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Modular Industrial Solar Retrofit System Constrains Specifications, and Guidelines

Karl Wally, Editor

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MODULAR INDUSTRIAL SOLAR RETROFIT SYSTEM

CONSTRAINTS, SPECIFICATIONS AND GUIDELINES

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ABSTRACT

Provisions governing the design and construction of Modular Industrial Solar Retrofit (MISR) systems have been developed in order to insure improved potential for wide applicability, reliable operation, and reduced installed costs. These provisions are based on experience with previous solar thermal energy systems, and incorporate proven engineering practices from the power and process industries. This report serves to document this material, which was originally developed for inclusion in the MISR System Development Request for Proposal released by Sandia on April 24, 1981.

PREFACE

This document presents, under separate cover, the MISR System Constraints, Specifications, and Guidelines which were developed for inclusion in the MISR System Development Request for Proposal, Document Number 61-3399, released April 24, 1981. The intent of this separate issue is to make this material generally available to the solar community.

This compilation is the editor's synthesis of contributions from many personnel, whose contributions to the content or review of the substance of this document are gratefully acknowledged. Special citation is due to the engineering staff of Stearns-Roger Services, Inc. and to the solar projects staff at Sandia National Laboratories, Albuquerque:

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1. INTRODUCTION

The Modular Industrial Solar Retrofit (MISR) project is being conducted for the purpose of bringing line-focus solar thermal systems to the point of technical readiness. How this is to be accomplished can be found in the project name. "Modular" indicates that the project approach is to develop modular system designs which can be widely applicable with minimum or no modifications. System economics should be improved by elimination of one-of-a-kind costs. Simultaneously, improved reliability should be achieved through standardized components and installation. The "Industrial" process heat market is large and diverse and has been selected as the target application for MISR. The "Solar" systems will be limited to the use of line-focus collectors, as it is believed that they are nearest to being considered developed. MISR systems are intended for "Retrofit" installation in existing industrial process steam applications requiring saturated steam at pressures up to 250 psig.

To be saleable to prospective industrial customers, a modular solar system package should be comprehensive in that it must include all of the solar collector equipment, heat transfer fluid circulation piping and equipment, electrical power distribution cabling and equipment, control and instrumentation cabling and equipment, steam generation subsystem, and so on. Only site preparation, system assembly, and utility and process connections should be necessary to make the systems operational. It is anticipated that modular system designs illustrative of these concepts will be implemented in a series of MISR field experiments at a variety of industrial sites, as outlined in the MISR multiyear project plan.

These Constraints, Specifications, and Guidelines are intended to aid the development of such modular system designs by incorporating the lessons learned from previous solar thermal system experiments and demonstrations, while simultaneously adapting appropriate engineering practices from the process and power industries. Systems that are designed around these principles should have an improved potential for reliable operation, low installed cost, and good performance. However, these Constraints, Specifications, and Guidelines are not presumed to be an authoritative design code for solar thermal industrial process steam systems. Neither the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of these specifications and guidelines. Rather, they are intended solely to aid in the design of systems to be implemented in the MISR project. Project results will indicate whether similar criteria may prove of value for other solar applications.

The Constraints, Specifications, and Guidelines are written assuming a scenario for relationships between major participants that closely parallels the relationship that might be typical for packaged boiler installations. That is, it is assumed that MISR systems would be made available by a system supplier who would be responsible for the design, fabrication, and delivery of a system that can be installed at a prepared site following prescribed procedures. Specifications for the site preparation and installation procedures are the responsibility of the system supplier. A second participant, the site owner, is assumed to be responsible for having the installation site prepared to the system supplier's specification. For the purposes of the MISR project and these Constraints, Specifications, and Guidelines, it has been assumed that the system supplier will also be responsible for complete installation of the system at the site. This last element of the scenario may differ somewhat from the procedures typically followed for packaged boiler installation, where most often the same contractor that prepared the site for the site owner will also install the packaged boiler. This difference in approach is believed necessary because there are many aspects of the installation of solar energy systems, such as receiver assembly or alignment, where special handling or care may be required. At least until solar energy systems become more commonplace, it is unlikely that the typical contractor will have sufficient experience to confidently handle these aspects of installation. Until then, a more prudent approach is for the system supplier to handle the installation so that experienced personnel can perform these tasks.

2. VARIANCES

2.1 CONSTRAINTS

The Constraints presented herein consist of programmatic, physical, or institutional conditions which must be accommodated by MISR systems. Variances from the Constraints shall not be allowed without specific prior approval from SNLA. Any variance from the Constraints will constitute a serious compromise.

2.2 SPECIFICATIONS

The Specifications presented herein consist of design concepts, features, and procedures, that, in the judgement of SNLA, are required for achieving a successful MISR system design. Variances from the Design Specifications may be proposed as an option provided they are (1) explicitly identified, and (2) sufficiently justified on technical or cost grounds. Implementation of the proposed option shall remain subject to approval by SNLA.

2.3 GUIDELINES

The Guidelines presented herein consist of design concepts, features, and procedures, that, in the judgement of SNLA, may be recommended for consideration in MISR system designs. Since they are advisory only, no approval from SNLA is necessary for variance from the Guidelines.

3. DEFINITIONS, ABBREVIATIONS, AND NOMENCLATURE

3.1 DEFINITIONS

It is assumed that the reader will be generally familiar with the various technical terms relating to the more conventional technologies encountered herein (e.g. steam generation terminology, electrical engineering terminology, etc.). Therefore, only certain solar-related terminology may be unfamiliar to the reader and is included here. Further, several terms used throughout these Constraints, Specifications and Guidelines to convey a carefully intended meaning are also defined below.

Aperture-Tracking--Refers to solar collector equipment in which the collector structure is incrementally positioned to follow the sun's movement in at least one axis, so as to present the largest projected aperture to the sun.

Delta-T Loop--A series-connected fluid flow path through which collector field heat transfer fluid undergoes a rise in temperature as solar energy is added to the fluid. A collector field is made up of many identical delta-T loops all connected in a parallel flow arrangement.

Direct Normal Insolation--Specular radiation as measured at a plane directly normal to the directional ray pointing towards the sun.

Drive Group--An assemblage of solar collector modules sharing a common drive system and drive system controller. Generally, the collector modules are arranged co-linearly, are rigidly coupled to each other, and focus along a linear receiver assembly. At the ends of a drive group, the receiver assembly is often terminated using flexible-hose connectors.

Flex-Hose Assembly--A flexible fluid conduit capable of withstanding fluids at high temperatures and/or pressures while subject to flexure or bending.

Line-Focus--Refers to a solar collector concept in which the reflector or refractor structure focuses incident sunlight onto a linear receiver structure.

Receiver Assembly--An assembly for conducting the collector field heat transfer fluid through the region of concentrated sunlight created by the collector optics. Generally, a receiver assembly consists of a rigid tube fluid conduit coated with a selectively absorbing material, a transparent envelope for reducing thermal losses which is mounted to the fluid conduit by means of a low heat conductance structure, an environmental seal to keep the space between envelope and receiver free from dust, and mechanical joints for interconnecting lengths of receiver assemblies to make up the fluid circuit.

Site Owner--The owner of the industrial plant to which the MISR system will be retrofit. He makes available a plot of land for locating the MISR system and prepares the site to the system supplier's specifications.

System Supplier--The commercial supplier of the MISR system. He is responsible for the design, fabrication, and installation of the system on the site.

3.2 ABBREVIATIONS

ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
IEEE	Institute of Electrical and Electronic Engineers
MISR	Modular Industrial Solar Retrofit
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
OSHA	Occupational Safety and Health Administration
SNLA	Sandia National Laboratories, Albuquerque
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers

3.3 NOMENCLATURE

Combinations of letters or numbers with abbreviations such as those given in 3.2 can be interpreted in the manner of the following example:

- 40-CFR-112 means Code of Federal Regulations, Title 40, Part 112.

4. DESIGN CONSTRAINTS

This section defines a programmatic, physical and regulatory reference environment for which MISR systems shall be designed. These are intended to encompass a large segment of process steam applications, so that system designs developed to them will be widely applicable with little or no modification.

4.1 PROGRAMMATIC CONDITIONS

Programmatic conditions are derived from consideration of the project goals and objectives as stated in the MISR Multiyear Project Plan.

4.1.1 Eligible Solar Technologies

Solar technologies eligible to participate shall be limited to line-focus, single axis aperture-tracking collectors.

4.1.2 Modularity

System designs must be modular. This means that the MISR systems should be engineered to be as site-independent as possible; that they should take maximum advantage of prefabrication of components and subsystems; that support systems such as fire protection systems, or emergency power systems should be largely self-contained. Design requirements reflecting modularity are incorporated into the Specifications.

4.1.3 Retrofit

System designs must be suitable for retrofit to a wide variety of existing process heat applications. This means that MISR systems need to be largely self-contained; that their plant and process interface requirements be few, simple, and commonly acceptable to existing installations; that they be relatively tolerant to variations in siting. Design requirements reflecting retrofit considerations are incorporated into the Specifications.

4.2 ENVIRONMENTAL CONDITIONS

The environmental conditions are derived from consideration of the MISR project goals and objectives which seek to develop a system applicable generally throughout the United States. However, for reasons of practicality, environmental conditions based on unusual geographic regions such as mountainous areas subject to severe snowstorms, regions subject to severe earthquakes, or coastal areas subject to occasional risk of hurricane have been avoided. As a consequence, the listed conditions represent bounding conditions believed to be generally applicable to the continental United States, exclusive of any of the special regions mentioned above.

4.2.1 Survival Environment

Systems shall be designed to survive the following extremes of environment, and to resume normal operational capability after exposure to such extremes without the need for repairs, maintenance, or adjustment. The system may be designed to survive these extremes with the collectors oriented in some protected or stowed position.

- Extreme wind speed - 80 mph,
- Temperature extremes - +130°F to -20°F,
- Hail - 0.75 inch at 55 fps,
- Snow or ice accumulation - 20 psf,
- Blowing dust or sand - blowing particles, 150 microns or less in size,
- Rain - 0.025 inch/minute extreme rate, with a duration of only several minutes (0.75 inch/hour average rate per 24-hour),
- Earthquakes - Risk Zones 1 and 2 from ANSI A58.1-1972,
- Lightning - strikes as close as 1/4 mile to installed collector field, and
- Fauna - common rodents, birds, insects, etc.

4.2.2 Operational Environment

Systems shall be designed to operate continuously when conditions are within the following limits of operation:

- Wind speed - up to 25 mph,
- Temperatures - 0°F to +120°F,
- Humidity coincident with upper temperature extreme-humidity ratio of 0.018 $\frac{\text{lbs H O}}{\text{lbs dry air}}$, and
- Insolation - extreme intensity of 1100 W/m^2.

4.2.3 Assembly and Construction Environment

The environment encountered during assembly and construction of a system can influence the selection of techniques such as inert gas welding, application of adhesives, etc. To facilitate system design, the site assembly and construction environment shall be assumed to be the same as the operational environment.

4.3 PLANT CONDITIONS

This section consists of a set of reference or nominal conditions describing the process steam application for which the MISR system shall be designed. These conditions consist of the physical site, utility connections, and process connections available to the MISR systems.

4.3.1 Utility Connections

- Electric power supply shall be supplied by the site owner, and shall be rated either 120/208V, or 277/480V, 3 phase, 4 wire, 60 Hz, with a solidly grounded neutral. The system supplier, in his site preparation specification package, shall select one of these voltages as the primary voltage to interface with his system.
- Service water shall be available at nominally 40 psig, and a maximum flow rate of 6 gpm for collector washing, etc. Water quality shall be as required by the system supplier's site preparation specification, with treatment supplied by the site owner, and

- Instrument air will not be available from the site.

4.3.2 Site

- Sites shall be assumed to have no solar obstructions for solar elevation angles above 10 degrees from the horizon, as viewed by the collectors,
- Sites shall be assumed to be accessible by conventional, over-the-road vehicles,
- Sites shall be assumed to be of a size and shape required to accommodate a system per the system supplier's site preparation specification; however, orientation of the site may be arbitrary, and
- For system installation, it shall be assumed that the site has been prepared to comply with the site preparation specifications developed by the MISR system supplier.

4.3.3 Process Connections

It is assumed that the site has an existing steam generation capability with which the MISR system will be expected to interface. This means that the MISR system must be capable of accepting whatever quality feedwater is normally supplied by the site to its existing boilers, and that blowdown must be disposed of in a manner acceptable to the site. The following conditions shall be assumed in designing the MISR system steam generation subsystem:

- Feedwater --
  - Flowrate--Flowrate shall be provided by the site as per the requirements of the MISR system designer, as specified in his Site Preparation Specification Package.
  - Pressure--Feedwater shall be available to the MISR system at sufficient pressure to fill the steam generator to the required operating level while operating at the steam conditions described below. This pressurization shall be the responsibility of the site owner.

- Temperature--Feedwater may be available to the MISR system at any temperature from 40°F to 230°F, depending on the site. The MISR system shall be designed to accommodate any feedwater temperature within this range without modification to the MISR system, except for adjustments to be made to adjustable control elements.
- Quality--Feedwater quality shall be the responsibility of the site owner and shall be within limits as required by the MISR System Supplier in the Site Preparation Specification Package. The MISR System designer should try to accommodate as wide a range of potential feedwater qualities as practical. Table 1 is a tabulation of the quality characteristics of raw surface waters that have been used for steam generation in the U.S. The listed values are maximums likely to be encountered, but no one water will exhibit all the maximums shown.
- Physical Interface--A feedwater connection of the size, type, and location required by the MISR System Supplier in his Site Preparation Specification Package shall be provided by the site owner.

• Steam--A 300 lb. flange connection to be sized and located per the MISR system supplier's specification shall be provided by the site owner from an existing steam line. Continuous steam back-pressure shall be limited to the pressure capability specified by the system supplier, from 100 psig up to 250 psig. Steam pressure will normally be available on a continuous basis for steam-blanketing.

• Blowdown--A 300 lb. flange connection to be sized and located per the MISR system supplier's specification shall be provided by the site owner for connection to an existing blowdown line leading to an existing blowdown tank or pit furnished by the site owner.

Table 1

Water Characteristics*

Silica (SiO_2)	150
Aluminum (Al)	3
Iron (Fe)	80
Manganese (Mn)	10
Copper (Cu)	**
Zinc (Zn)	**
Calcium (Ca)	**
Magnesium (Mg)	**
Ammonia (NH_3)	**
Bicarbonate (HCO_3)	600
Sulfate (SO_4)	1,400
Chloride (Cl)	19,000
Nitrate (NO_3)	**
Phosphate (PO_4)	**
Dissolved solids	35,000
Hardness ($CaCO_3$)	5,000
Acidity ($CaCO_3$)	1,000
Alkalinity ($CaCO_3$)	500
pH, units	**
Color, units	1,200
Organics	
Methylene blue active substances	1
Carbon tetrachloride extract	100
Chemical oxygen demand (O_2)	100
Odor	**
Hydrogen sulfide (H_2S)	**
Dissolved oxygen (O_2)	**
Temperature, °F	120
Suspended solids	15,000

*Steam pressure: 0-700 psig. Unless otherwise indicated, units are mg/l and values are maximums.

**Accepted as received (if meeting total solids or other limiting values); has never been a problem at concentrations encountered.

Source: "Water Quality Criteria", U.S. Department of the Interior, Fed. Water Pollut. Control Adm., April 1968.

4.4 REGULATORY CONDITIONS

As a minimum, the MISR system design shall be in compliance with the following laws, ordinances, and regulations:

4.4.1 EPA

- 40-CFR-112-et. seq. - "Oil Pollution Prevention"

4.4.2 OSHA

- 29-CFR-1910.144 - "Accident Prevention Signs and Tags,"
- 29-CFR-1910.212 - "Rotating Equipment Guards,"
- 29-CFR-1910.101 - "Compressed Gases (General Requirements),"
- 29-CFR-1910.167 - "Safety Relief Devices for Compressed Gas Cylinders,"
- 29-CFR-1910.106 - "Flammable and Combustible Liquids,"
- 29-CFR-1910.110 - "Storage and Handling of Liquified Petroleum Gases," and
- 29-CFR-1910.1000 - "Air Contaminants."

5. DESIGN REQUIREMENTS

5.1 COMPREHENSIVE DESIGN

As a minimum, a MISR system design shall include all material to be furnished and installed by the system supplier:

- All mechanical, electrical, instrumentation and control, and structural equipment required to convert solar energy to process steam. This equipment shall be exclusive of any items furnished at the site by the owner as required in the Site Preparation Specification Package (e.g., foundations, transformers, etc.).

- Complete drawings of the system design, including as a minimum the following information:

  - System General Arrangement
  - System Flow Diagram
  - Skid Assembly
  - Steam Generator Assembly
  - Steam Generator Instrument Details
  - Feedwater Heater Assembly (if applicable)
  - Heat Transfer Fluid Circulating Pump and Motor
  - Heat Transfer Fluid Circulating Pump Motor Data
  - Fire Protection System Assembly (if applicable)
  - Fire Protection System Details (if applicable)
  - Fire Protection System Controls (if applicable)
  - Fire Protection System Electrical (if applicable)
  - Skid Structural Assembly
  - Pipe Rack Assembly
  - Pipe Rack Details
  - Collector Assembly
  - Collector Details

- Collector Drive Assembly
- Collector Drive Motor Data
- Collector Control
- Collector Electrical
- Piping Assembly
- Piping Details
- Piping Supports
- Electrical One Line (Equipment Interconnect Schematic)
- Electrical Raceway
- Instrumentation and Control Details
- Control Logic Diagrams
- Safety Relief Valves
- Nitrogen System (if applicable)
- Control Valves (if applicable)
- Control Valve Data (if applicable)
- Motor List
- Instrument List
- Circuit Schedule
- Pipe Line Schedule
- Heat Tracing List
- Valve List
- Strainer List.

5.2 CONCEPTUAL DESIGN REQUIREMENTS

The items listed in this section shall be included in the design of all MISR systems.

5.2.1 General

MISR system designs are primarily intended for retrofit to process steam applications requiring saturated steam at pressures up to 250 psig. In general, the systems are intended to be capable of deployment almost anywhere within the United States. It is intended that the initial installations of MISR systems will be in applications where the rated steam production of the solar energy system is small compared to the overall site steam production and consumption. Consequently, interfacing requirements are minimized, and the process application is capable of absorbing any and all steam production of which the MISR system is capable. Applications seeking to displace larger percentages of their process loads with solar energy, or those located where more stringent constraints on process steam production are encountered, may require modification of the basic MISR system as specified herein. However, these more complex applications represent a natural evolutionary development, and can be expected to benefit from the successful demonstration of the simpler MISR systems specified herein.

As a consequence of the programmatic considerations briefly discussed above, the following design requirements shall be incorporated in the MISR system designs:

- Ground-Mounted--Since retrofit installation will often find roof-mounting impractical, the MISR systems shall be designed for mounting atop foundations embedded in the ground at sites adjacent to existing process plants. No considerations for roof-mounting shall be required.
- Arbitrary Siting--Since retrofit installation may require compromise siting, the MISR system shall be designed to function properly despite arbitrary siting of the axis of the solar collector field with respect to compass direction. However, one-time modifications to the collector control system(s) at the time of installation shall be acceptable.
- Above Ground Piping and Electrical Raceways--In order to make installation compatible with retrofit applications and to enhance both the reliability of operation and convenience of maintenance, the MISR system shall be designed with all piping and electrical raceways run above ground (i.e., not buried).
- Vehicular Access--The physical layout of the MISR system collector field shall provide access throughout the field for any vehicles required for installation, maintenance, replacement, or collector cleaning. As a minimum, permanent access shall be provided to all components or subsystems requiring

the use of vehicles or special equipment (e.g., crane or forklift) for their installation, replacement or maintenance.

- Personnel Access--The physical layout of the MISR system collector field and piping system shall provide convenient access for personnel to all components or subsystems requiring manual operation of switches or valves for maintenance, replacement or collector cleaning.

5.2.2 Design Parameters

- Collector Field Heat Transfer Fluid (HTF)--The MISR system design may employ either
  - Pressurized water (including additives),
  - Heat Transfer Fluid such as a hydrocarbon oil, mineral oil, or
  - An other Synthetic-based medium.

The design of the HTF system shall be subject to the following constraints:

- Molten salts or alkali metals shall be prohibited.
- No Heat Transfer Fluid shall be operated at temperatures above its autoignition point.
- Nitrogen gas ullage blanketing systems shall be incorporated into the MISR system design if operating conditions are such that the supplier of the HTF recommends their use.
- Fire Protection systems shall be incorporated into the design of the MISR system mechanical equipment skid if mechanical joints or equipment seals are used in HTF systems and if it is operated at temperatures above the HTF flash point.
- Systems using pressurized water shall provide a means of freeze protection.
- If drain-down is used for freeze protection, some form of corrosion protection shall be provided for piping and equipment not made of corrosion resistant materials.

Other design parameters include

- Size--The MISR design to be developed in detail for deployment as proposed in the MISR Multiyear Project Plan shall be based on a nominal collector field size of 25,000 ft^2 of collector aperture area. System designers shall design as near to the 25,000 ft^2 as achievable using integral multiples of their basic delta-T loop.
- Output--The output of a MISR system shall be saturated steam. As a minimum, a MISR system shall be capable of generating steam at a pressure of 100 psig, preferably up to 250 psig. Any and all steam production shall be delivered to the industrial user.
- Nominal Rating--The system output shall be rated on the basis of an insolation of 650 W/m^2 direct normal to the solar collector aperture.
- Life--The MISR system shall be designed for a service life of at least 15 years. (Nominally 10,000 thermal and flexural cycles.)

5.2.3 Special Subsystems Required

The following subsystems shall be required in order to provide safe or convenient installation and operation of the MISR system.

- Equipment Skid--To the maximum extent possible, all major mechanical, electrical, and control components or subsystems shall be preassembled onto a skid (or skids) and delivered to the site as a unit (or units). As a minimum this skid-mounted equipment shall include:
  - Heat transfer fluid circulation, control, and conditioning equipment, and tanks,
  - Steam generation subsystem,
  - MISR system controller,
  - Electrical power distribution equipment,
  - Equipment Skid Fire Protection System (if applicable),
  - Emergency Power Supply System,
  - Nitrogen Gas Ullage Blanketing system (if applicable), and
  - Freeze Protection for Steam Generation Subsystem.

- Freeze Protection for systems using Pressurized Water--If pressurized water is used as the collector heat transfer medium, means of automatic freeze protection shall be provided. This automatic system shall function any time the system is filled with water and potentially exposed to freezing temperatures.
- Wash System--A system for washing collectors shall be included as part of the MISR system design. The method and system used is at the discretion of the system supplier.

5.2.4 System Control Requirements

The following control features shall be incorporated into the MISR System design:

- Automatic Unattended Operation--The MISR system shall be operable by automatic control without the need for an operator in continuous attendance. As a minimum, the control system shall be able to perform the following functions:
  - Normal Operation
    (a) Acquisition and tracking of the sun by the collector subsystem when sufficient insolation is available, as long as weather conditions fall within the operational limits of Section 4.2.2. The minimum operational insolation value shall be specified by the MISR system supplier. This automatic startup shall include:
      (1) Acquisition of the sun, to be accomplished within a system designer specified time not to exceed 15 minutes,
      (2) Proper conditioning and startup of the collector heat transfer fluid system,
      (3) Proper conditioning and startup of the feedwater system, and
      (4) Proper conditioning and startup of the steam system to include delivery of steam into the user's plant.

(b) Shutdown automatically to a safe position once insolation drops below the minimum operational value for a system designer specified time not to exceed 15 minutes. Automatic shutdown functions shall include:

(1) Solar collector stowing,
(2) Steam system shutdown,
(3) Collector heat transfer fluid system shutdown,
(4) Feedwater system shutdown, and
(5) Actuation of any inerting or heat tracing required for corrosion or freeze protection.

(c) Shutdown automatically to a safe position during severe weather conditions as detailed in Section 4.2.1. Automatic shutdown shall include the items listed above.

(d) The system must exhibit stable control of the heat transfer fluid, feedwater, steam, and collector loops, even during intermittent cloudy weather.

- Abnormal Operation--The MISR control system shall be designed for fail-safe operation. That is, the system shall be designed to initiate automatic shutdown to a safe condition if any of the following failures or system upsets occur and shall remain shutdown until reset by an operator:

(a) System Upsets:

(1) Collector field inlet overtemperature,
(2) Collector field return overtemperature,
(3) Steam generator overpressure,
(4) Steam generator water level low,
(5) Steam generator water level high,
(6) Heat transfer fluid expansion tank level high,
(7) Heat transfer fluid expansion tank level low,
(8) Ullage system nitrogen pressure low (if applicable), and
(9) Loss of heat transfer fluid flow.

(b) Power Failures:

(1) Complete primary power loss, and
(2) Loss of any power phase.

- Manual Operation --
  - Full System Operation--The MISR system controller shall provide manually operable switches to initiate system start-up or system shutdown as described in Sections 5.2.4(a). On manual start-up, all system safeties shall remain in operation.
  - Collector Field Operation--The MISR system controller shall provide a manually operable control to synchronously position the entire collector field to any position required. All system safeties shall remain in operation.
  - Collector Drive Group Operation--A local collector controller at each drive group shall provide a manually operable control for positioning of that drive group. System safeties shall be overridden in this mode, and control shall be completely isolated from the MISR system controller. An electrical disconnect switch shall be provided for complete electrical isolation of the drive group.
- Emergency Operation -- Safe system shutdown--Safe system shutdown shall be possible from emergency shutdown switches. One switch shall be located at the MISR system control panel, and other switches shall be locatable at the discretion of the site owner using the remote control contacts at the MISR system controller. Switches shall be conspicuous and clearly marked.
- System Alarms--Out-of-limits conditions which lead to system shutdown shall be visually alarmed at the MISR system control panel. The individual alarms shall also drive a common alarm contact which may be used as a remote "MISR System Trouble" alarm.

The Equipment Skid Fire Protection System, if required, shall activate both visual and audible alarms at the MISR System

Control Panel, and shall complete a circuit which may be used as a remote "MISR System Fire" alarm.

5.3 SELECTED DETAIL DESIGN REQUIREMENTS

The following section describes those aspects of the detail design of MISR systems which are felt to be requirements. They are intended to enhance reliable or convenient operation and to comply with safety or insurance considerations. All MISR system designs shall incorporate these required features.

5.3.1 Mechanical

- General --
  - Except where otherwise specified, all piping within the MISR system shall be designed and constructed to comply with the ANSI/ASME B31.1 Power Piping Code.
  - Wherever practical, piping joints and connection to equipment shall be welded.
  - Piping shall be prefabricated to the largest practical extent, as determined by shipping clearances or damage protection requirements. This is to minimize field installation time and cost.
  - Mechanical joints, where used, shall be either bolted flanged joints or compression-type or proprietary joints that experience or tests have shown to be safe for the required service conditions. Threaded joints are unacceptable. If possible, use of bolted flanged joints should be restricted to the equipment skid only.
  - Piping shall be designed for 10,000 thermal cycles.
  - Piping, valves, and in-line components shall be steel and shall be either forged or cast. Cast-iron bodies shall not be acceptable. Where possible, component trim material shall be steel. Bronze trim materials should be avoided.
  - Elastomeric or plastic materials in valve seats, seals, or packing is unacceptable.

how come everyone used them anyway?

- Insulation - installation of insulation on any field erected heat transfer fluid piping shall await completion of any required cleaning, inspection, test, and acceptance.
- Control valves requiring automatic actuation shall either be self-actuating or shall use electric valve operators. Operators shall be complete with electric motor drive, gearing, limit switches, and position indicators, mounted on the control valve by the vendor. Pneumatically actuated control valves shall not be used.
- Control valves shall require no active cooling for the valve or its components including the electric actuator. Materials selected for use in the valve shall be capable of continuous exposure to operating temperature without failure or degradation leading to failure.
- Valve stem seals shall be either hermetic or, if stempacking is used, shall be graphite type. Valve bonnets shall be either hermetic or shall be bolted, flanged, or compression ring-type bonnets. Screw-type bonnets shall not be acceptable.
- Valves shall be designed, manufactured, rated, tested, and marked in accordance with ANSI B16.5 or with the requirements for Standard Class Valves in accordance with ANSI B16.34. Additionally, all valves shall meet the requirements of ANSI B31.1.
- The feedwater, blowdown, and steam piping systems, including all anchors, valves, connections, miscellaneous in-line components, heat exchangers and vessels shall be insulated to provide protection for personnel and to minimize thermal losses from the MISR system. As a minimum, insulation shall be sufficient to maintain external surfaces subject to casual contact at or below 130°F under calm wind conditions.
- Insulation materials shall be suitable for continuous exposure to the design operating temperature of the piping.
- Insulation shall be provided with suitable protective jacketing or covering to keep the insulation dry and protect it from environmental damage.

- Non-wicking type insulation shall be placed at mechanical joints.
- Installation of insulation on any preassembled, equipment skid mounted piping shall be completed prior to shipment to the site. Insulation for the flanged process interface connections at the site shall be installed in the field after the connections have been cleaned, inspected and tested. Sufficient uninsulated piping shall be provided at these process interface connections to facilitate connections to the site. Termination of the insulation at these points shall be neat and workmanlike.
- Identification of piping should comply with ANSI A13.1.
- All exposed steel surfaces shall be either passivated or adequately painted to satisfy the environmental conditions and minimum system design life.

• Solar Collectors --

- Receiver assemblies shall be preassembled at the factory to the largest possible extent. Only interconnections completing the Heat Transfer Fluid circuits, and installation of receiver assemblies on support structures shall be required for installation. Receivers shall have adequate seals to prevent dust or sand from entering any enclosed optical spaces. No mechanical joints in the Heat Transfer Fluid circuit are allowed within the enclosed optical assemblies. Brazed joints or threaded connections shall not be used in the heat transfer fluid circuit of receiver assemblies.
- Drive mechanisms shall be preassembled to the largest possible extent. Motors, bearings, and gearing should be enclosed for personnel protection and shall have adequate seals to prevent dust and sand from entering the mechanism. The drive mechanism shall have provisions for manual movement for emergency operation. That is, (1) gear box drive units shall have a protruding shaft such that the drive mechanism can be rotated manually by wrench, and (2) hydraulic drive units shall have positioning valves that can be

manually actuated to allow movement of the collectors by hand. Drive mechanisms shall include mechanical stops to limit rotation of the collectors such that receiver assemblies and reflector structures cannot be damaged by being driven into support structures.

- The collector shall be capable of tracking the sun $\pm$ 85° from vertical.
- Any flex-hose assemblies or Rotary-Joint assemblies used to connect receiver tubes to fixed manifolds at the ends of collector drive groups shall be factory assembled units. These assemblies should include insulation to ensure personnel safety, and shall have a durable covering capable of surviving concentrated reflected sunlight spilling from the collectors, as well as surviving any mechanical flexures or rotations the connection shall undergo during the life of the system.
- A fixed termination for flex-hose assemblies shall be provided on the end pylons of collector drive groups in order to positively locate the interface with the heat transfer fluid piping and to avoid mechanical loading of receiver assemblies. Receiver tubes shall be of steel construction, satisfying the requirements of ANSI B31.1 for temperature and cyclic operation. Flex-hose assemblies, if used, shall be of steel construction, satisfying the requirements of ANSI B31.1 for temperature and cyclic operation.

• Steam Generation Equipment --

The steam generator shall be designed, constructed and stamped in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII. The steam generator shall include provisions for moisture separation, and shall be furnished with a water level sight glass, pressure gauge, heat transfer fluid and steam side pressure relief valves, automatic level control system including feedwater control valve, high and low water level switches for alarm, temperature indicators to monitor steam temperature and heat transfer fluid inlet and outlet temperatures.

If feedwater to the steam generator is to be preheated by the heat transfer fluid discharge from the steam generator, additional heat exchangers may be used. These feedwater heaters shall be designed, constructed and stamped in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII. The feedwater heater shall be furnished with heat transfer fluid and feedwater relief valves.

- Feedwater, Blowdown and Steam Piping Subsystem --

  - Exceptions to all-welded construction shall be:

    (a) At the MISR system boundary where these systems interface with the site. At these points, connections shall be by 300 lb. flanged connections.

    (b) Where connections to equipment require periodic disassembly for maintenance purposes. At these points, connections shall be by 300 lb. flanged connections.

  - Feedwater, blowdown, and steam piping within the scope of the ASME Boiler and Pressure Vessel Code, Section I, shall comply with the requirements of this code.

  - Feedwater, blowdown or steam piping within the boundary of the MISR system shall be heat-traced for freeze protection if not self-draining. The MISR system supplier shall recommend suitable freeze protection measures for feedwater, blowdown, or steam piping outside the MISR system but within the scope of the Site Preparation Specification Package provided by the MISR system supplier to the site owner.

  - All feedwater, blowdown and steam piping within the boundary of the MISR system shall be preassembled along with the steam generation equipment and accessories onto the equipment skid prior to shipment to the site. Piping shall be anchored to the equipment skid to provide structural support during shipment and during thermal cycling operation.

- Heat Transfer Fluid Circulation, Control and Conditioning Equipment --

  - Expansion Tank --

    (a) Shall be designed, constructed and tested in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, and

    (b) Shall be furnished complete with all necessary supports, heat transfer fluid inlet and outlet connections, a liquid level sight glass, automatic level indicator switches for high and low fluid levels, safety pressure relief valve, vent, drain, fill, and nitrogen blanketing connections.

  - Nitrogen Gas Ullage Blanketing System (if applicable) - The nitrogen gas ullage blanketing system for the heat transfer fluid expansion tank shall:

    (a) be self-contained on the MISR equipment skid. Station shall include cylinder rack, regulating station, and shut-off valves. However, if cylinders of compressed nitrogen are used as a gas source, these may be installed into the system after the equipment skid has been delivered and installed at the site. The installation of any compressed nitrogen cylinders shall, at most, require only the placement of the cylinder(s) into a predesigned location providing suitable support, and the hook-up of the cylinder to an in-place nitrogen gas pressure regulation and delivery piping system.

    (b) maintain ullage pressure automatically within a preset design range. Whenever ullage pressure drops below this range, the system should automatically supply additional nitrogen gas to the ullage. Whenever ullage pressure rises above this range, the system should vent the vapor overpressure automatically to a suitable fire-suppressant catch tank.

(c) monitor nitrogen supply pressure and initiate an automatic system safe-shutdown in the event that nitrogen supply pressure drops below a preset minimum.

(d) use either steel tubing or piping satisfying the requirements of ANSI B31.1. Threaded connections within the nitrogen gas ullage blanketing system shall be allowed, provided they shall conform to the requirements of ANSI B2.1 for pipe threads.

- Equipment Skid Fire Protection System (if applicable) - The design of the equipment skid fire protection system is largely at the discretion of the system supplier. However, all equipment skid fire protection systems shall satisfy the following requirements.

  (a) All fire protection work shall be in accordance with the latest editions of the applicable National Fire Protection Association and Factory Mutual Standards.

  (b) The fire protection system shall be an automatically actuated system capable of detecting and suppressing a fire on the equipment skid.

5.3.2 Electrical

- General --
  - The electrical system shall be designed and constructed to comply with the National Electric Code (NEC), 1981 Edition.
  - MISR systems shall be designed to operate from an electrical power supply with either 120/208V or 277/480V, 3 phase, 4 wire, with a solidly grounded neutral. Selection of either voltage rating is at the discretion of the system designer. This voltage rating and the required KVA power rating shall be specified to the site owner as part of the MISR system site specification package prepared under Task III.
  - Electrical equipment and systems shall be preassembled, wired, tested, and adjusted for operation prior to shipment

to the largest extent practical. Power, control, and instrumentation cables and raceways shall be designed to minimize the amount of time and labor required for field installation.

- Motors 3/4 HP or larger shall be provided with a separate motor controller and combination starter.
- Motors smaller than 3/4 HP may have the motor controller integral with the collector controller.
- The voltage used in any control circuits shall not exceed 120 volts.
- All electrical equipment and circuits shall be provided with NEMA ICS1-110.15.1 Type 4 weatherproof enclosures.
- All wiring shall use copper, stranded wiring satisfying the requirements of the National Electrical Code. Where interconnections are made between components with terminals or between components and terminal blocks, terminal connectors shall be used. Bare wire connections under screw heads shall not be used.

• Emergency Power Supply Equipment --

- The emergency power supply shall be capable of starting and running all critical (as defined by the system designer) service loads necessary to achieve a safe shutdown of the MISR System.
- The Emergency Power Supply Equipment shall include all transfer equipment, batteries, battery chargers, engines, generators, fuel system and control equipment required to provide power. All this equipment shall be skid-mounted.
- All power supply transfer equipment required to transfer from the primary power to emergency power and back shall include sensors and logic to detect and respond to primary power phase reversal, phase loss and undervoltage. The logic shall signal the integral circuit breakers to execute a supply transfer when emergency supply is available, and shall provide secondary contacts to activate a transfer alarm and a safe shutdown command to the MISR System Controller.

- Power and Control Cables --
  - Cables shall be designed in accordance with IEEE Standard 422-1977 as well as the NEC.
  - Cables shall run from termination to termination without a splice.
- Cable Raceways --
  - All power, control and instrumentation circuits required on the equipment skid shall be installed within rigid steel conduit raceway in accordance with the requirements of the National Electrical Code for hazardous locations.
  - All power, control, and instrumentation cable raceways sharing a common route throughout the solar collector field shall utilize common supports to the largest extent practical.
  - Where circuits share common routes, cable trays may be used as well as conduit. Cable trays, when used, shall be covered to protect cables from the weather, fluid spills or abuse.

5.3.3 Control and Instrumentation

- General --
  - All connections to sensors shall be weatherproof.
  - All control and instrumentation wiring shall be enclosed in cable raceways, either conduit or trays.
- Solar Collectors --
  - Each drive mechanism shall be supplied with rotational position limit switches at the extremes of rotation to stop rotation.
  - Each collector drive string shall be provided with a receiver overtemperature switch. Actuation shall occur whenever temperatures which would result in damage to the receiver assemblies are encountered. The switch shall actuate the local emergency stow mode.

- Individual sun trackers for each collector drive string, if used, shall be protected from errant signals due to stray reflections, and shall be environmentally protected against failure due to dust or moisture.
- Sensors requiring immersion in the collector heat transfer fluid, if used, shall be compatible with the fluid under the conditions specified. Only welded seals or compression type fittings shall be used for immersion sensors.

• MISR System Controller -- Control of the complete system shall be accomplished from a central control panel provided on the equipment skid which accomplishes integration of the various subsystem components. This will include but not necessarily be limited to:

- A weather sensor package to allow automatic system operation with the environmental conditions in Section 4.2.2.
- A process control package which includes all necessary primary elements and sensors, analog and digital logic, collector control logic, power supplies, final control devices, input/output interface relays and switches.

The controller shall be capable of performing the functions listed in Section 5.2.4.

• Steam Generation Subsystem --

- Instrumentation and control piping and tubing shall comply with the requirements of the ASME Boiler and Pressure Vessel Code and with the ANSI B31.1 Power Piping Code.
- Required Instrumentation shall be, as a minimum, the following:

(a) Steam Generator Water Level Indicator,
(b) Steam Pressure,
(c) Steam Temperature,
(d) Heat Transfer Fluid Inlet and Outlet Temperatures, and
(e) Heat Transfer Fluid Flow Rate.

Visual display of these measured parameters at the MISR system control panel, combined with automatic alarms for out-of-limit conditions shall be provided.

- Heat Transfer Fluid Circulation, Control and Conditioning Systems - Required Instrumentation shall be, as a minimum, the following:

  - Collector Field Inlet Temperature,
  - Collector Field Outlet Temperature,
  - Heat Transfer Fluid Flow Rate,
  - Expansion Tank Fluid Level, and
  - Ullage System Nitrogen Gas Pressure.

  Visual display of these measured parameters at the MISR system control panel, combined with automatic alarms for out-of-limit conditions shall be provided.

6. GUIDELINES

The guidelines represent methodologies, design features, and design practices which may be recommended for consideration in any MISR design. They incorporate lessons learned from previous solar projects as well as good engineering practices from the process and power piping industries.

6.1 RECOMMENDED DESIGN METHODOLOGIES

6.1.1 Wind Loading Determination

Determination of wind loads on collectors is critical for sizing collector drives, establishing structural requirements for the collectors, and establishing loads to be used in the design of foundations. For the MISR system design, it is recommended that wind loads be determined using the procedure described in "Wind Load Definition for Line-Focus Concentrating Solar Collectors," Duane E. Randall, Sandia National Laboratories, (Reference 1). A 25 year mean recurrence interval should be used. Gust factor for ground mounted collectors should be 1.0.

6.1.2 Collector Foundation Design

Collector foundations to be included in the site specifications should be based on the design and procedures outlines in "Foundations for Line-Focusing Solar Collectors," Harry E. Auld, Higging, Auld & Associates (Reference 2).

6.1.3 Economic Analysis

Economic analysis for parametric trade-off studies, etc., should be based on methodology described in Dickinson and Brown (Reference 3).

6.2 CONCEPTUAL DESIGN RECOMMENDATIONS

6.2.1 "Elastic" or "Breathable" Design

The MISR system should be based on a conceptual design that is compatible with the concept of an "elastic" or "breathable" design. That is, the system should be one that could be developed into a series of pre-engineered detail designs, each perhaps designated by a separate model number, and incrementally sized so as to span a significant range of applications. Each of the detail designs in such a series would share in common physical arrangement of components within subsystems, designs, types of major components, etc. Different sizes in the series would be achieved by deploying larger or smaller collector fields built up of modular collector field increments such as a delta-T fluid loop. The balance of the system--piping, pumps, valves, steam generator, expansion tank etc., would be appropriately sized to correspond to the collector field size. Major components used in such a system might themselves be available within a vendor design series cataloged by size (e.g., pumps, heat exchanger). For even larger applications, multiple MISR systems would be deployed. They would be manifolded to a common steam main and would be controlled from a single remote control site.

6.2.2 Thermal Storage

Thermal storage has not been required for MISR systems; however, it may be included. It is clear that many process applications, which exhibit their peak loads at times which are skewed relative to peak insolation availability, would benefit from the inclusion of a thermal storage subsystem. Other applications may wish to use thermal storage to level the steam production of the MISR system, possibly enhancing the system's utility.

Should the system supplier wish to include thermal storage in his MISR design, only well developed thermal storage techniques should be considered. The best understood of these, with the largest body of experimental and demonstration history, are the sensible heat storage concepts using liquid media: (1) thermocline storage and (2) multitank storage.

Inclusion of either of these systems will introduce no additional technological systems to the MISR design, as either uses heat transfer fluids, nitrogen ullage systems, and conventional piping, tanks, and insulation materials. If thermal storage using liquid media is to be used, the following guidelines should be followed:

- For bulk storage of heat transfer fluids, consideration should be given to using lower cost, fluids for storage, while a more expensive, more competent fluid might still be used in the collector loop. This requires intermediate heat exchange but has the added advantage of isolating the thermal storage volume from the collector field via an intermediate heat exchanger.
- Nitrogen ullage systems should be used.
- Tanks should be designed to ASME Code, Section VIII, Division 1.
- Spill containment site work should be per EPA Regulations, Part 112.

Thermal storage using pressurized water is not recommended.

6.2.3 Wash System

Two types of wash systems have been postulated for use in solar collector systems. Broadly speaking they may be described as:

- Fixed Systems, and
- Portable Systems.

Fixed systems generally employ networks of piping feeding an array of fixed nozzles or sprinklers whose action rinses the solar collectors. Such systems can be automatic, using commercially available automatic timers, sprinklers, piping and drain components. Or, they may be manually actuated. Either way, their effect is limited by the inability of the sprinklers to apply truly directed sprays at soiled areas. The sprinklers are not capable of the vigorous mechanical action available at higher pressures, either.

Alternatively, portable systems employ commercially available high pressure washing equipment. The high pressure action, combined with the directed application resulting from a human operator, gives these systems an advantage in potential cleaning ability. Further, the initial cost of such systems is lower than the cost of fixed systems. Of course, countering this is the increased cost for labor to operate the washer.

Of the two systems, it is recommended that a portable system be used. The recommendations presented in Cleaning Strategies for Parabolic Trough Solar Collector Fields: Guidelines for Decisions, Kenneth D. Bergeron and James M. Freese; Sandia National Laboratories (Reference 4) should be followed.

6.3 SELECTED DESIGN RECOMMENDATIONS

6.3.1 Solar Collectors

6.3.1.1 Design Considerations --

- The collectors should be able to assume an inverted stow position for protection from air borne particles and debris and to avoid excessive accumulation of ice or snow.
- The collectors should be designed such that, if failures occur, they are preferentially directed toward non-critical items or items that are relatively easy to repair or replace. For example, failure of a drive motor may be preferred over damage to a receiver.
- Because of the variable nature of the solar input, it is recommended that the collectors be operated well below their materials degradation temperature limits, so that transient overtemperatures do not cause damage. This "headroom" should enhance both reliability and safety.

6.3.1.2 Minimum Recommended Performance -- Solar collectors are available which can meet or exceed the performance listed below. Lower performance should only be accepted if significant cost advantages can be realized.

- The peak efficiency as measured per paragraph 8.3.2 of ASHRAE Standard 93-77 should be greater than the following:

Temperature	Peak Efficiency
0°C	60.0%
100°C	57.5%
200°C	52.0%
315°C	44.0%

- Minimum optical incident angle modifier (K_o) as derived from the incident angle modifier (K) measured per paragraph 8.3.3 of ASHRAE Standard 93-77 should not be less than

Angle	K_o
0°	1.00
15°	0.98
30°	0.93
45°	0.85
60°	0.65
70°	0.45

6.3.2 Collector Heat Transfer Fluid System

The following recommendations may be made for the Collector Heat Transfer Fluid System:

- An oil or synthetic type heat transfer fluid exhibiting low vapor pressure at operating temperatures and possessing a pour point below the minimum ambient temperature specified under Section 4.2.1, Survival Environment, be used in the collector field. This will minimize parasitic energy requirements for pumping because of the relatively small change in vapor pressure over the system temperature differential. Additionally, it provides for passive freeze protection within the widely distributed collector field. Nontoxic fluids satisfying these conditions are available at reasonable cost.

- The thermal expansion of the fluids can be substantial over the temperature range encountered during operation. To accommodate this, the working volume of the expansion tank should be sized so that it is 1/4 full at 75°F and 3/4 full at operating temperature. The tank should be elevated so that the tank vent is the highest point in the MISR system heat transfer fluid piping network.
- For oil or synthetic fluid systems, mechanical seals should be used in the circulation pump, and special stem packing or hermetic seals should be used for valves. The mechanical seals and valve stem packings should be recommended by the manufacturer for the particular fluid, operating temperatures, and cyclical operation. The circulation pump should be designed and constructed per API Standard No. 610.

6.3.3 Miscellaneous Mechanical Systems

6.3.3.1 Steam Generator --

- A good choice for the steam generator would be a pot or kettle type boiler to provide stable operation during minor transients in insolation.
- Unfired steam generators made expressly for use with pressurized water or specially designed for use with oil type heat transfer fluids are commercially available.

6.3.3.2 Fire Protection System (if required) --

- The fire protection system for the equipment skid should use ultraviolet detectors for fire detection.
- The fire extinguishing system should use either: (1) a dry chemical system, or (2) a carbon dioxide system.

  The carbon dioxide system has the added advantage of providing a cooling effect in addition to smothering a fire. If the dry chemical system is selected, it should be designed and installed in accordance with NFPA Standard No. 17-1969 "Standard for Dry Chemical Extinguishing Systems."

6.3.3.3 Piping Recommendations --

- Location and Routing of Pipe --

  The following design features should be considered:

  - Removable flanged spools should be provided at components which will be removed for maintenance and inspection.
  - To avoid pocketing, piping should be arranged so it drains back into equipment.
  - Equipment, valves, etc., should be positioned with adequate clearance for operation and maintenance.

- Location Valves --

  Valves should be located for ease of operation and maintenance. The following should be considered when locating valves:

  - Valves should be placed in pipe lines from headers in horizontal rather than vertical runs, so pipe can drain when valves are closed.
  - Where flanged connections are required, valves should be mounted directly to flanged equipment to avoid spooling unnecessary lengths of pipe.
  - Adequate clearance should be provided between flanges and supports, etc., for ease of installation.
  - Avoid locating valves on pipe racks.
  - Orient valves so that any stem leakage will drain to grade and away from valve bodies and insulation.
  - Manually-operated valves should be located at access aisles.
  - Locate valves so their supports will not be on removable spools.
  - Locate valves such that valve stems do not project into walkways, ladder space, etc.

- Expansion Loops vs. Expansion Joints --

  Expansion joints should be used for accommodating pipe movement <u>only</u> if such movement cannot be taken up by:

- Rerouting or respacing the line.
- Expansion loops.
- Calculated placement of anchors.

  Expansion joints, if used, should be of the bellows type. Bellows should be stainless steel.

- Vertical Supports and Guides -- Pipe support components should be as simple as conditions will allow and, whenever possible, should be commercial items.

  Pipe supports for the feedwater, steam and heat transfer fluid piping systems should be of the pre-insulated pipe support (thermal hanger shield) type. Pre-insulated pipe supports are recommended because: (1) they provide rigid piping support elements, (2) they provide less heat loss than welded T's, welded insulation saddles or pipe clamps fastened directly to the pipe.
- Flanged Connections -- Flanged Connections, where required in an oil system, should be 300# flanges, with high-temperature alloy studs, and should have concentric rather than spiral type grooves.
- Fittings -- Welding elbows should have a radius of one and one-half times the diameter of the pipe and tees should have well-rounded branch outlets. Miter welded bends should not be used.
- Branch Connections -- For branch connections in small (1-1/2 inch or less) pipe, integrally reinforced, socket weld type branch connectors should be used.
- Welding -- Socket welds should be used for 2 inch or smaller pipe. Butt welds should be used for pipe larger than 2 inches; backing rings can be used to aid in alignment and speed the butt welding.

6.3.3.4 Insulation Recommendations --

- Materials --

  - Fiberglass Pipe Insulation -- Preformed fiberglass (6 pcf density) pipe insulation (one-piece hinged construction) without canvas jacketing should be suitable for temperatures up to 650°F.

- Non-wicking Insulation -- A closed-cell, foamed glass insulation is recommended. This material is available as preformed pipe covering.
- Fiberglass Board (Block) Insulation -- Fiberglass board (6 pcf density) insulation should be suitable for temperatures up to 650°F. Molded radius block (pipe insulation) should be used, when commercially available, for insulating cylindrical vessels and tanks. Flat block insulation should be used for all other shapes.
- Mastic Finish -- Where it is impractical to apply metal jacketing to insulated valve bodies, fittings, and equipment, those insulation surfaces should be finished with a bedding coat of mastic, a layer of glass fabric applied into the bedding coat while still tacky, and a brush-applied finish coat of mastic over the glass fabric, sealing all pores in the fabric.
- All materials should be asbestos-free.

• Application --

  - All straight horizontal piping should be insulated with preformed pipe insulation.
  - Insulation over 3 inches thick should be applied in 2 layers with the outer layer equal to or thicker than the inner layer. Each layer of pipe insulation should be wired on.
  - Insulation should be installed next to smooth surfaces wherever possible. Welded wire mesh should be used to support insulation over ribbed construction, uneven surfaces and other surfaces having stiffeners, projections, etc.
  - All insulation should be applied in a manner resulting in tightly butted joints. Longitudinal joints of all single layer insulation should be staggered wherever practical. In multiple layer applications, longitudinal joints should be staggered by substantially one-half the segment or block width, and circumferential or block-end joints should be staggered by the maximum practical extent.

- At all access openings, manholes, handholes, removable heads, equipment flanges, blind flanges, pipe flanges or similar maintenance points, both the insulation and jacketing should be of a design permitting removal and replacement of suitable formed sections without disturbing adjacent insulation. Flashing should be installed around the access opening in the insulation and legged to form a neat and weathertight maintenance opening. Care should be taken to keep all instruments clear of insulation materials. Any such removable sections should be adequately reinforced with poultry netting or such other corrosion resisting metal reinforcement as necessary to prevent breakage when handled with reasonable care during removal or replacement.

- Instrument Connections -- All instrument connections for gages, test connections, flow meters, etc., on pipes, vessels, or equipment should have insulation materials shaped at these connections by tapering it to and around the connection with insulating cement and finishing with finishing cement. After thorough drying, these surfaces should be covered with mastic.
- Nameplates and Code Stamps -- Where nameplates and code stamps will be covered by insulation, all information contained thereon should be stamped or engraved on a nonferrous metal plate which should be permanently installed on the outside of the insulation and directly over, or in the immediate vicinity of the nameplate and/or code stamp covered by the insulation.
- Pre-insulated Pipe Supports -- Pre-insulated pipe supports (thermal hanger shields) should consist of calcium silicate pipe insulation, a special insulation insert (preferable Johns-Manville's Marinite) for the load bearing point and a corrosion resistant outer protective shield. The insulation thickness for the pre-insulated pipe supports should be equal to the adjacent pipe insulation thickness.

6.3.4 Electrical System

6.3.4.1 Design --

- Low Voltage Power --

- Recommended Voltage Regulation Limits -- The regulation on the terminals of all distribution system loads during normal full-load operation of the MISR field should be maintained within the range 90% to 100% of load voltage rating.

  The regulation on the terminals of all distribution system loads during starting should be maintained with the range 80% to 90%.

- Recommended Distribution System Arrangements --

  (a) Low Voltage Power Distribution System - The distribution system should be arranged such that all loads will be served from either single- or multiple-tap radial feeder circuits originating in low voltage molded-case circuit breaker distribution panels.

  (b) Utility and Local Convenience Outlet Distribution Network - It is recommended that convenience outlets be located within 100 feet wherever power may be required for routine maintenance. Any convenience outlet distribution network should be arranged such that all collector local outlets will be served from multiple-tap radial feeder circuits originating in low voltage molded-case circuit breaker distribution panels. Any utility distribution network should be arranged such that all utility loads, such as heat tracing, should be served from multiple-tap radial feeder circuits originating in low voltage molded case circuit breaker distribution panels. All taps should be protected by either circuit breakers or fuses.

• Power, Control and Instrumentation Raceway --

  - Main Raceway Corridors -- All power, control, and instrumentation circuits that share a common route should be considered for installation together in a covered tray raceway along the route of joint occupancy.
  - Single-Circuit Raceway -- All individual power, control, and instrumentation circuits that solely occupy a route should be installed in rigid steel conduit raceway.

- Circuit Low Zero Sequence Fault Impedance -- In order to be able to detect, interrupt, and isolate all "poor contact" phase-to-ground faults, cable configurations which provide the best zero-sequence impedance practicable should be used. All power circuit cables should be furnished with integral ground fault current return conductors. The conductors should be bare stranded copper with at least 45% capacity of one phase conductor.

  The cable bare ground conductor should be bonded to the next adjacent metallic structure and to ground at each location where accessible. All cable bare ground conductors should be interconnected and bonded directly to the distribution system neutral terminals of the supply transformer and of the emergency engine generator.

  The insulated neutral conductors of the distribution system should be grounded only in two locations, at the neutral terminal of the supply transformer and at the neutral terminal of the emergency engine generator.

  All equipment containing electrical circuits should be externally bonded by bare copper conductors to all adjacent metallic structures, equipment, and surfaces, and to ground for personnel and equipment protection against fault voltage and lightning discharges.

- Fault and Overload Protection -- Molded-case circuit breakers with ambient-compensated thermal and magnetic characteristics should be used to individually serve and protect each feeder circuit, feeder circuit tap, and separate and identifiable component load.

- Emergency Power System -- The Emergency Power System should have an emergency short-time overload output capability equal to or greater than the composite kW or kVA demand of all connected critical loads starting and running simultaneously. The power supply transfer devices should be circuit breaker equipped for circuit fault and overload protection in addition to their switching function.

The circuit breakers should have a standard continuous-duty rating at least to 115% of the composite demand of the connected loads operating simultaneously.

- Pump Drive Motors -- The drive motors should be capable of starting and accelerating their connected loads to rated speed with no more than 80% rated terminal voltage, and should be capable of continuous and stable operation at slightly reduced speed with a momentary reduction in terminal voltage to 70%.
- MISR System Controller and Collector Controller -- The control processor equipment should be capable of continuous and stable operation with no more than 80% rated terminal voltage and of restored nondisruptive operation with a momentary reduction in terminal voltage to 70%.
- Heat Tracing -- The heat tracing elements should be sized so as to maintain a fluid 3°F above freezing temperature under worst case conditions.

  Heat trace element utilization voltage should not exceed 120 volts to ground.
- Identification -- Each conductor should have a permanently affixed identification band on each end that clearly identifies the conductor with its representation on any associated schematic and wiring diagrams. Each cable should be identified by the circuit number shown on any Drawings. One (1) identification tag should be attached at each end of the cable and at intermediate pull boxes. All cables should be tagged at all points where connected to terminal blocks. Each terminal block should have marking strips containing the wire identification numbers. Power conductors should be identified as to circuit and phase; phases should be marked A, B, or C.

6.3.4.2 <u>Electrical Material and Equipment</u> --

- Control Circuits -- All controls should be designed so that any logic or component failure does not permit an unsafe operating condition to be created. The design of the control systems should be such that any logic or component failure is readily identifiable by utilizing logic level indicating lights and test points in both internal logic and external circuits. Surge Suppression Devices may prove useful for reliable operation of electronic logic circuitry.

- Interfacing Cable Space -- All enclosure interiors should be arranged to provide adequate space for the cables interconnecting remote devices. This space should allow the cables, when installed in a neat and orderly manner, sufficient clearance from and non-screening of, conductors of other cables, internal wiring, terminal blocks, and internally-mounted components. All enclosure interiors should be arranged to provide for testing, maintenance, and component removal without requiring cable to be removed from terminal blocks.
- Internal Wiring -- All wiring should be classified as either low-level signal, low voltage control, or low voltage power. Wiring of each classification should be consolidated and separated as far as practicable from the others to ensure isolation and to avoid induced interference. Where adequate physical separation cannot be accomplished to avoid induced inteference, electrostatic and electromagnetic shielding should be provided where interference may affect satisfactory operation. All equipment internal wiring should be designed so as to consolidate related interface terminal points to be extended to common remote locations. Wiring should be bundled and enclosed in suitable nonmetallic wireways and should be complete with suitable clamps and supports.
- Terminal Blocks -- Within each enclosure, all wiring and interface terminals of the same classification to be used for interconnecting with all associated devices in one remote location should be grouped together on one or more adjacent terminal block(s). The terminal blocks should be mounted for easy accessibility and entry of the interfacing cables.

All internal wiring should be terminated with no more than two conductors per terminal block screwhead, and on only one side of a terminal block array.

- Accessories -- Filters, blowers and/or other suitable ventilating devices should be installed and wired as an integral part of each enclosure that contains equipment requiring supplemental ventilation for proper operation.
- Emergency Power System -- An engine-generator unit is recommended for the Emergency Power System. The unit should be enclosed in a weather protective housing suitable for the specified environment.

  The unit should be equipped with all manufacturer's Standard and Optionally-available accessories necessary to ensure reliable and trouble-free operation in the specified environment.

  - Engine -- The engine of the unit should be an air-cooled, internal combustion, 4-cycle, gas-fueled, direct-connected, automatic-electric starting engine.

    The unit should utilize an integrally-mounted charger in order to maintain the cranking battery in a fully charged condition.
  - Generator -- The generator of the unit should be a revolving-field type with a brushless exciter and solid-state voltage regulator. The generator should be rated the same as the MISR system supply, either 120 Grd Y/208 volts or 277 Grd Y/480, 3-phase, 4-wire, 60 Hertz, depending on the designer's selection. The generator should conform to the requirements of NEMA MG-1.

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