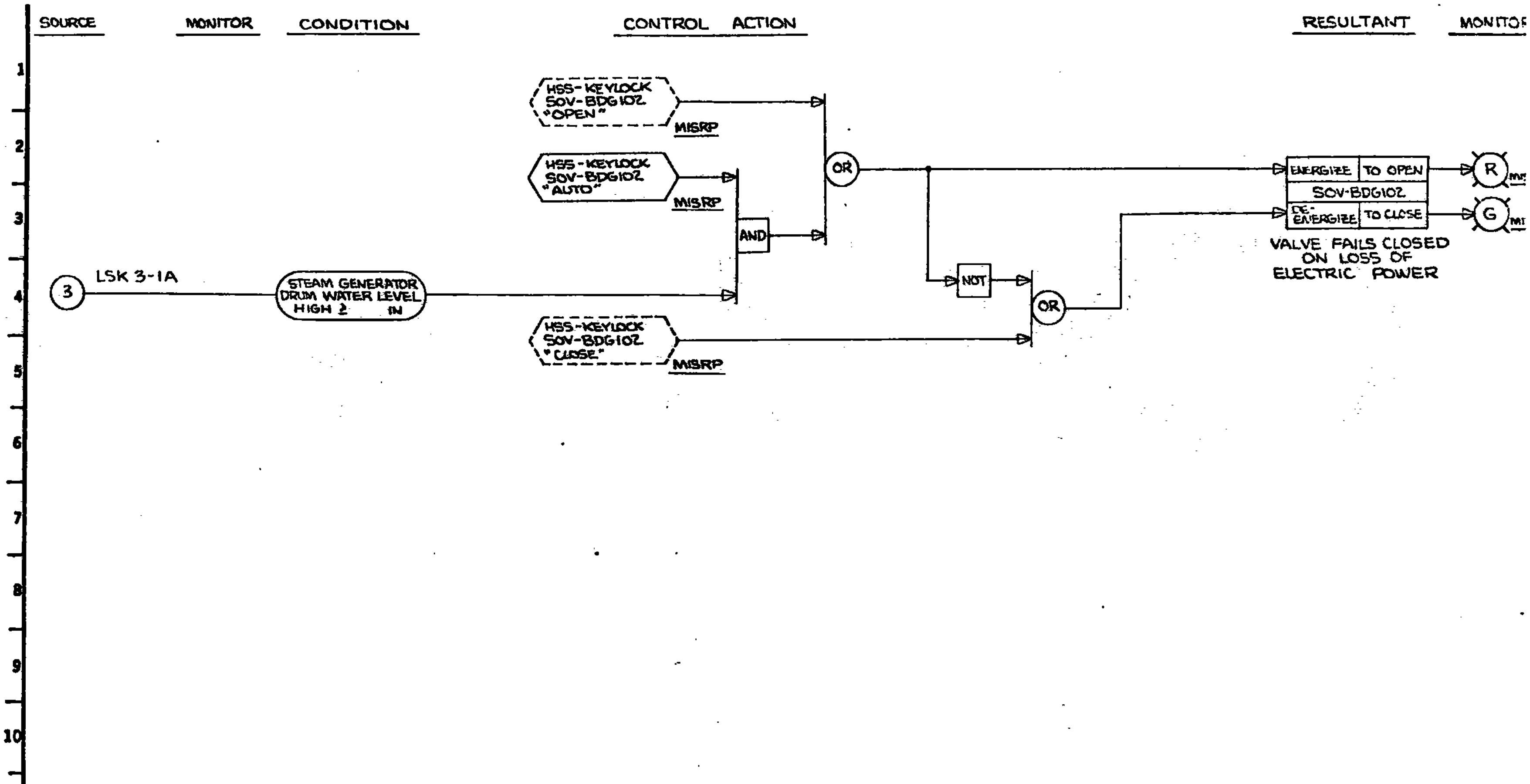


NOTES

1. "FWS" - FEEDWATER SYSTEM SYSTEM CODE
2. "MISRP" - INDICATES ITEMS MOUNTED ON MODULAR INDUSTRIAL SOLAR RETROFIT PANEL
3. REFERENCED LSK'S PREFIXED WITH "14063.00"
4. DEVICES SHOWN WITH BROKEN-LINES ARE OUT OF FUNCTION
5. "HTF" - HEAT TRANSFER FLUID SYSTEM SYSTEM CODE

LOGIC DIAGRAM
FEEDWATER SYSTEM
MODULAR INDUSTRIAL SOLAR RETROFIT (MISR)
SOLAR KINETICS INCORPORATED
STONE & WEBSTER ENGINEERING CORPORATION
14063.00 - LSK-3-1A

3-12-82



NOTES

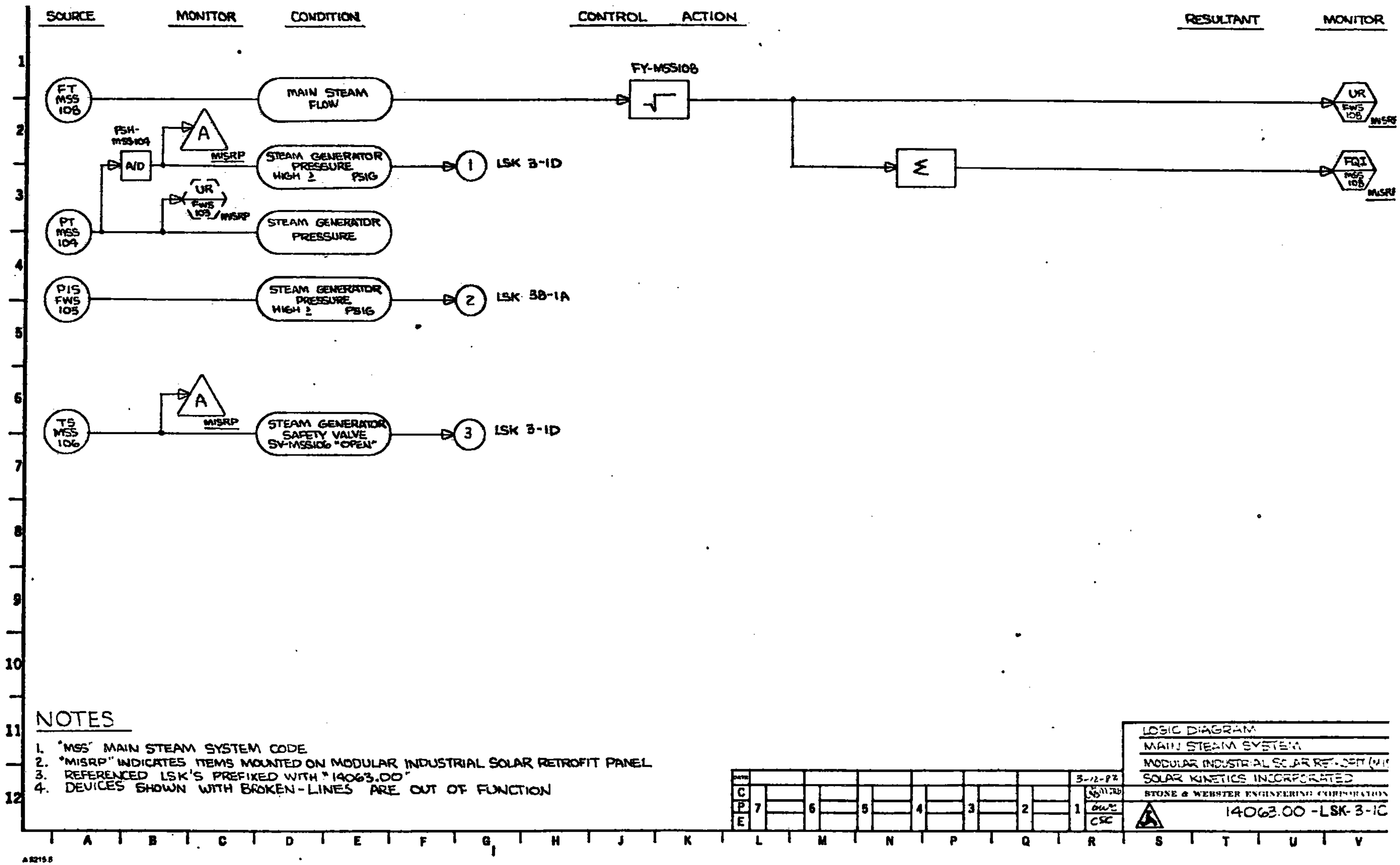
1. "BDG" - BLOWDOWN SYSTEM SYSTEM CODE
2. "MISRP" - INDICATES ITEMS MOUNTED ON MODULAR INDUSTRIAL SOLAR RETROFIT PANEL
3. REFERENCED LSK'S PREFIXED WITH "14063.00"
4. DEVICES SHOWN WITH BROKEN-LINES ARE OUT OF FUNCTION

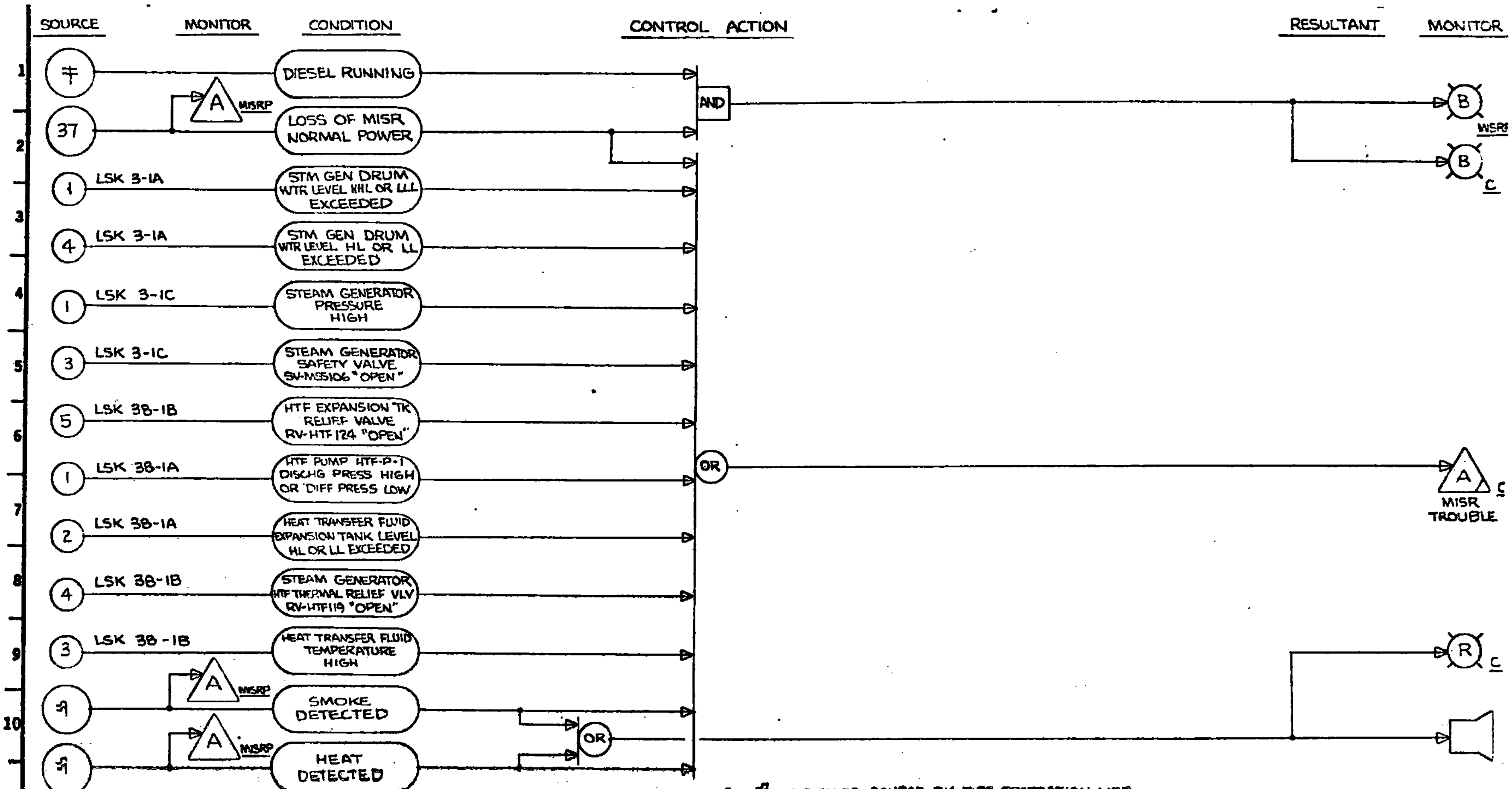
LOGIC DIAGRAM
BLOWDOWN SYSTEM
MODULAR INDUSTRIAL SOLAR RETROFIT
SOLAR KINETICS INCORPORATED
STONE & WEBSTER ENGINEERING CORPORATION
14063.00 - LSK-3-

3-12-82
CSC

A B C D E F G H J K L M N P Q R S T U V

A5215.5


SOURCE
MONITOR
CONDITION
CONTROL ACTION
RESULTANT
MONITOR
FT MSS 108
MAIN STEAM FLOW
FY-MSS108
UR FWS 108 MISRP
FQI MSS 108 MISRP
PSH-MSS104
A/D
A
MISRP
STEAM GENERATOR PRESSURE HIGH ≥ PSIG
1 LSK 3-1D
PT MSS 104
UR FWS 109 MISRP
STEAM GENERATOR PRESSURE
PIS FWS 105
STEAM GENERATOR PRESSURE HIGH ≥ PSIG
2 LSK 3B-1A
TS MSS 106
STEAM GENERATOR SAFETY VALVE SV-MSS106 "OPEN"
3 LSK 3-1D
NOTES
1. "MSS" MAIN STEAM SYSTEM CODE
2. "MISRP" INDICATES ITEMS MOUNTED ON MODULAR INDUSTRIAL SOLAR RETROFIT PANEL
3. REFERENCED LSK'S PREFIXED WITH "14063.00"
4. DEVICES SHOWN WITH BROKEN-LINES ARE OUT OF FUNCTION
LOGIC DIAGRAM
MAIN STEAM SYSTEM
MODULAR INDUSTRIAL SOLAR RETROFIT
SOLAR KINETICS INCORPORATED
STONE & WEBSTER ENGINEERING CORPORATION
3-12-82
14063.00 -LSK-3-1C



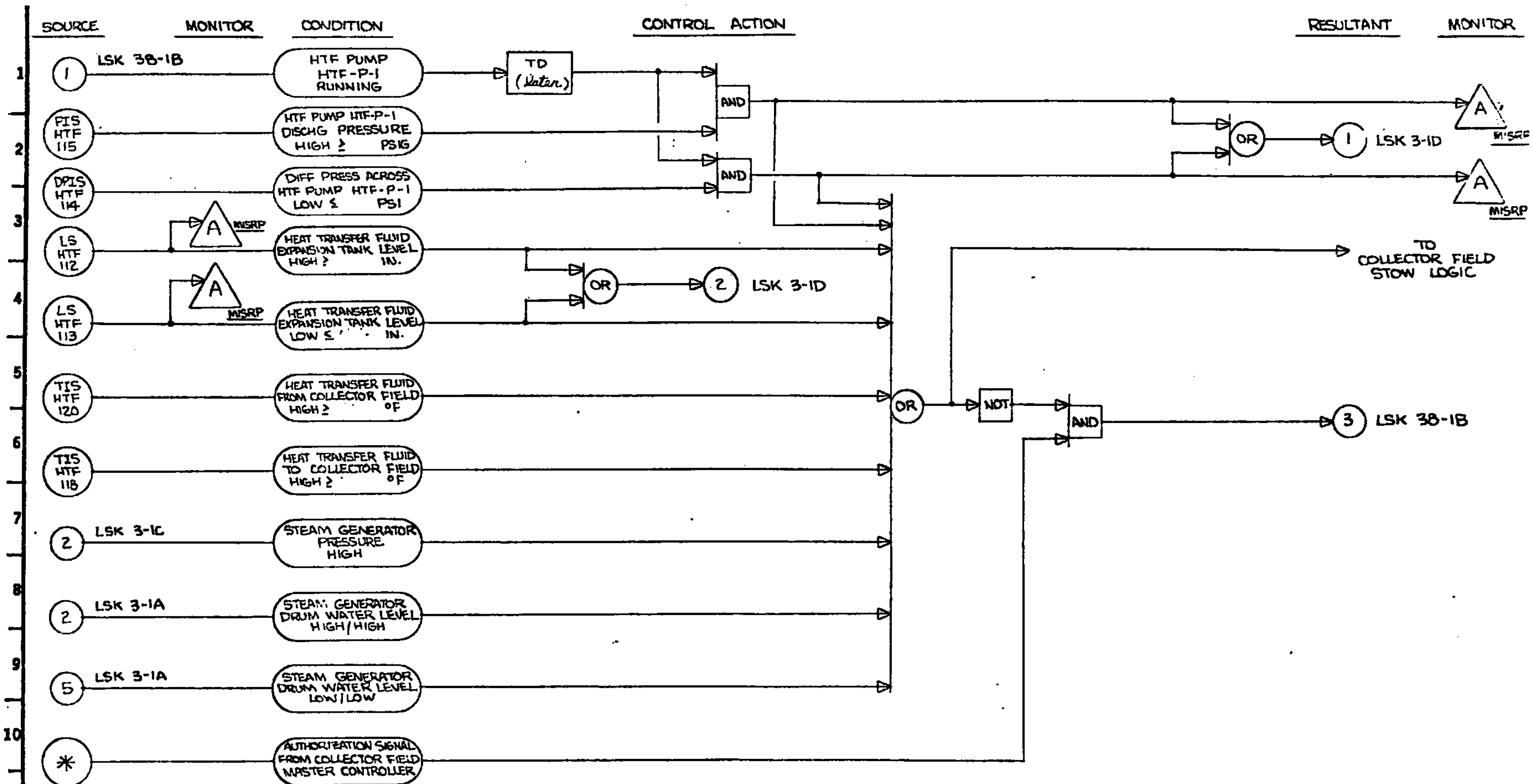
NOTES

1. "MSS"- MAIN STEAM SYSTEM SYSTEM CODE
2. "HTF"- HEAT TRANSFER FLUID SYSTEM SYSTEM CODE
3. "MISRP"- INDICATES ITEMS MOUNTED ON MODULAR INDUSTRIAL SOLAR RETROFIT PANEL
4. REFERENCED LSK'S PREFIXED WITH "14063.00"
5. ╪ - INDICATES SOURCE BY DIESEL MFR.
6. ╕ - INDICATES SOURCE BY FIRE PROTECTION MFR.
7. LL & HL - INDICATE LOW LIMIT & HIGH LIMIT, RESPECTIVELY
8. LLL & HHL INDICATE LOW/LOW LIMIT & HIGH/HIGH LIMIT, RESPECTIVELY

LOGIC DIAGRAM
MISR TROUBLE ALARM
MODULAR INDUSTRIAL SOLAR RETROFIT (M.S...
SOLAR KINETICS INCORPORATED
STONE & WEBSTER ENGINEERING CORPORATION
14063.00 - LSK-3-1...

3-12-8.. CSC

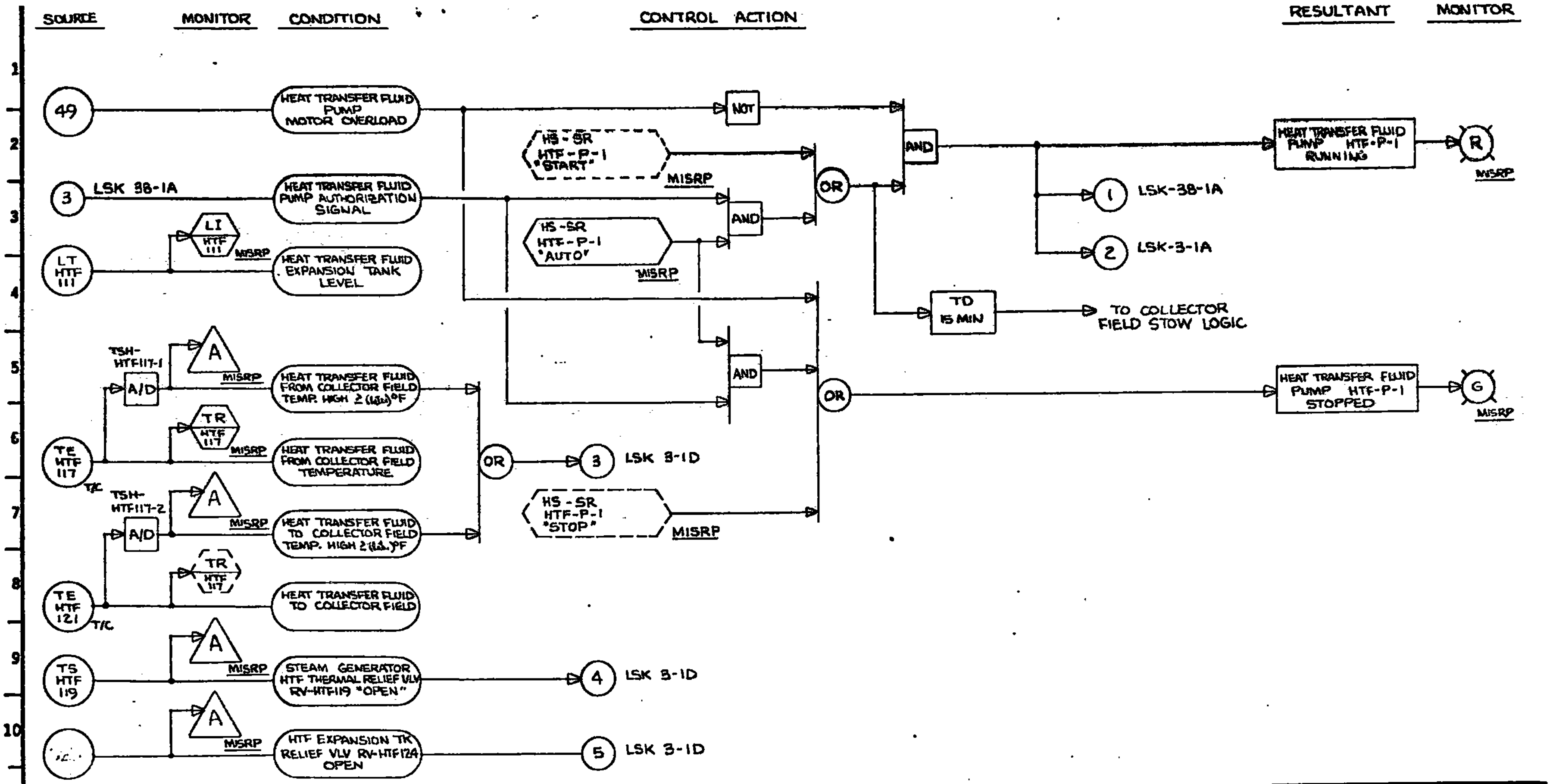
A B C D E F G H J K L M N P Q R S T U V



NOTES

1. "HTF"-HEAT TRANSFER FLUID SYSTEM SYSTEM CODE
2. "MISRP-INDICATES ITEMS MOUNTED ON MODULAR INDUSTRIAL SOLAR RETROFIT PANEL
3. REFERENCED LSK'S PREFIXED WITH "14063.00"

LOGIC DIAGRAM
HEAT TRANSFER SYSTEM
MODULAR INDUSTRIAL SOLAR RETROFIT (MISR)
SOLAR KINETICS INCORPORATED
STONE & WEBSTER ENGINEERING CORPORATION
14063.00-LSK-38-1A



NOTES

1. "HTF" - HEAT TRANSFER FLUID SYSTEM SYSTEM CODE
2. "MISRP" - INDICATES ITEMS MOUNTED ON MODULAR INDUSTRIAL SOLAR RETROFIT PANEL
3. REFERENCED LSK'S PREFIXED WITH "14063.00"
4. DEVICES SHOWN WITH BROKEN-LINES ARE OUT OF FUNCTION

LOGIC DIAGRAM
HEAT TRANSFER FLUID SYSTEM
MODULAR INDUSTRIAL SOLAR RETROFIT (MISR)
SOLAR KINETICS INCORPORATED
STONE & WEBSTER ENGINEERING CORPORATION

3-12-82

14063.00 - LSK-38-1B

STONE & WEBSTER ENGINEERING CORPORATION
LINE DESIGNATION TABLE

J.O. No. - 14063

Client - Sandia National Labs

Project - Modular Industrial
Solar Retrofit
System Development

Date - March 7, 1982

By - BWG

Issue No. - 3

LEGEND

Example = FWS - 150 - 1

System Code	Pipe Size	Line No.

SYSTEM CODES

FWS - Feedwater
MSS - Mainsteam
BDG - Blowdown
CNS - Condensate
HTF - Heat Transfer Fluid

PIPE SIZE CODES

Nominal 1/2 in - 500
Nominal 3/4 in - 750
Nominal 1 in - 001
Nominal 1 1/2 in - 150
Nominal 2 in - 002
Nominal 2 1/2 in - 025
Nominal 3 in - 003
Nominal 4 in - 004
Nominal 6 in - 006

LINE DESIGNATION TABLE (cont)

LINE NO.	FLUID	FROM	TO	PIPE CLASS	PIPE SCHED	OPERATING FLOW GPM	OPERATING PRES PSIG	OPERATING TEMP °F	DESIGN PRES PSIG	DESIGN TEMP °F	TEST PRES PSIG	INSUL SCHED IN.	REF PID DWG
FWS-150-1	WTR	Feedwater	MSS-SG-1	301	80	11	300	200	375	230	550	2	3-1
FWS-150-2	WTR	SOV-FWS-101	Bypass	301	80	11	300	200	375	230	550	2	3-1
BDG-750-1	WTR	MSS-SG1	Blowdown Drain	301	80	-	250	200	300	230	475	2	3-1
BDG-750-2	WTR	SOV-BDG-102	Bypass	301	80	-	250	200	300	230	475	2	3-1
MSS-003-1	STM	MSS-SG1	Mainsteam	301	40	4,600 lb/hr	250	406	300	422	475	3	3-1
MSS-150-2	STM	MSS-SG1	SV-MSS-106	301	80	4,600 lb/hr	250	406	300	422	475	3	3-1
MSS-002-3	STM	SV-MSS-106	Atmosphere	301	80	4,600 lb/hr	250	406	300	422	475	3	3-1
CNS-003-1	WTR	MSS-003-1	CNS-500-2	301	40	-	250	406	300	422	475	2	3-1
CNS-500-2	WTR	CNS-003-1	Condensate Drain	301	80	-	250	406	300	422	475	2	3-1
CNS-500-3	WTR	CNS-TRP1	Bypass	301	80	-	250	406	300	422	475	2	3-1
HTF-004-1	HTF	HTF-P1	HTF-006-2	151	40	280	85	416	110	600	165	3	38-1
HTF-006-2	HTF	HTF-004-1	HTF-004-3	151	40	280	83	416	110	600	165	3½	39-1
HTF-004-3	HTF	HTF-006-2	HTF-003-4	151	40	280	82	416	110	600	165	3	39-1
HTF-003-4	HTF	HTF-004-3	HTF-025-5	151	40	280	81	416	110	600	165	3	39-1

LINE DESIGNATION TABLE (cont)

LINE NO.	FLUID	FROM	TO	PIPE CLASS	PIPE SCHED	OPERATING FLOW GPM	OPERATING PRES PSIG	OPERATING TEMP °F	DESIGN PRES PSIG	DESIGN TEMP °F	TEST PRES PSIG	INSUL SCHED IN.	REF PID DWG
HTF-025-5	HTF	HTF-003-4	Supply Blind Flange	151	40	280	80	416	110	600	165	2½	39-1
HTF-025-6	HTF	Return Blind Flange	HTF-003-7	151	40	280	52	486	75	600	110	2½	39-1
HTF-003-7	HTF	HTF-025-6	HTF-004-8	151	40	280	51	486	75	600	110	3	39-1
HTF-004-8	HTF	HTF-003-7	HTF-006-9	151	40	280	50	486	75	600	110	3	39-1
HTF-006-9	HTF	HTF-004-8	HTF-004-10	151	40	280	49	486	75	600	110	3½	39-1
HTF-004-10	HTF	HTF-006-9	MSS-SG1	151	40	280	47	486	75	600	110	3	38-1
HTF-004-11	HTF	MSS-SG1	HTF-P1	151	40	280	36	416	45	600	75	3	38-1
HTF-004-12	HTF	HTF-004-11	HTF-TK1	151	40	-	34	416	45	600	75	2	38-1
HTF-004-13	HTF	HTF-004-11	HTF-TK1	151	40	-	34	416	45	600	75	2	38-1
HTF-150-14	HTF	HTF-V24	Bypass	151	80	-	34	416	45	600	75	2	38-1
HTF-750-15	HTF	HTF-004-10	HTF-TK1	151	80	-	47	486	75	600	110	-	38-1
HTF-001-16	HTF	HTF-TKI	RV-HTF-124	151	80	-	45	416	75	600	110	-	38-1
HTF-150-17	HTF	RV-HTF-124	HTF Vent Sump	151	80	-	45	416	75	600	110	-	38-1
HTF-002-18	HTF	HTF Fill	HTF-TK1	151	80	-	10	100	15	150	25	-	38-1

STONE & WEBSTER ENGINEERING CORPORATION
EQUIPMENT AND VALVE DESIGNATION TABLE

J.O. No. - 14063

Client - Sandia National Labs

Project - Modular Industrial Solar Retrofit System Development

Date - March 7, 1982

By - BWG

Issue No - 3

LEGEND

Example = MSS - SG1

System Code — Equipment Code

SYSTEM CODES

FWS - Feedwater
MSS - Mainsteam
BDG - Blowdown
CNS - Condensate
HTF - Heat Transfer Fluid

EQUIPMENT CODES

V - Valve
SG - Steam Generator
STR - Strainer
TRP - Trap
TK - Tank
STRT - Temporary Strainer
P - Pump

EQUIPMENT AND VALVE DESIGNATION TABLE

IDENTIFICATION NUMBER	DESCRIPTION	REFERENCE DIAGRAM	REFERENCE DRAWING
FWS - V1	Upstream Isolation Valve for SOV-FWS-101	PID-3-1	
FWS - V2	Upstream Test Connection Root Valve for SOV-FWS-101	PID-3-1	
FWS - V3	Upstream Drain Valve for SOV-FWS-101	PID-3-1	
FWS - V4	Downstream Drain Valve for SOV-FWS-101	PID-3-1	
FWS - V5	Downstream Test Connection Root Valve for SOV-FWS-101	PID-3-1	
FWS - V6	Downstream Isolation Valve for SOV-FWS-101	PID-3-1	
FWS - V7	Bypass Valve for SOV-FWS-101	PID-3-1	
FWS - V8	Bypass Valve for SOV-DBG-102	PID-3-1	
FWS - V9	Root Valve for PT-MSS-104	PID-3-1	
FWS - V10	Feedwater Check Valve for MSS-SG1	PID-3-1	
FWS - V11	Feedwater Isolation Valve for MSS-SG1	PID-3-1	
MSS - SG1	Steam Generator	PID-3-1 PID-38-1	
BDG - V13	Blowdown Isolation Valve for MSS-SG1	PID-3-1	
BDG - V14	Upstream Isolation Valve for SOV-BDG-102	PID-3-1	
BDG - V15	Upstream Drain Valve for SOV-BDG-102	PID-3-1	

69

EQUIPMENT AND VALVE DESIGNATION TABLE

IDENTIFICATION NUMBER	DESCRIPTION	REFERENCE DIAGRAM	REFERENCE DRAWING
BDG - V16	Downstream Drain Valve for SOV-BDG-102	PID-3-1	
BDG - V17	Downstream Isolation Valve for SOV-BDG-102	PID-3-1	
FWS - V18	Lower Isolation Valve for MSS-SG1 Standpipe	PID-3-1	
FWS - V19	Standpipe Drain Valve for MSS-SG1	PID-3-1	
FWS - V20	Lower Root Valve for LG-FWS-100	PID-3-1	
FWS - V21	Lower Root Valve for LT-FWS-101	PID-3-1	
FWS - V22	Upper Root Valve for LG-FWS-100	PID-3-1	
FWS - V23	Upper Root Valve for LT-FWS-101	PID-3-1	
FWS - V24	Standpipe Vent Valve for MSS-SG1	PID-3-1	
FWS - V25	Upper Isolation Valve for MSS-SG1 Standpipe	PID-3-1	
MSS - V27	Root Valve for PIS-MSS-105	PID-3-1	
MSS - V28	Downstream Isolation Valve for PCV-MSS-107	PID-3-1	
MSS - V29	Mainsteam Free-Blow Drain Valve	PID-3-1	
MSS - V30	Second Mainsteam Isolation Valve for MSS-SG1	PID-3-1	
MSS - V31	Upstream Root Valve for FT-MSS-108	PID-3-1	
MSS - V32	Downstream Root Valve for FT-MSS-108	PID-3-1	
MSS - V33	Mainsteam Admission Stop Check Valve	PID-3-1	

EQUIPMENT AND VALVE DESIGNATION TABLE

IDENTIFICATION NUMBER	DESCRIPTION	REFERENCE DIAGRAM	REFERENCE DRAWING
CNS - V34	Upsteam Isolation Valve for CNS-STR1 and CNS-TRP1	PID-3-1	
CNS - V35	Drain Valve for CNS-STR1	PID-3-1	
CNS - STR1	Condensate Strainer	PID-3-1	
CNS - TRP1	Condensate Steam Trap	PID-3-1	
CNS - V36	Downstream Isolation Valve for CNS-STR1 and CNS-TRP1	PID-3-1	
CNS - V37	Bypass Valve for CNS-STR1 and CNS-TRP1	PID-3-1	
FWS-V39	Upper Root Valve for LS-FWS-123	PID-3-1	
FWS-V40	Lower Root Valve for LS-FWS-123	PID-3-1	
FWS-V41	Upper Root Valve for LS-FWS-122	PID-3-1	
FWS-V42	Lower Root Valve for LS-FWS-122	PID-3-1	
MSS-V43	Upstream Isolation Valve for PCV-MSS-107	PID-3-1	
HTF - V1	Upstream Channel Isolation Valve for MSS-SG1	PID-38-1	
HTF - V2	Channel Vent Valve for MSS-SG1	PID-38-1	
HTF - V3	Channel Drain Valve for MSS-SG1	PID-38-1	

EQUIPMENT AND VALVE DESIGNATION TABLE

IDENTIFICATION NUMBER	DESCRIPTION	REFERENCE DIAGRAM	REFERENCE DRAWING
HTF - V4	Downstream Channel Isolation Valve for MSS-SG1	PID-38-1	
HTF - V6	First Suction Leg Isolation Valve for HTF-TK1	PID-38-1	
HTF - TK1	Heat Transfer Fluid Expansion Tank	PID-38-1	
HTF - V7	Lower Isolation Valve for HTF-TK1 Standpipe	PID-38-1	
HTF - V8	Standpipe Drain Valve for HTF-TK1	PID-38-1	
HTF - V9	Lower Root Valve for LG-HTF-110	PID-38-1	
HTF - V10	Lower Root Valve for LT-HTF-111	PID-38-1	
HTF - V11	Upper Root Valve for LG-HTF-110	PID-38-1	
HTF - V12	Upper Root Valve for LT-HTF-111	PID-38-1	
HTF - V13	Standpipe Vent Valve for HTF-TK1	PID-38-1	
HTF - V14	Upper Isolation Valve for HTF-TK1 Standpipe	PID-38-1	
HTF - V15	Vent Valve for HTF-TK1	PID-38-1	
HTF - V19	Drain Valve for HTF-TK1	PID-38-1	
HTF - STR1	Heat Transfer Fluid Fill Line Strainer	PID-38-1	
HTF - V20	Drain Valve for HTF-STR1	PID-38-1	
HTF - V22	Heat Transfer Fluid Fill Line Shutoff Valve	PID-38-1	
HTF - V23	Upstream Isolation Valve for HTF-P1	PID-38-1	

EQUIPMENT AND VALVE DESIGNATION TABLE

IDENTIFICATION NUMBER	DESCRIPTION	REFERENCE DIAGRAM	REFERENCE DRAWING
HTF - V24	Second Suction Leg Isolation Valve for HTF-TK1	PID-38-1	
HTF - V25	Suction Leg Thermal Siphon Bypass Valve	PID-38-1	
HTF - STRT2	Suction Line Temporary Strainer for HTF-P1	PID-38-1	
HTF - V26	Drain Valve for HTF-STRT2	PID-38-1	
HTF - V27	Root Valve for DPIS-HTF-114	PID-38-1	
HTF - P1	Heat Transfer Fluid Circulation Pump	PID-38-1	
HTF - V28	Drain Valve for HTF-P1	PID-38-1	
HTF - V29	Root Valve for PIS-HTF-115	PID-38-1	
HTF - V31	Downstream Isolation Valve for HTF-P1	PID-38-1	
HTF-V32	Upper Root Valve for LS-HTF-112	PID-38-1	
HTF-V33	Lower Root Valve for LS-HTF-112	PID-38-1	
HTF-V34	Upper Root Valve for LS-HTF-113	PID-38-1	
HTF-V35	Lower Root Valve for LS-HTF-113	PID-38-1	
HTF-V40 thru HTF-V-67 inclusive	Collector Row Isolation Valves (28)	PID-39-1	

STONE & WEBSTER ENGINEERING CORPORATION

INSTRUMENT DESIGNATION TABLE

J.O.No. 14063

Client - Saudia National Labs

Project - Modular Industrial Solar
Retrofit System Development

Date - March 7, 1982

By - RBM

Issue - 2

LEGEND

Example: LG - FWS - 100

INSTRUMENT CODES

C - Conductivity
F - Flow
L - Level
P - Pressure
T - Temperature
U - Multifunction

E - Element
G - Gauge
HS - Hand Switch
I - Indicator
IS - Indicator with Switch
KS - Sequence Timer
QI - Flow Integrator
R - Recorder
S - Switch
T - Transmitter
X - Power Supply
Y - Functional Translator

SYSTEM CODES

FWS - Feedwater
MSS - Mainstream
BDG - Blowdown
HTF - Heat Transfer Fluid

VALVES

PCV - Pressure Regulating Valve
RV - Thermal Relief Valves
SV - Safety Valve
SOV - Solenoid Operated Valve

INSTRUMENT DESIGNATION TABLE

Identification Number	Description	Reference P&ID	Reference Logic Dia.	Data Sheet
LG-FWS-100	Level Gauge for MSS-SG1	PID-3-1	-	
HS-FWS-101	Hand Switch for SOV-BDG-101	PID-3-1		
LI-FWS-101	Level Indicator for MSS-SG1	PID-3-1		
LT-FWS-101	Level Transmitter for MSS-SG1	PID-3-1	LSK-3-1A	
LSH-FWS-101-1&2	High Level Switches for MSS-SG1	PID-3-1	LSK-3-1A	
LSL-FWS-101-1&2	Low Level Switches for MSS-SG1	PID-3-1	LSK-3-1A	
LX-FWS-101	Power Supply for LT-FWS-101	PID-3-1		
SOV-FWS-101	Feedwater Solenoid Valve	PID-3-1		
HS-BDG-102	Hand Switch for SOV-BDG-102	PID-3-1	LSK-3-1B	
SOV-BDG-102	Solenoid Valve for Blowdown	PID-3-1		
PX-MSS-104	Power Supply for PT-MSS-104	PID-3-1	-	
PT-MSS-104	Pressure Transmitter for MSS-SG1(To UR-MSS-108)	PID-3-1	LSK-3-1C	
PIS-MSS-105	Pressure Indicat. Switch for MSS-SG1	PID-3-1	LSK-3-1C	
SV-MSS-106	Safety Valve for MSS-SG1	PID-3-1	-	
TS-MSS-106	Temperature Switch for SV-MSS-106	PID-3-1	LSK-3-1C	

INSTRUMENT DESIGNATION TABLE

Identification Number	Description	Reference P&ID	Reference Logic Dia.	Data Sheet
PCV-MSS-107	Pressure Control Valve for Steam Blanket of MSS-SG1	PID-3-1	-	
FE-MSS-108	Steam Flow Orifice	PID-3-1	-	
FT-MSS-108	Transmitter for FE-MSS-108	PID-3-1	LSK-3-1C	
FX-MSS-108	Power Supply for FT-MSS-108	PID-3-1	-	
FY-MSS-108	Square Root Extractor	PID-3-1	LSK-3-1C	
FQI-MSS-108	Steam Flow Integrator (To UR-MSS-108)	PID-3-1	LSK-3-1C	
UR-MSS-108	Pen Multifunction Recorder			
TE-FWS-109	Temperature Element for Feedwater Temperature (To TR-HTF-117)	PID-3-1	LSK-3-1A	
LG-HTF-110	Level Gauge for HTF-TK1	PID-38-1	-	
LT-HTF-111	Level Transmitter for HTF-TK1	PID-38-1	LSK-38-1B	
LI-HTF-111	Level Indicator for HTF-TK1	PID-38-1	LSK-38-1B	
LX-HTF-111	Power Supply for LT-HTF-111	PID-38-1	-	
LS-HTF-112	High Level Switch for HTF-TK1	PID-38-1	LSK-38-2A	
LS-HTF-113	Low Level Switch for HTF-TK1	PID-38-1	LSK-38-1A	

INSTRUMENT DESIGNATION TABLE

Identification Number	Description	Reference P&ID	Reference Logic Dia.	Data Sheet
DPIS-HTF-114	Differential Pressure Indicat. Switch for HTF-P1	PID-38-1	-	
PIS-HTF-115	Pressure Indicat. Switch for HTF-P1 Discharge	PID-38-1	LSK-38-1A	
TE-HTF-117	Temperature Element for HTF-P1 Discharge (To TR-HTF-117)	PID-38-1	LSK-38-1B	
TR-HTF-117	3 Pen Temperature Recorder	PID-3-1 PID-38-1	LSK-3-1A LSK-38-1B	
TSH-HTF-117-1	Pen No. 1 Position Switch - High HTF Inlet Temp to MSS-SG1 (Alarm)	PID-38-1	LSK-38-1B	
TSH-HTF-117-2	Pen No. 2 Position Switch - High HTF Outlet Temp from HTF-P1 (Alarm)	PID-38-1	LSK-38-1B	
TIS-HTF-118	Temp. Indicat. Switch for HTF-P1 Discharge	PID-38-1	LSK-38-1A	
RV-HTF-119	Thermal Relief Valve for MSS-SG1 Channel	PID-38-1	-	
TS-HTF-119	Temperature Switch for RV-HTF-119	PID-38-1	LSK-38-1B	
TIS-HTF-120	Temperature Indicat. Switch for HTF Inlet to MSS-SG1	PID-38-1	LSK-38-1A	
TE-HTF-121	Temperature Element for HTF Inlet to MSS-SG1 (To TR-HTF-117)	PID-38-1		
LS-FWS-122	Low Level Switch for MSS SG1	PID-3-1		
LS-FWS-123	Low Level Switch for MSS SG1	PID-3-1		
RV-HTF-124	Thermal Relief Valve for HTF-TK1	PID-38-1		

ADDENDUM TO MODULAR INDUSTRIAL SOLAR RETROFIT SYSTEM SAFETY ANALYSIS

Feedwater and Mainsteam Subsystems

The event-response actions discussed here are shown in detail on logic diagrams LSK-3-1A (feedwater sub-system), LSK-3-1B (blowdown sub-system), LSK-3-1C (mainsteam sub-system), and LSK-3-1D (MISR trouble alarm).

High pressure in the steam generator is independently monitored by PIS-MSS-105 and PT-MSS-104. Both will be set to take response action if pressure exceeds the design pressure rating of 300 psig. PIS-MSS-105 will activate the MISR trip circuit, resulting in shutdown of the heat transfer fluid pump (HTF-P1), closure of the feedwater solenoid valve (SOV-FWS-101) and stowage of the solar collectors. PT-MSS-104 will independently activate a panel-mounted annunciator. Any pressure excursion above 300 psig will activate opening of safety relief valve SV-MSS-106 which will vent the excess pressure to the atmosphere.

Activation of the safety relief valve will also energize a separate alarm on the control panel. Any vented steam will be directed to a safe area away from personnel access.

Excessive flow of feedwater will cause level switch LS-FWS-123 to alarm a condition of high level in the steam generator. Additionally, this will activate the trip circuit to shutdown the MISR system as discussed above. (The risk of excessive flow is a flooding of the steam system). Note that feedwater solenoid valve SOV-FWS-101 will fail closed, preventing such flooding in the event of loss of power.

Inadequate feedwater flow would risk a drop in steam generator water level to the point at which the tube bundle would be exposed. At this point tube temperatures would rise dramatically risking possible tube rupture. Level switch LS-FWS-122 will alarm a condition of low water level (2 inches above the top of the tube bundle) under such circumstances. In addition, this switch is interlocked to the MISR trip circuit.

Heat Transfer Fluid Subsystem

The event-response actions for the HTF subsystem are shown in detail on logic diagrams LSK-38-1A and LSK-38-1B (heat transfer fluid subsystem).

During normal operational temperatures experienced by the MISR system, the expansion tank (HTF-TK1) will pressurize to 30 psig due to HTF thermal expansion. Pressures higher than this could be caused by thermal fluid

fluid temperature excursions, a rupture of the tubes in the steam generator, or inadvertant over-charge of fluid on initial system fill. Any internal pressure in the expansion tank exceeding the 45 psig design pressure will open relief valve RV-HTF-124. The valve is sized to handle a worst case flow of 15 gpm (an assumed tube bundle break with full feedwater flow). Gas and fluid will be safely passed to a vent sump. The expansion tank is also designed to accept full vacuum internal pressure.

The potential for excessive pressure exists in the steam generator tube bundle, channel and bonnet-area piping within the isolation valves HTF-V1 and HTF-V2. This could occur if the isolation valves are closed during periods of high (400°F) shellside water temperature and corresponding low (<400°F) HTF temperature. Thermal expansion pressures will be relieved under such circumstances by relief valve RV-HTF-119. Fluid will be returned to the expansion tank, and opening of the valve alarmed at the control panel.

Temperature from the collector field will be monitored independently by TE-HTF-121 and TIS-HTF-120. The former (thermocouple) will activate a panel alarm at temperatures above 550°F. The latter (temperature indicator and switch) will activate the MISR trip circuit. Similiar capability is provided on the collector field return flow from the HTF pump discharge via TE-HTF-117 and TIS-HTF-118. Elevated temperature excursions could arise from low flow conditions or failure of the steam generator to exchange heat (due to a closure or blockage in the main steam line). Low flow will also be monitored and alarmed by DPIS-HTF-114 and PIS-HTF-115.

Fire Protection

The entire steam generation skid will be enclosed in a building to facilitate a CO_2 fire extinguishing subsystem. Smoke detectors of the ionization type will active control panel alarms, but will not activate the CO_2 flooding valves. Rate-compensated thermal detectors are provided to sense enclosure temperatures of 280°F or greater. (Normal enclosure temperature should not exceed 104°F due to the ventilation system). Above 280°F, the thermal detectors will signal for a CO_2 letdown, preceeded by a 30-second delay with local alarms to allow personnel evacuation. CO_2 concentration will reach and hold at 46 percent for 10 minutes. Fire damper ventilation louvers will automatically shut upon CO_2 letdown.

Electrical

The entire electrical power supply to the MISR can be deactivated with a "kill" switch. In addition, over-ride of the standby generator is provided. Local disconnect switches for the collector drive motors are provided in order to facilitate safe maintenance. Ground fault protection is provided at all field receptacles.

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