DOE/SF/11439-1/3

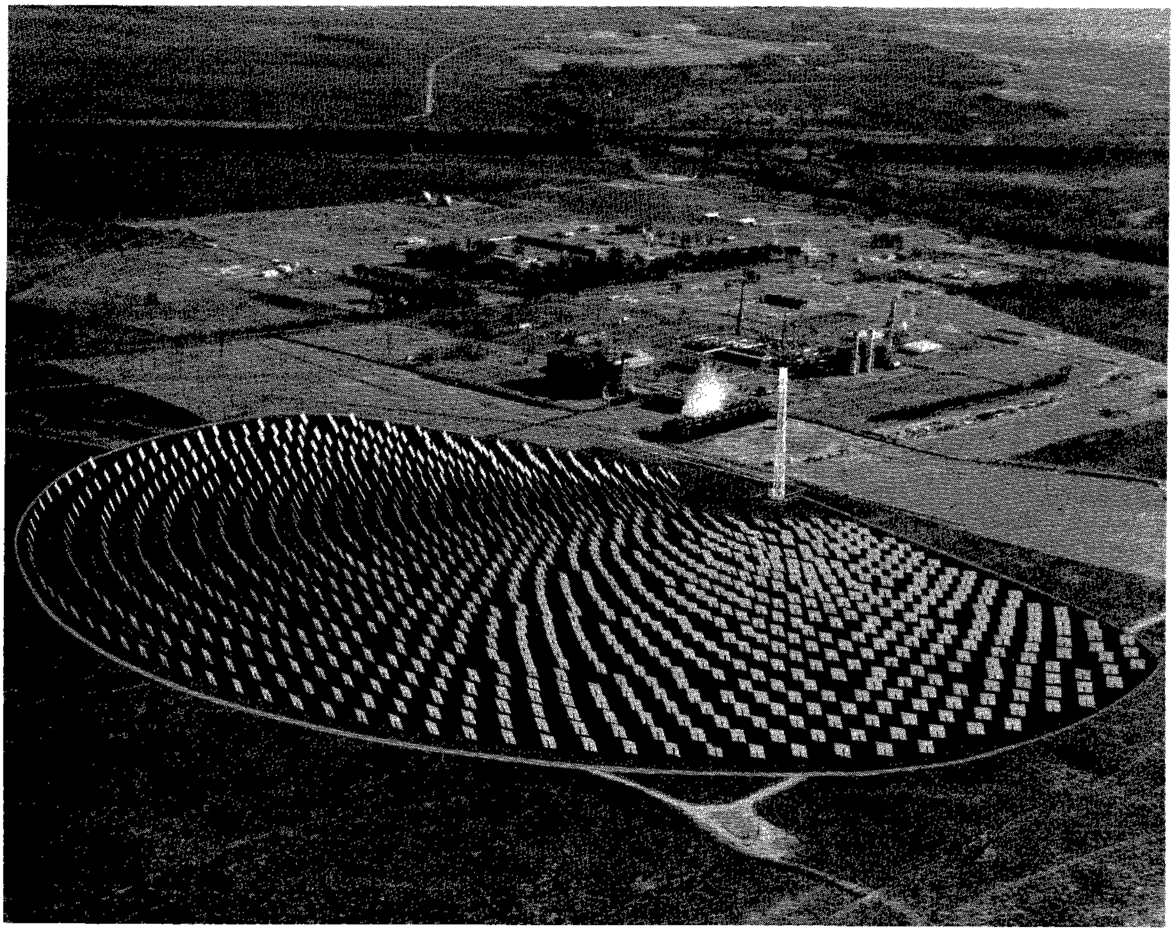


Vol 3

# SOLAR COGENERATION FACILITY

## CIMARRON RIVER STATION

## CENTRAL TELEPHONE & UTILITIES - WESTERN POWER



## APPENDICES

August 7, 1981

Black & Veatch, Consulting Engineers
Central Telephone & Utilities - Western Power
Babcock & Wilcox Company
Foxboro Company

Department of Energy
Contract No. DE-AC03-81SF 11439

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# SOLAR COGENERATION FACILITY
## CIMARRON RIVER STATION
## CENTRAL TELEPHONE & UTILITIES - WESTERN POWER

# APPENDICES

**Prepared for**

**DEPARTMENT OF ENERGY**
**CONTRACT NO. DE-AC03-81SF 11439**

**by**
**BLACK & VEATCH, Consulting Engineers**
CENTRAL TELEPHONE & UTILITIES - WESTERN POWER
BABCOCK & WILCOX COMPANY
FOXBORO COMPANY

August 7, 1981

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## APPENDIX A
## SYSTEM SPECIFICATION

The System Specification is a design control document that has been used in the development of the conceptual design, integration of the plant systems and components, and description of the configuration.

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# 1.0 GENERAL

## 1.1 SCOPE

Sections 1 through 4 of this specification define the characteristics, design requirements, and environmental requirements for the Cimarron River Station (CRS) Solar Cogeneration Facility. Section 5 contains the facility conceptual design, performance, and economic data for the solar facility addition as well as certain design data for the existing facility.

This specification is applicable as a design requirement only to the new or modified portions of the Solar Cogeneration Facility.

## 1.2 SYSTEM DESCRIPTION

The Cimarron River Station Solar Cogeneration Facility project will consist of the following major elements.

(1) Site.

(2) Site Facilities.

(3) Collector System.

(4) Receiver System.

(5) Receiver Piping System.

(6) Solar Master Control System.

(7) Fossil Energy Delivery System.

(8) Electric Power Generating System.

(9) Process Heat System.

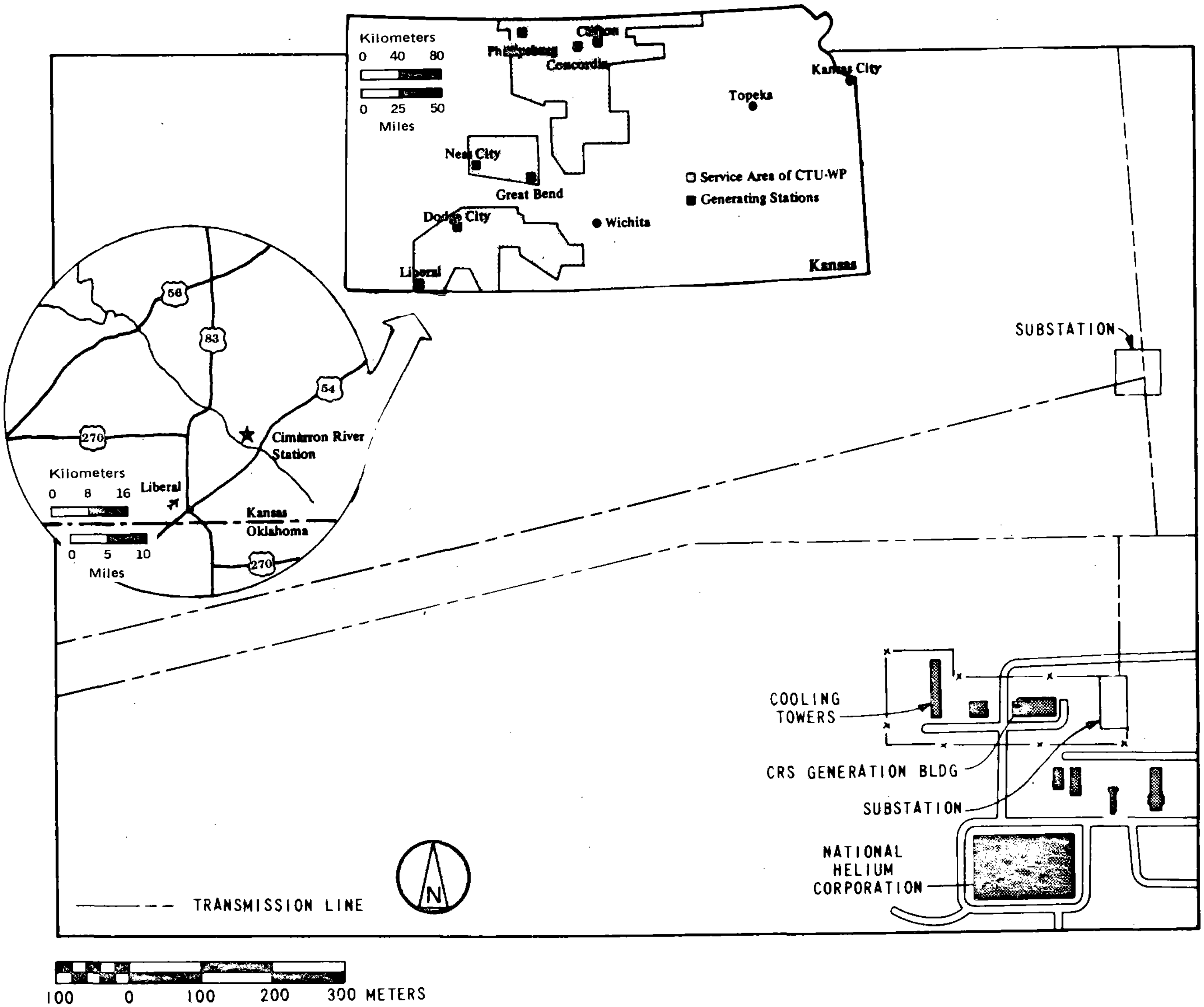
(10) Solar Auxiliary Electric System.

(11) Specialized Equipment.

### 1.2.1 <u>Site</u>

The Cimarron River Station is located on a site adjacent to the National Helium Corporation, approximately 18 kilometers (11 miles) northeast of Liberal, Kansas. The location of the site is illustrated on Figure 1.2-1.

The site is within the High Plains Section of the Great Plains Physiographic Province and lies on the east valley slope of the Cimarron River. The geology in the vicinity of the site is the Ogallala formation which consists of sand, gravel, silt, clay, shale, and caliche. The lower




PLANT LOCATION AND SITE ARRANGEMENT--CIMARRON RIVER STATION, NATIONAL HELIUM CORPORATION

FIGURE I.2-I

strata of the Ogallala formation consist of sand and gravel, the middle strata are mixed sand, silt, and caliche, and the upper strata at the surface are clay or shale and sand. The Ogallala formation is of Pliocene Age of the Tertiary Period at its lower strata and of Pleistocene Age of Quaternary Period at its upper strata. This formation is mostly unconsolidated and yields moderate to abundant supplies of ground water.

The elevation above mean sea level in the vicinity of the heliostat field varies from approximately 823 m (2,700 ft) in the north to approximately 805 m (2,640 ft) in the south. Surface soils have been derived from parent materials of the Ogallala formation and are generally sandy loams with some clay content. Most of this area is vegetated with native grass/forb/shrub mixtures.

1.2.2 Site Facilities

Facilities at the Cimarron River Station currently include Units 1 and 2, an auxiliary process steam generator, and other supporting facilities. Unit 1 consists of a natural gas fueled steam generator, a 44 MWe (nominal) steam turbine and supporting auxiliaries. Unit 2 is a 14 MWe (nominal) natural gas fueled combustion turbine. Ordinarily, Unit 1 is operated as a base-load unit and Unit 2 is used for summer peaking. Unit 1 supplies the adjacent National Helium Corporation Plant with process steam on a contract basis. During times when Unit 1 is shut down, an auxiliary process steam generator, also natural gas fueled, is used to supply process steam to National Helium Corporation (NHC).

Other facilities on the site include the following.

(1) Electrical substation and transmission lines.
(2) Five makeup water wells.
(3) Fuel gas supply system.
(4) Mechanical draft cooling towers.
(5) Wastewater treatment, plant drainage, and sewerage system.
(6) Office, shop, and warehousing facilities.
(7) Supply and return pipelines for NHC process steam.
(8) Roads, parking, fencing, etc.

1.2.3 Collector System

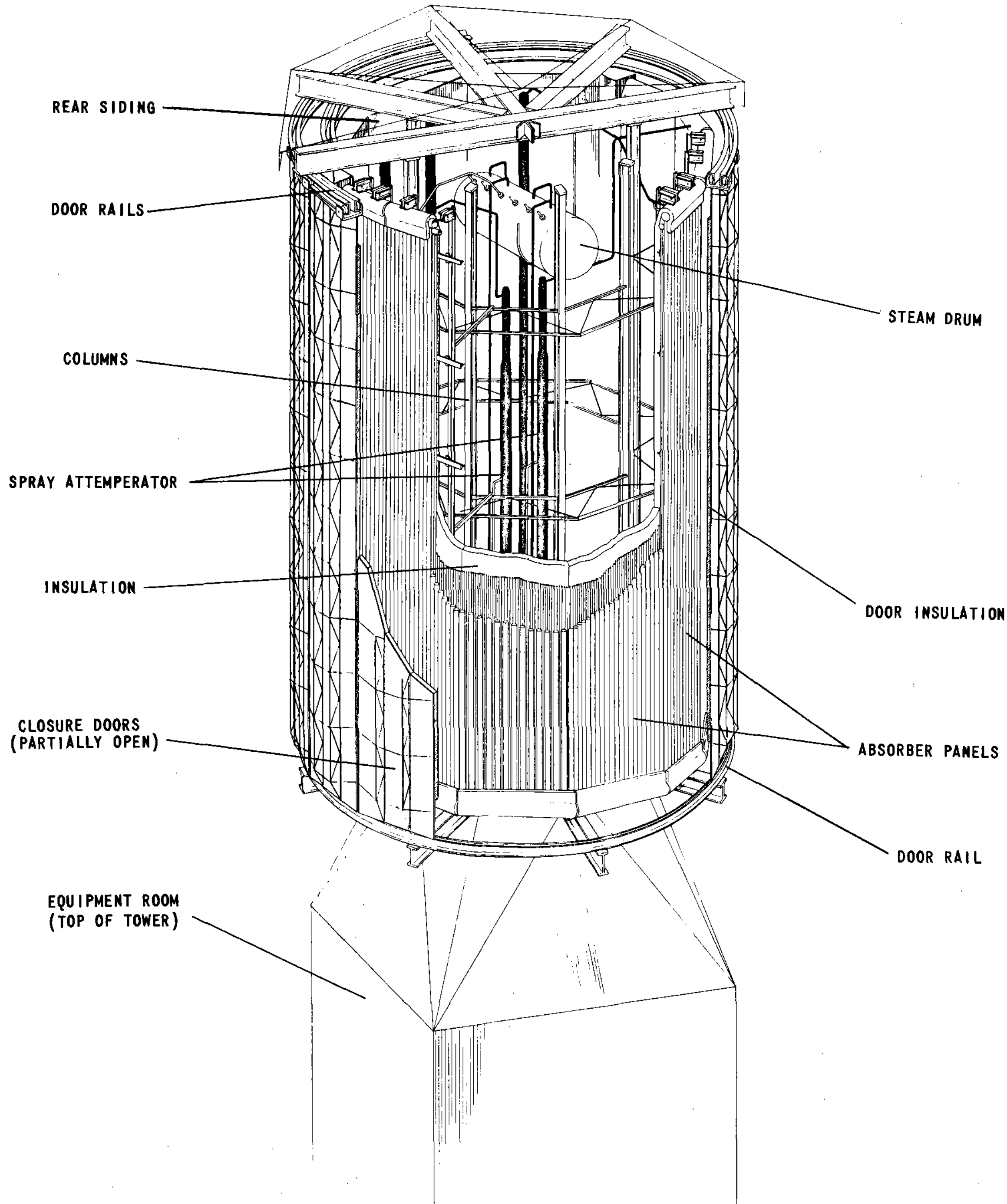
The Collector System consists of an array of computer-controlled, two-axis tracking heliostats which redirect and concentrate solar radiation onto the receiver absorber surfaces. Heliostat orientations are constantly altered throughout the day, in response to computer generated commands, based on the instantaneous sun position and aim strategy, so that the redirected solar flux landing on the receiver satisfies the receiver incident heat flux requirements. The heliostat locations within the collector field are selected to provide the most cost effective means of energy collection.

The Collector System also includes electromechanical and electrical controllers, including individual heliostat and heliostat field controllers, control system interface electronics, and power supplies. The heliostat itself consists of reflective surfaces, structural supports, drive units, control sensors, pedestals, foundations, cabling, and cable array installations.

1.2.4 Receiver System

The Receiver System intercepts the solar energy redirected by the heliostats of the Collector System, converts this energy to thermal energy, and transfers this thermal energy to the receiver fluid, thus changing feedwater to superheated steam. The Receiver System includes the solar receiver with closure doors, associated pumps, valves, heat exchangers, controls, the receiver support tower and the tower accessories. The feedwater, steam, blowdown, and drain piping within the tower are included in the Receiver Piping System.

1.2.4.1 Solar Receiver. The water-steam solar receiver will have an external absorber surface as shown on Figure 1.2-2. The receiver will be similar to steam generators in many conventional fossil fuel fired power plants in that it will consist of three main sections: economizer (or preheater), boiler, and superheater. The boiler section consists of an outer row of spaced, vertical tubes which form a screen in front of an inner row of tubes which are welded to form membrane superheater panels. The screen tubes absorb part of the incident solar energy to maintain a




EXTERNAL RECEIVER ARTIST'S RENDERING

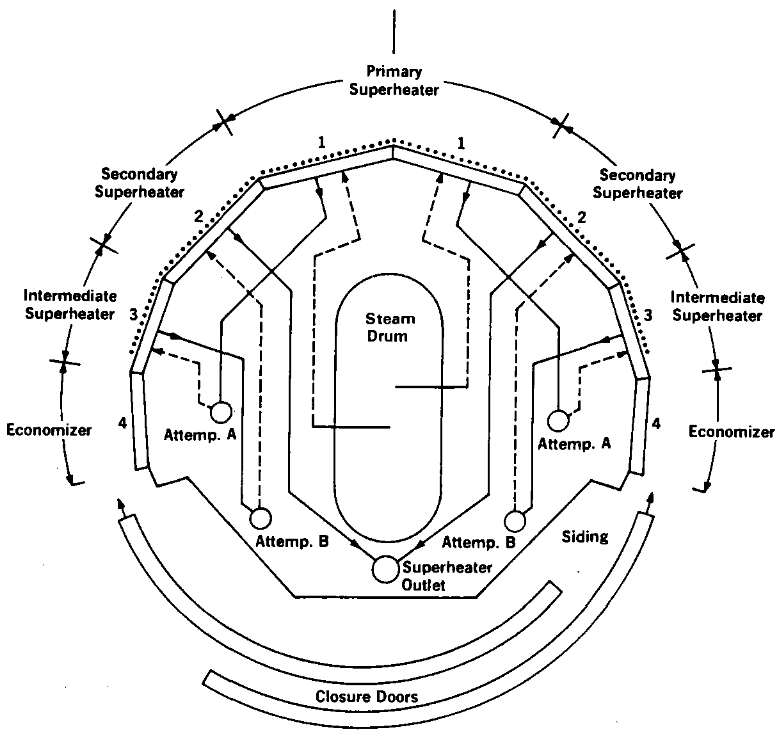
FIGURE I.2-2

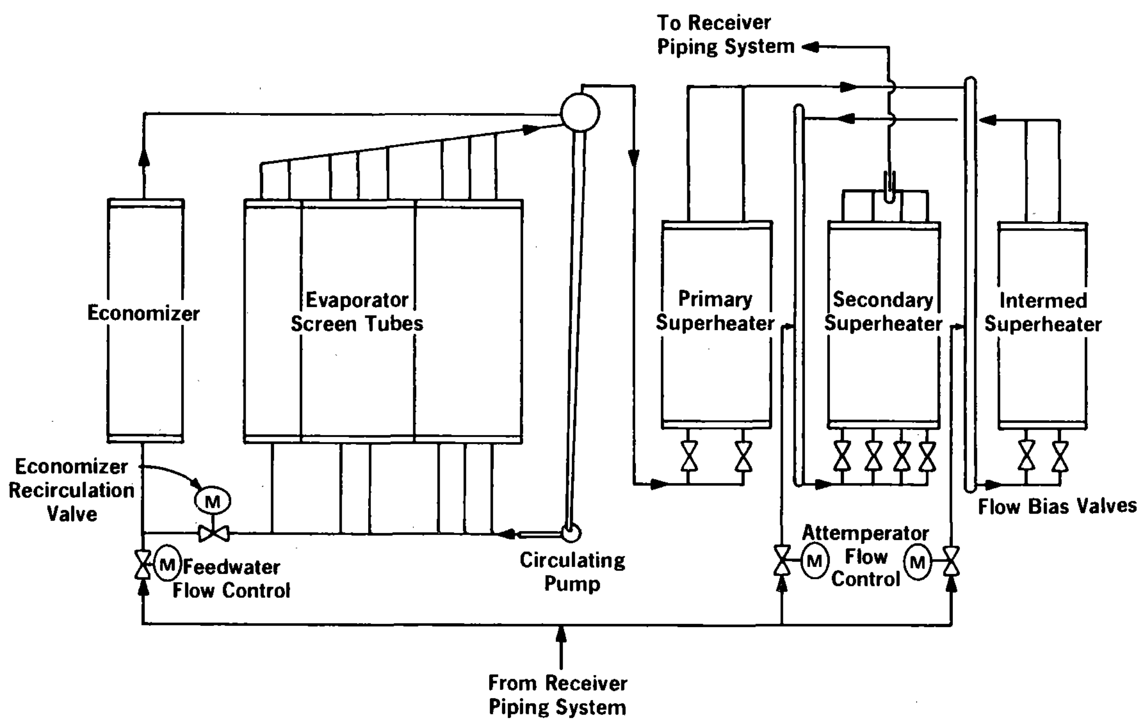
relatively low heat flux required on the superheater tubes. The incident solar flux is non-uniform around the receiver; however, the screen tube center-to-center spacing varies around the solar receiver in such a manner that the solar energy which penetrates the screen is fairly uniformly distributed on the superheater tubes. The screen tubes are capable of absorbing very high solar fluxes without DNB (Departure from Nucleate Boiling) difficulties, because of the use of ribbed tubes.

The flow sequence through the solar receiver is illustrated on Figure 1.2-3. Feedwater is introduced into the economizer, where it is preheated prior to entry to the steam drum. Slightly subcooled water flows from the drum, through a downcomer, and is pumped through supply pipes into headers which distribute the flow to the boiler screen tubes. The steam/water mixture flows from the boiler screen tubes into the steam drum where the water and steam are separated by cyclone separators and steam scrubbers. The saturated water returned to the drum is again mixed with feedwater from the economizer; this mixture flows through the downcomer to the pump and is recirculated. Moisture-free steam from the drum flows to the superheater.

The superheater is divided into two symmetrical flow paths, east and west, each consisting of three series passes with spray attemperation between the passes. Flow bias valves are located at the inlet to each superheater panel to provide proper flow distribution to panels during severe cloud transients. Steam from the drum enters the primary superheater where initial superheating occurs. The steam leaving the primary superheater flows through a steam downcomer to the intermediate superheater. A spray attemperator, located in the steam downcomer, is used to control the steam temperature by injection of feedwater into the steam flow. The steam leaving the intermediate superheater passes through the second stage attemperator located in another steam downcomer. From the attemperator, the steam enters the secondary superheater, where it is heated to the final steam temperature.

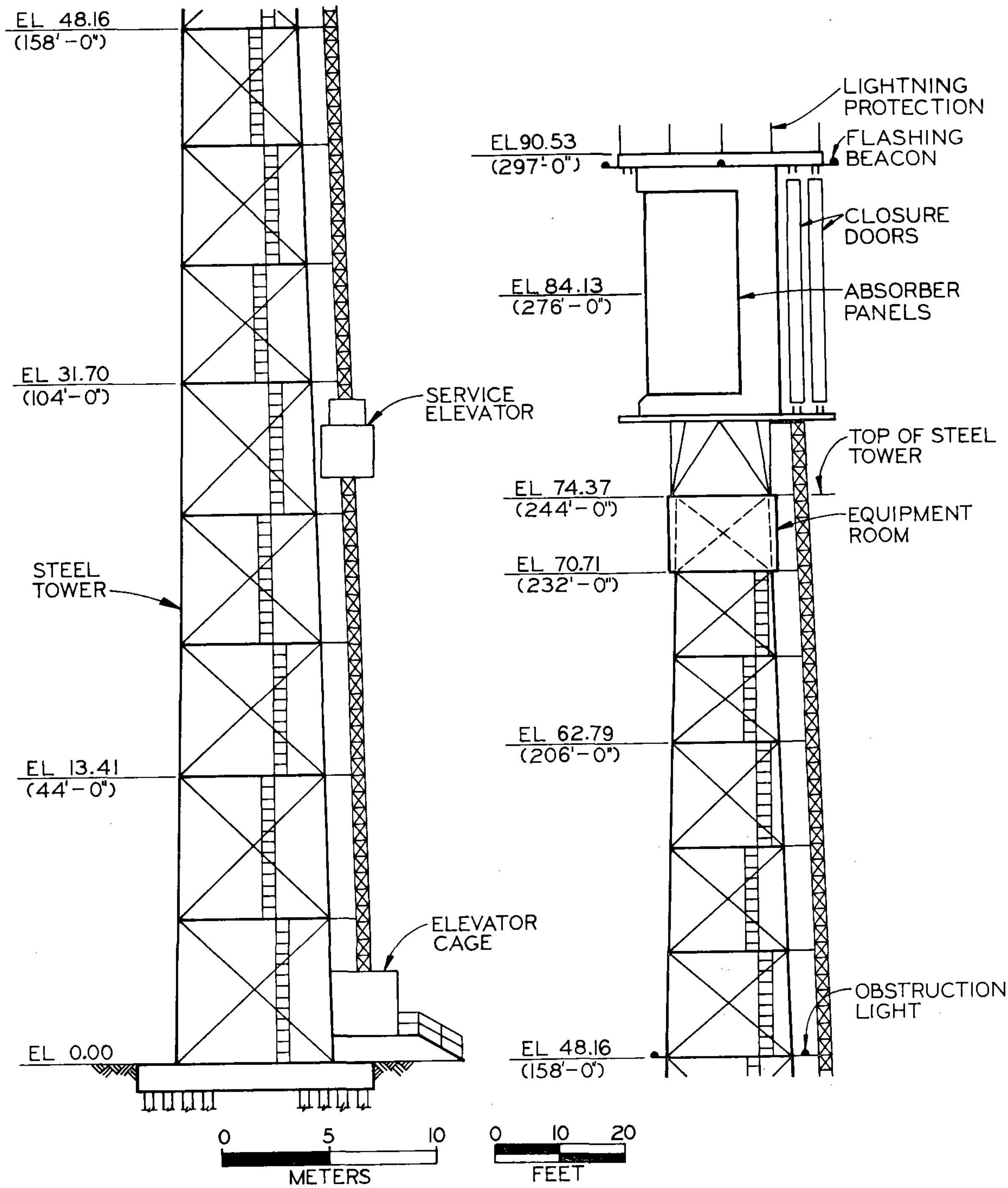
1.2.4.2 <u>Receiver Support Tower</u>. The receiver support tower, as shown on Figure 1.2-4, supports the solar receiver, withstanding gravitational,




SCHEMATIC ARRANGEMENT OF THE EXTERNAL RECEIVER

FIGURE I.2-3




RECEIVER TOWER

FIGURE 1.2-4

wind, and seismic loads. The tower also provides support for the feedwater and steam piping and electrical cables running up and down the tower.

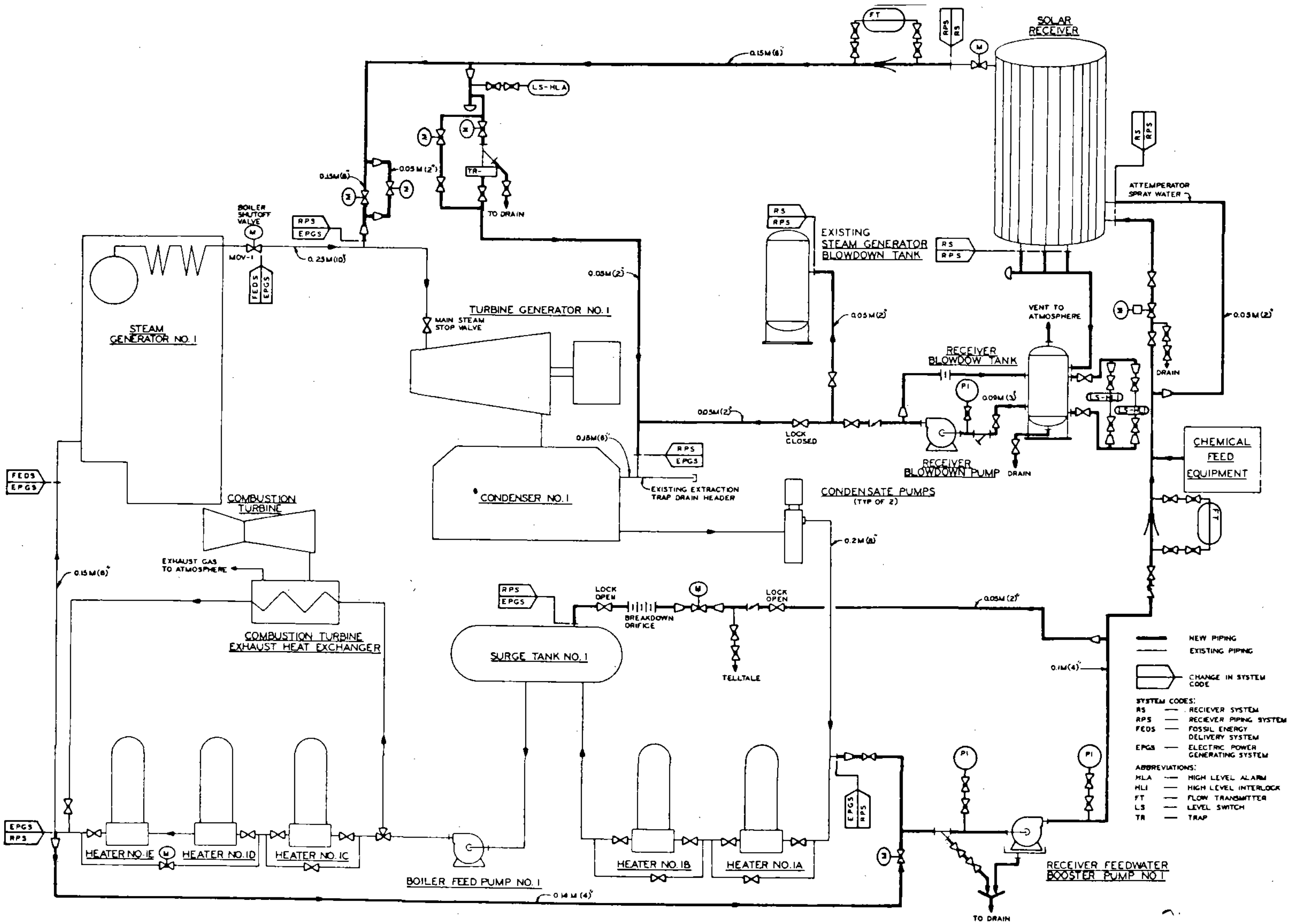
The tower will be of bolted steel construction with four support legs and X-bracing. The tower will be tapered, having a larger base than top. The tower foundation will be a reinforced concrete mat supported by concrete piles.

Tower accessories will include an elevator, caged ladder, equipment room lighting, communication equipment, and lightning protection. The elevator and ladder will provide access to both the equipment room and the receiver.

### 1.2.5 Receiver Piping System

The Receiver Piping System (RPS) provides the piping interface between the existing Electric Power Generating System (EPGS) and the Receiver System. A flow diagram of the RPS and its interconnections with other systems is provided on Figure 1.2-5. The RPS transports feedwater from the last high pressure feedwater heater in the EPGS to the solar receiver. A receiver feedwater booster pump is provided to overcome the higher pressure associated with the RPS and Receiver System as compared to the existing steam generator. This higher pressure is due to the longer piping lengths, the elevation of the receiver, and the pressure drop through the receiver. The RPS also transports the high pressure, high temperature steam produced in the solar receiver to the existing EPGS main steam line for delivery to the turbine. Piping, valves, instrumentation, and equipment to recirculate feedwater through the receiver for warming or freeze protection, to protect the receiver feedwater pump from overheating, and to drain the receiver and RPS steam piping are also included as part of the RPS.

Drains and blowdown from the receiver are taken to the solar receiver blowdown tank located near the receiver base. The receiver blowdown tank is normally pumped to the existing EPGS blowdown tank for disposal. However, during start-up, and when draining the receiver, a method of recovering this water is provided by pumping the receiver blowdown tank through a normally locked closed valve to the main condenser.




RECEIVER PIPING SYSTEM
FLOW DIAGRAM

FIGURE 1.2-5

Condensate collected in the main steam line is drained to the EPGS through a trap located at the low point in the piping system. A motor operated valve in the bypass around each trap will open upon detection of water in the associated drip leg. This serves as a backup for removing excessive condensate from the steam line. The RPS drain lines interface with the EPGS at the extraction trap and drain header.

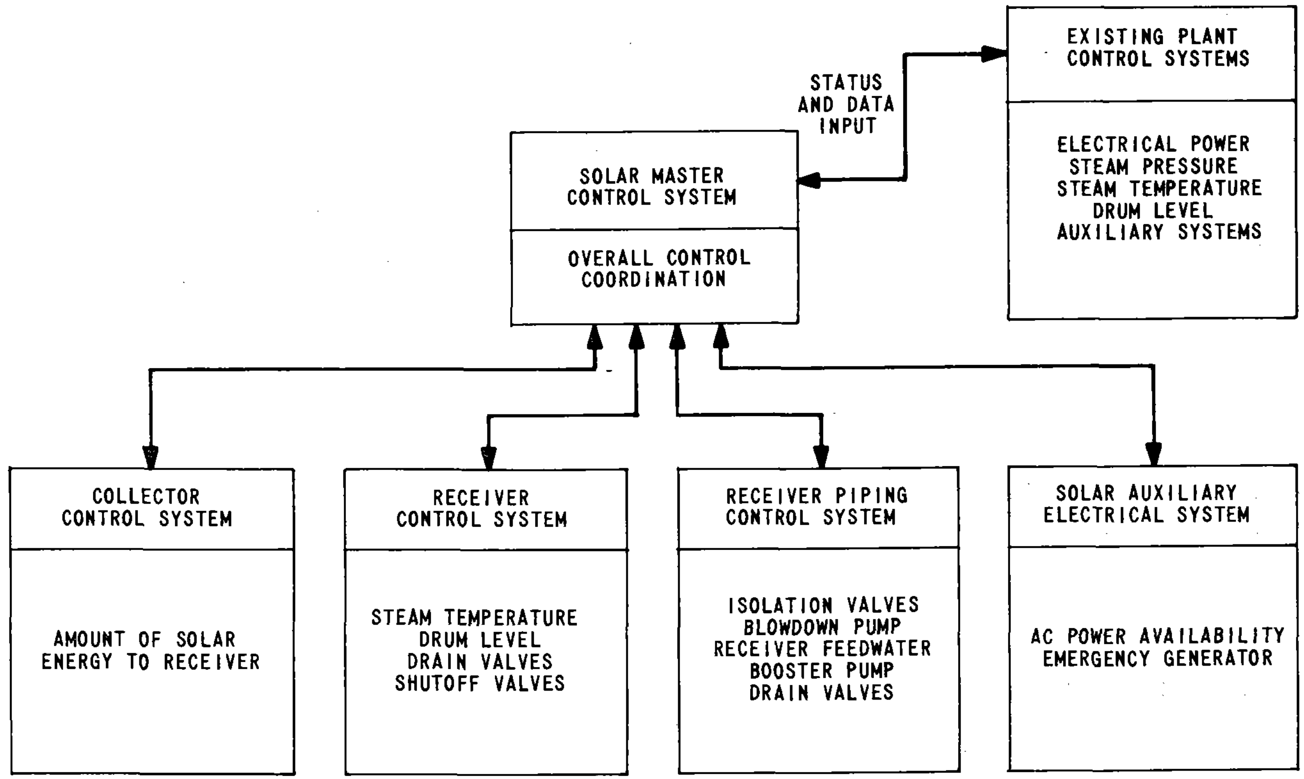
The RPS includes phosphate chemical feed additive equipment for chemical treatment of the solar receiver boiler water.

The steam, feedwater, and condensate piping located within the receiver tower is supported from the tower structure by pipe supports that permit the movement of piping to accommodate thermal expansion. The steam, feedwater, and condensate piping located at grade level is supported by concrete and steel structures, with pipe support attachments as required for anchoring and guiding the piping during movement due to thermal expansion. An elevated pipe support structure is also provided near the existing plant where the RPS must cross the roadway and parking space. All piping includes sufficient expansion loops to accommodate thermal expansion. The piping is insulated to reduce thermal losses.

### 1.2.6 Solar Master Control System

The Solar Master Control System will coordinate the operation of the Collector, Receiver, Receiver Piping, and Solar Auxiliary Electric Systems to ensure safe and proper operation of the solar cogeneration facility. The Solar Master Control System operates at the highest level in the control hierarchy shown on Figure 1.2-6. The Solar Master Control System issues commands to the control systems at the lower level of this hierarchy and receives feedback status information from these control systems. The Solar Master Control System provides the capability for automatic start-up, normal operation, and shutdown of the Collector, Receiver, and Receiver Piping Systems. The Solar Master Control System will also issue emergency shutdown commands whenever critical process parameters exceed allowable operating limits.

This system will also serve as a central data acquisition system which monitors, analyzes, and displays all critical solar parameters.




CONTROL SYSTEM HIERARCHY

FIGURE I.2-6

The Solar Master Control System consists of a control computer, a data acquisition computer, computer peripheral equipment, control and display consoles, interface equipment to the other process systems, and all software required for a fully operational system.

The hardware configuration of the SMCS is shown on Figure 1.2-7. The key elements of the SMCS will be a control computer, a data acquisition computer, and a control panel. These computers will be supported by a complete set of peripherals for program editing and loading, for display of operating parameters to the operator, and for storage of data for off-site analysis. The computer will be located in an area adjacent to the main control room. Remote multiplexing equipment will be located in the receiver tower. The SMCS control panel, located in the main control room, will contain all displays and manual controls needed to operate the solar equipment.

### 1.2.7 Fossil Energy Delivery System

The Fossil Energy Delivery System (FEDS) utilizes natural gas to generate steam for delivery to the Electric Power Generating System. The interface points between the Fossil Energy Delivery System and the EPGS are the boiler shutoff valve (included in FEDS) for steam and, for feedwater, the feedwater piping (included in EPGS) to the boiler. The Fossil Energy Delivery System consists of the following.

(1) The steam generator.

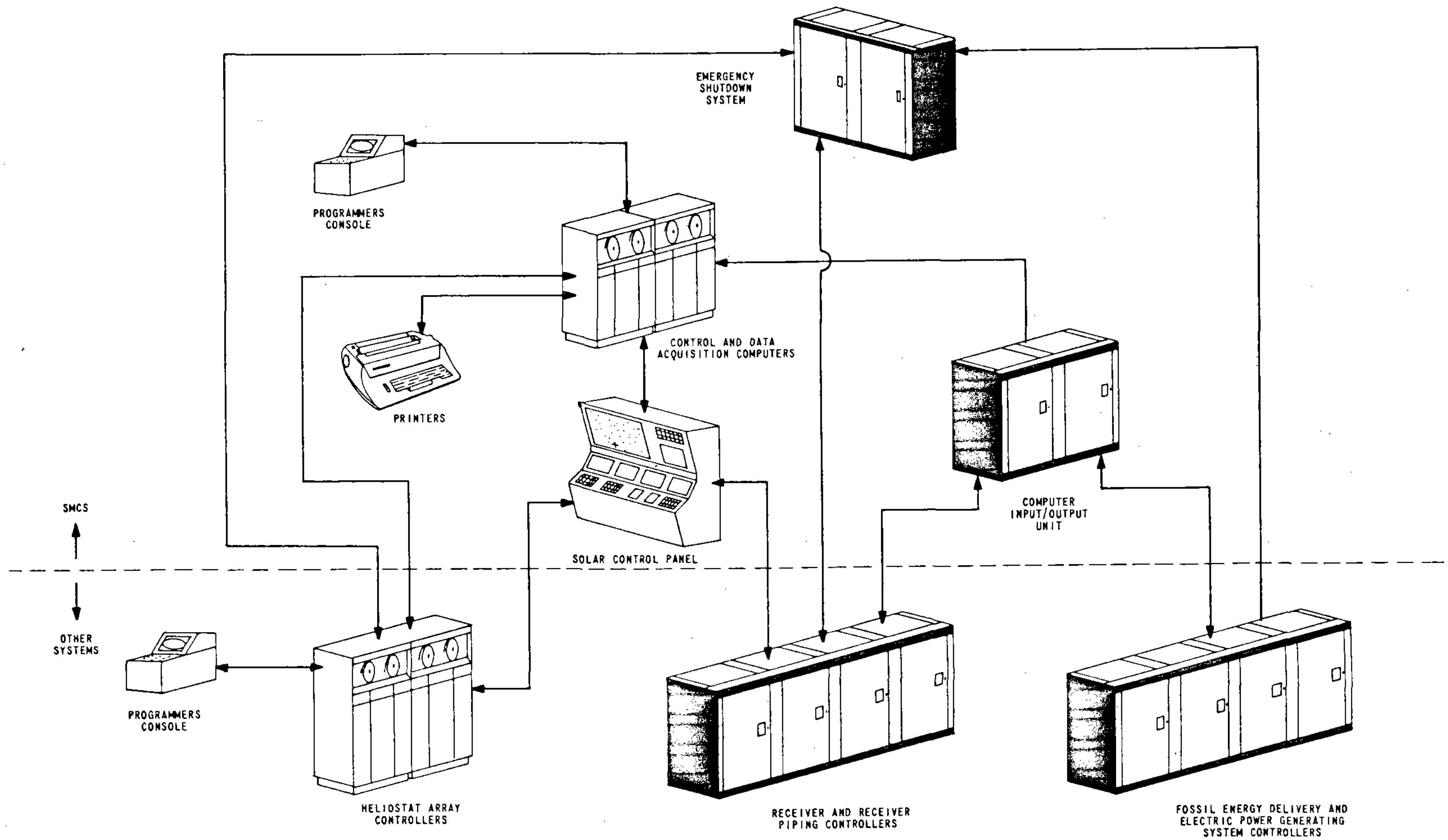
(2) Piping and valves needed to provide fossil fuel to the steam generator.

(3) Control system necessary for safe and efficient start up, operation, shut down, and standby of the Fossil Energy Delivery System.

The addition of the solar cogeneration facility does not require any modification of the FEDS.

### 1.2.8 Electric Power Generating System

The Electric Power Generating System (EPGS) receives thermal energy from the Receiver Piping System, and/or the Fossil Energy Delivery System and converts a portion of the thermal energy to electricity. Interfaces




**SOLAR MASTER CONTROL SYSTEM EQUIPMENT CONFIGURATION**

FIGURE 1.2-7

with the FEDS and Receiving Piping System are as defined in Section 1.2.5 and 1.2.7. The Electric Power Generating System includes the following.

(1) The turbine-generator.

(2) Feedwater heaters.

(3) Condenser, cooling towers and other heat rejection equipment.

(4) Turbine lubricating equipment.

(5) Generator cooling equipment.

(6) Piping, pumps, and valves.

(7) Control system necessary for safe and efficient start up, operation, shut down, and standby of the Electric Power Generating System.

The solar addition to the existing plant will require modifications to the existing steam generator combustion and turbine control systems to permit a variable steam pressure operating strategy which is necessary to maintain steam generator outlet steam at rated temperature during low load operation. Slight modifications to the existing service water system will be made to provide seal water cooling for the receiver feedwater booster pump and a hose connection will be added to the demineralized water system to provide a means of filling the heliostat wash vehicle.

1.2.9 Process Heat System

The Process Heat System delivers process heat in the form of extraction steam to the National Helium Corporation (NHC). It receives thermal energy from the Receiver System and/or the Fossil Energy Delivery System, via the Electric Power Generating System. This system does not require modification as a result of adding solar and hence, is described here only briefly for continuity. (See Section 5.2, Existing Facility Description, for more details.) The point of interface between the Process Heat System and EPGS shall be the pressure control valves branching off of the first two extraction steam lines of the turbine; these valves are a part of the Process Heat System. The Process Heat System consists of the following.

(1) Steam piping to NHC and condensate return piping to the EPGS.

(2) Related piping, pumps, and valves.

(3) Control system necessary for safe and efficient start up, operation, shut down, and standby of the Process Heat System.

1.2.10 Solar Auxiliary Electric System

The Solar Auxiliary Electric System (SAES) provides electric power to the solar cogeneration facility system components from the existing station power distribution system. It also provides uninterruptible power to equipment having critical control and instrumentation functions. The SAES consists of the following.

(1) Emergency Diesel Generator.
(2) Transformers, switchgear, motor control centers and distribution panels needed exclusively for delivering electric power to the solar facility system components.
(3) Battery, chargers, and inverters for uninterruptible power supply.
(4) Associated cable and raceway.
(5) Control system necessary for safe and efficient operation of the SAES in all modes.
(6) Building and area lighting.
(7) Grounding and lighting protection.

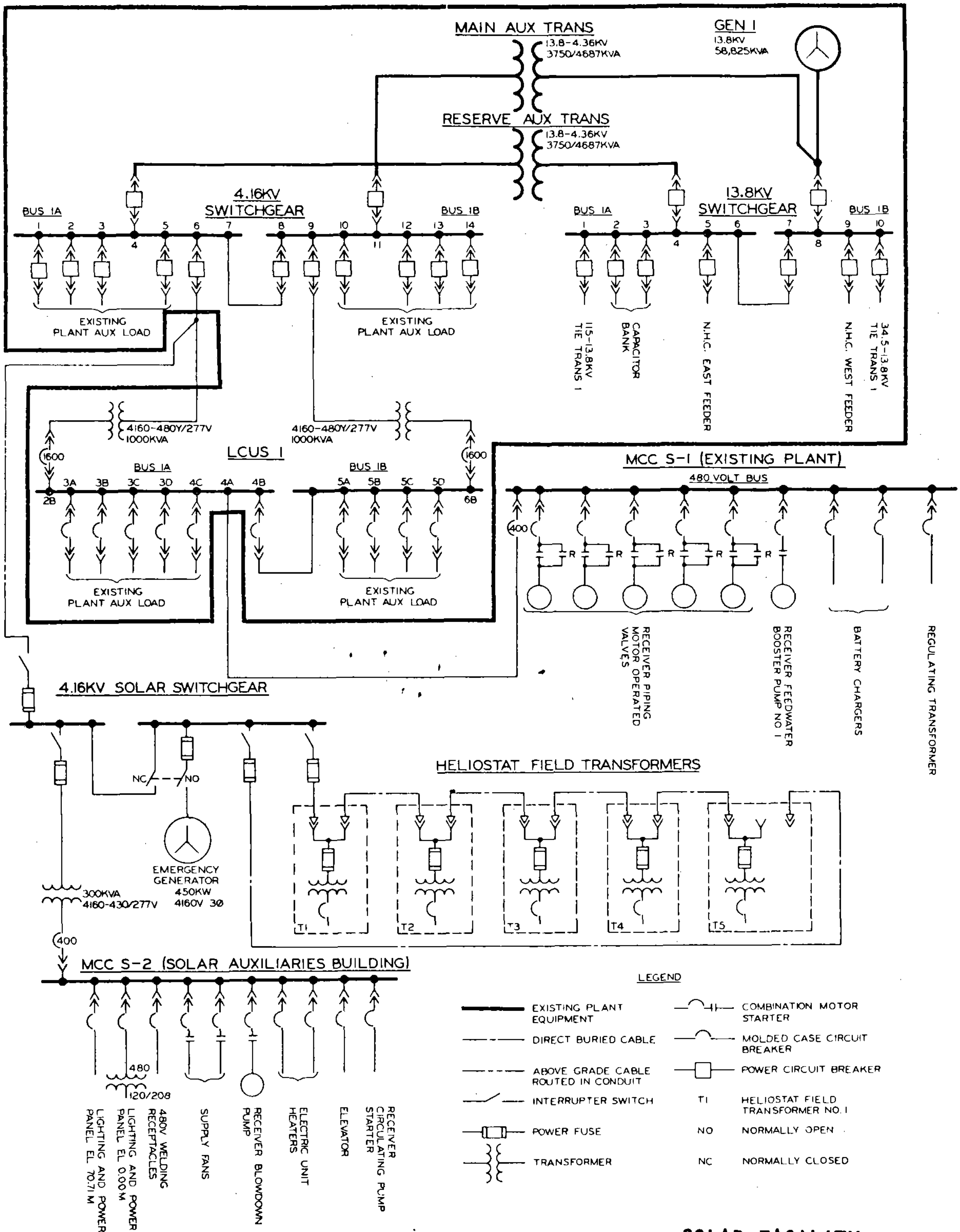
One-line diagrams of the SAES normal ac power supply and the uninterruptible ac power supply are provided on Figures 1.2-8 and 1.2-9.

1.2.11 Specialized Equipment

Specialized equipment required for maintenance of the solar receiver and heliostats is described in the following.

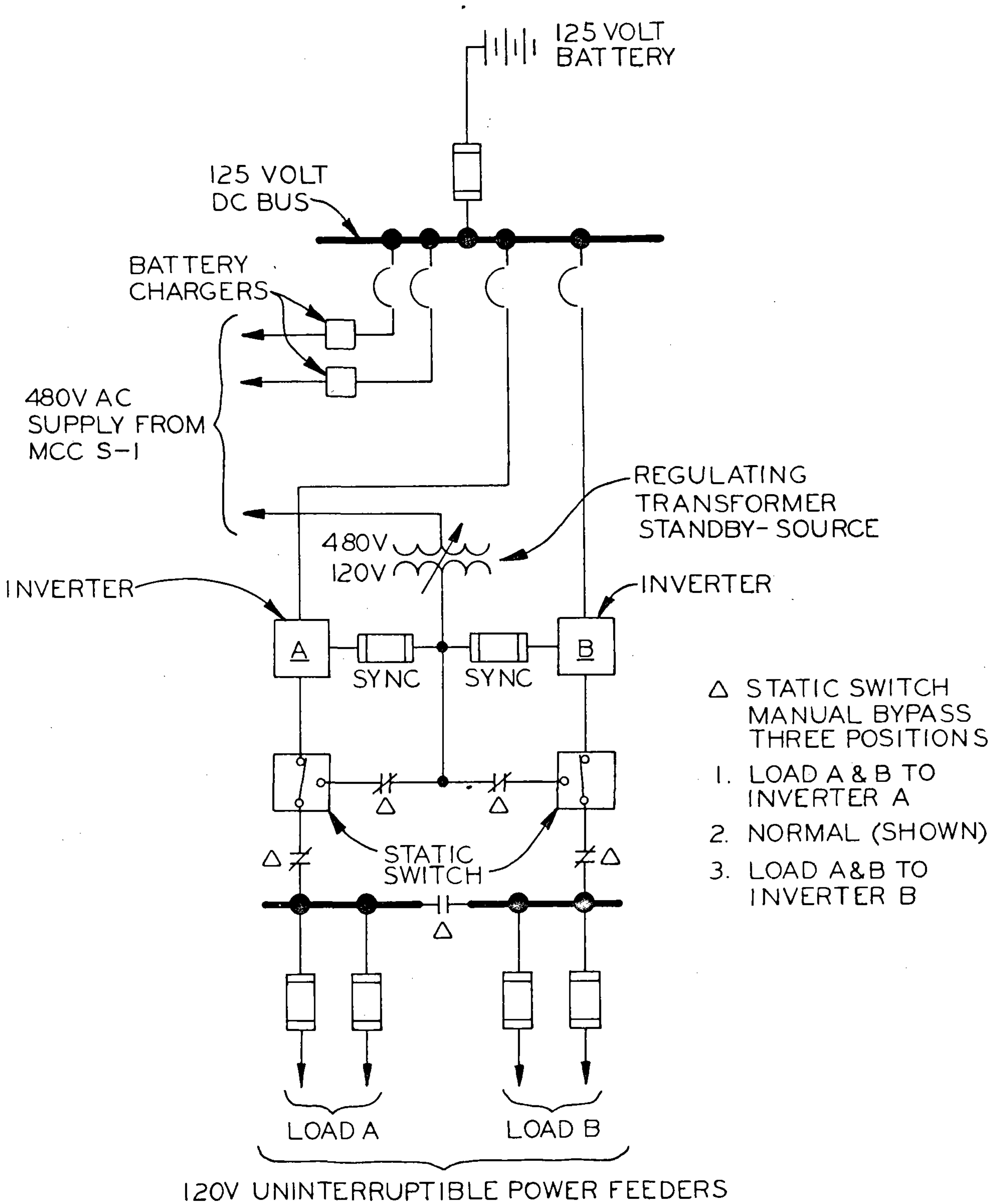
1.2.11.1 Specialized Solar Receiver Equipment. The solar receiver will be designed for a 30 year lifetime with no replacement of major components. However, the random replacement of failed boiler or superheater tubes and the periodic recoating of the receiver's high-absorptivity coating will be required. These corrective maintenance actions will involve the use of specialized equipment.

The receiver support tower will be equipped with a caged ladder and a 1,000 kg (2,200 lb) capacity service elevator to provide maintenance personnel access to the solar receiver atop the tower. A hoist may be




**SOLAR FACILITY**
**NORMAL AC POWER SUPPLY**
**ONE-LINE DIAGRAM**

**FIGURE 1.2-8**




**SOLAR FACILITY UNINTERRUPTIBLE AC POWER SUPPLY**

**FIGURE 1.2-9**

provided inside the tower to lift tools and equipment which are too heavy for the elevator. The hoist will facilitate replacement of valves and pumps and other components atop the receiver tower.

1.2.11.2 Specialized Heliostat Equipment. The heliostats of the Collector System will require scheduled maintenance consisting primarily of reflector cleaning. Cleaning of the heliostat reflectors will be accomplished via the heliostat washing vehicle. This vehicle will consist of a flat-bed truck carrying a self-contained, high pressure spray system and tanks of detergent and rinse solutions. A fixed vertical spray arm with multiple spray nozzles will spray the detergent or rinse solution onto the heliostat reflector, spraying the entire reflector width in one pass as the washing vehicle slowly drives past a heliostat. The Solar Master Control System will turn the heliostats to the proper orientation for washing: reflector surfaces vertical and facing the receiver support tower.

In addition to the above scheduled maintenance, the heliostats will require occasional corrective maintenance, due to the random failure of components and damage by the elements. Because damage to a heliostat from a lightning strike may be total, all equipment necessary for the assembly and installation of a complete heliostat will be required. This equipment will include leveling equipment for the adjustment of the foundation anchor bolts, a mobile crane and/or fork lift for the setting of heliostat pedestal, drive unit, and reflector unit, and the field collector and laser aiming system for the alignment of the heliostat. The special brackets, slings, and cradles required for the placement of a heliostat as well as the equipment itself will be available from the initial installation of the heliostats.

## 1.3 DEFINITION OF TERMS

(1) Beam Pointing Error--The angular difference between the aim point and the beam centroid of a mirror.

(2) Capacity Factor Annual, Nonsolar--Annual nonsolar $MWh_t$ divided by the product of 8,760 h and facility or unit rating in $MW_t$.

(3) Capacity Factor Annual, Overall--Annual solar $MWh_t$ plus annual nonsolar $MWh_t$ divided by the product of 8,760 h and facility or unit rating in $MW_t$.

(4) Capacity Factor Annual, Solar--Annual solar $MWh_t$ divided by the product by 8,760 h and facility or unit rating in $MW_t$.

(5) Cogeneration--The combined production of electrical or mechanical energy and useful thermal energy.

(6) Conversion Efficiency, Gross--Gross output provided by a conversion device divided by total input power at specified conditions.

(7) Conversion Efficiency, Net--Actual net output (after deducting parasitics) provided by a conversion device divided by the required input power at specified conditions.

(8) Demand--The power required versus time profile of the power required to satisfy the needs of the final consumer or end use consuming process.

(9) Design Point--The time and day of the year at which the system is sized with reference to insolation, wind speed, temperature, humidity, dewpoint and sun angles.

(10) Direct Insolation--Non-scattered solar flux falling on a surface of a given orientation (watts/$m^2$).

(11) Field Receiver Power Ratio--Maximum heliostat field power output divided by maximum receiver power absorption capability.

(12) Fluid, Working--The fluid used in the turbine or other prime mover.

(13) Fluid, Receiver--The fluid used to cool the solar receiver and distribute the absorbed solar energy to other parts of the system; the heat transport fluid of the receiver.

(14) Geometric Concentration Ratio--The ratio of the projected area of the collector system (on a plane normal to the insolation) divided by the active receiver area.

(15) Levelized Busbar Energy Cost--That price per unit of energy which, if held constant throughout the life of the system, would provide the required revenue, assuming that all cash flow interim

requirements or excesses are borrowed or invested at the utility's internal rate of return.

(16) Payback Period--A traditional measure of economic viability to an investment project. A payback period is defined in several ways, one of which is the number of years required to accumulate fuel savings which exactly equal the initial capital costs of system. Payback often does not give an accurate representation of total life-cycle values.

(17) Process Heat--Thermal energy which is used in industrial operations.

(18) Rated Thermal Power, Prime Mover--Thermal power input to the turbine or other prime mover at design point. For cogeneration, thermal power to operate the balance of the system is included.

(19) Receiver Efficiency--Ratio of thermal power output at the receiver base to incident solar power upon the receiver.

(20) Solar Cogeneration--Utilizing solar central receiver technology for the combined production of electrical or mechanical energy and useful thermal energy.

(21) Solar Flux--The level of solar radiation per unit area (watt/$m^2$).

(22) Solar Fraction, Annual--Ratio of solar energy delivered to the process divided by the total energy consumption of the process, computed on an annual average, and measured at the turbine inlet or at the process heat end-use device inlet.

(23) Solar Fraction, Design Point--As above, at the design point.

(24) Solar Multiple--Defined at the design point as thermal power from the receiver after downcomer and piping losses divided by the rated thermal power of the prime mover (definition above).

(25) Storage Capacity--The amount of net energy which can be delivered from a fully charged storage system ($MWh_e$ or $MWh_t$).

(26) Thermal Power, Fossil Boiler Output--Thermal power input to working or transport fluids from the fossil boiler after stack and miscellaneous losses.

(27) Thermal Power, Receiver Output--Thermal power derived from the receiver (does not include electrical parasitic or downcomer thermal losses).

# 2.0 REFERENCES

The equipment, materials, design, and construction of the Cimarron River Station Solar Cogeneration Facility shall comply with all federal, state, and local standards, regulations, codes, laws, and ordinances currently applicable for the specific site and user. These shall include but not be limited to the references listed below. If there is an overlap in, or conflict between the requirements of these references and the applicable federal, state, county, or municipal codes, laws, or ordinances, that applicable requirement which is the most stringent shall take precedence. In the event of conflict between the standards and codes referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

## 2.1 STANDARDS AND CODES

Applicable standards and codes are listed below.

(1) Uniform Building Code--1979 Edition by International Conference of Building Officials.

(2) International System of Units--as specified in NASA SP-7012 and ANSI-Y 10.19-1969.

(3) Human Engineering Design Criteria, MIL-STD-810C and MIL-STD-1472.

(4) ASME Boiler and Pressure Vessel Code.

- (a) Section I--Power Boilers.
- (b) Section II--Materials Specifications.
- (c) Section V--Nondestructive Tests.
- (d) Section VIII--Unfired Pressure Vessels.

(5) ANSI B31.1 1980 Power Piping Code.

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

(7) National Fire Protection Association (NFPA) National Fire Codes--1981 Edition.

(8) Design, Construction and Fabrication Standards.

- (a) Standards of AISC (American Institute of Steel Construction).
- (b) Standards of ACI (American Concrete Institute).

(c) Standards of TEMA (Tubular Exchanger Manufacturer's Association).

(d) Standard 650 of API (American Petroleum Institute) Welded Steel Tanks for Oil Storage.

(e) NRC Regulatory Guide 1.60 (seismic design response spectra).

(f) NRC Regulatory Guide 1.61 (damping values for seismic design).

(g) National Electrical Code, 1981 Edition.

(h) Standards of IPCEA (Insulated Power Cable Engineers Association).

(i) Standards of NEMA (National Electrical Manufacturers Association.

(j) Standards of UL (Underwriters' Laboratory).

(k) Standards of ASTM (American Society for Testing and Materials).

(l) Standards of ANSI (American National Standards Institute) for electrical equipment.

(m) Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, ANSI A58.1-1972.

## 2.2 OTHER PUBLICATIONS AND DOCUMENTS

Heliostat performance requirements are based on the requirements specified in the Collector Subsystem Requirement Specification, A10772, Issue D, December 11, 1979.

## 2.3 PERMITS AND LICENSES REQUIRED

The approvals from Federal and State administrative agencies which may be required for this Solar Cogeneration Facility are as follows.

(1) Kansas Department of Human Resources--Annual boiler inspection.

(2) Federal Aviation Administration--Notice of intent to construct.

(3) Kansas Department of Health and Environment Wastewater Discharge (NPDES)--A permit is required if there is any change in the quantity or content of the discharge.

(4) Kansas Department of Health and Environment Open Burning Exemption (28-19.45)--A permit is required if open burning is used during land clearing activities.

Furthermore, if federal funds are involved, the funding agency may require the preparation of an Environmental Assessment and, possibly, an Environmental Impact Statement before federal funds can be allocated to the project.

## 2.4 APPLICABLE LAWS AND REGULATIONS

The laws and regulations which apply to the Solar Cogeneration Facility are listed below.

(1) National Energy Conservation Policy Act of 1978.

(2) Power Plant and Industrial Fuel Use Act of 1978.

(3) Public Utilities Regulatory Policy Act.

(4) Natural Gas Policy Act of 1978.

(5) Energy Tax Act of 1978.

(6) National Environmental Policy Act (NEPA).

(7) Clean Air Act.

(8) Clean Water Act.

(9) Regulations of the Occupational Safety and Health Administration (OSHA).

(10) Regulations of the Federal Aviation Administration (FAA).

(11) Kansas Department of Health and Environment Regulation 28-19-45 (open burning).

# 3.0 REQUIREMENTS

The solar cogeneration facility shall be designed to meet the design requirements of this section. Additional design requirements may be added as a result of future, detailed design activities.

## 3.1 MODES OF OPERATION

The solar cogeneration facility shall be capable of operating in the following modes.

(1) Non-Solar Operation. The non-solar (fossil) mode of operation shall use the fossil steam generator as the only source of steam. The existing automatic controls of the fossil steam generator and turbine shall maintain the electrical and process steam output of the facility at the desired loads. In addition, during non-solar operation, all portions of the solar facility shall be safeguarded against damage due to extreme environmental conditions.

(2) Normal Solar Operation. The normal (hybrid) mode of solar operation shall use the fossil steam generator and the solar receiver as parallel steam sources. As in the case of non-solar operation, automatic controls shall maintain the electrical and process steam outputs of the facility at their desired levels. As the amount of available solar insolation changes throughout the day, the solar receiver steam flow will vary; the fuel firing rate of the fossil steam generator shall automatically compensate for changes in receiver steam flow to maintain the appropriate turbine steam flow.

(3) Intermittent Cloud Operation. During intermittent cloud passage, the facility shall continue to operate normally. The firing rate of the fossil steam generator shall automatically be adjusted to compensate for the changes in solar receiver steam flow.

(4) Solar Start-up. Start-up of the solar portion of the facility shall be automated, and shall provide coordination of all solar systems so as to bring the solar facility on-line quickly and

efficiently, without exceeding temperature or pressure ramp rates. Provisions shall be made for fossil-generated steam and feedwater to be utilized for receiver preheating.

(5) Solar Shutdown. Normal shutdown of the solar portion shall be automated. Shutdown shall be performed in an orderly manner, thus reverting the facility to non-solar operation. Solar components shall be returned to their overnight positions.

(6) Emergency Solar Shutdown. Upon detection of any abnormal operating condition which might compromise personnel safety or equipment integrity, a rapid automatic shutdown of the solar equipment shall be performed.

## 3.2 SITE

Site development work will primarily consist of grading, construction of access roads and parking, and security fencing. No lighting will be required except at the receiver tower. Site preparation work will be minimized to reduce costs and preserve natural drainage systems as much as possible.

### 3.2.1 Grading

The site will be graded to a maximum slope of four per cent. This will keep the amount of earthwork to a minimum, yet prevent shadowing of adjacent heliostats. A four per cent maximum grade will also permit access of maintenance vehicles to service the heliostats. The total volume of material to be moved is estimated to be 150,000 $m^3$ (200,000 $yd^3$).

### 3.2.2 Drainage

The natural site drainage will be preserved as much as possible, augmented by drainage ditches adjacent to the access roads, and culverts where the roads cross natural drainage patterns. Existing berms which direct runoff away from the plant will be modified as necessary to accommodate the heliostat field and access roads.

### 3.2.3 Roads and Parking

A paved road will be provided to connect the existing road at the cooling towers to the receiver tower. The parking area at the tower will also be paved to reduce dusting of the heliostat field. This main road and the parking area will be permanent-type construction with a crowned 6 m wide (20 ft) traffic lane, 1.5 m wide (5 ft) shoulders, and contoured drainage ditches.

A secondary 3.5 m wide (12 ft) unpaved road will be provided from the receiver tower around the heliostat field. It will be constructed of crushed rock and oiled to minimize dusting of the heliostat field.

#### 3.2.4 Security Fencing

The existing primary fencing section will be supplemented with new fencing to surround the solar facility.

#### 3.2.5 Foundations

Site soils consist of various mixtures of sand, clay, and gravel. There are no subsurface rock formations which will affect site grading or which may be used for foundation support. Heliostats and the receiver support tower will be supported on auger cast piles. Other small miscellaneous structures will be supported by slabs on grade.

### 3.3 SITE FACILITIES

The existing facilities at the Cimarron River Station will be used to supply most of the auxiliary services required by the solar facility addition. The following paragraphs summarize the required services and how they will be provided.

#### 3.3.1 Service Water

The design will include a connection to the existing plant service water system for cooling the receiver feedwater booster pump.

#### 3.3.2 Nitrogen

A separate nitrogen supply system will be provided for the solar facility. The system will be capable of supplying the maximum demands for inerting the receiver, feedwater pipe, and transport pipe during shutdown.

During normal overnight shutdowns, the closure doors on the receiver and insulation on the main steam pipe will minimize heat loss and pressure decay in the system. Nitrogen requirements during overnight shutdown will therefore be minimal.

The largest routine use of nitrogen will be in the winter months when the solar receiver may be shut down for more than one day at a time.

Feedwater would be recirculated and the system would not normally be drained. Nitrogen gas use during these winter shutdown periods is expected to be less than 11.3 scm (400 scf).

Nitrogen inerting will automatically be initiated whenever the system pressure drops below 0.14 MPa (20 psia).

The nitrogen gas storage containers will be standardized compressed gas bottles with an interconnecting manifold. The total storage capacity will be sufficient to inert the total system three times at 0.12 MPa (18 psia) plus 30 to 50 per cent margin to allow for leakage. The system will be capable of being refilled by local suppliers.

### 3.3.3 Fire Protection

Hand-held and movable cart-mounted dry chemical fire extinguishers will be provided in the receiver tower area. No interconnection with the existing plant fire protection system is planned.

### 3.3.4 Communications

A communications system between the solar receiver tower and the main control room will be provided.

### 3.3.5 Water Treatment

The existing plant water treatment facilities will be used for water treatment for various solar facility uses. A hose connection downstream of the demineralization system will be added to provide a means to fill the heliostat wash vehicle with demineralized water.

### 3.3.6 Control Room

The solar equipment control panel will be located in the main control room.

### 3.3.7 Control Equipment

The control equipment cabinets and computers will be located in an area adjacent to the main control room.

### 3.3.8 Personnel Facilities

The existing plant buildings and parking lot will accommodate the additional personnel needed for the solar facility. No modifications of these facilities are planned.

3.3.9 Storage and Maintenance

The existing plant warehouse and machine shop facilities will be used. No modifications to these facilities are planned.

3.4 COLLECTOR SYSTEM

The Collector System consists of an array of computer-controlled heliostats which will redirect solar radiation onto the Receiver System. The Collector System will satisfy the receiver incident heat flux requirements described in Section 3.5 by employing a beam control strategy to distribute the locations of the individual heliostat images on the receiver surface. The beam control strategy will distribute the redirected power as evenly as possible on the receiver absorber surfaces while limiting the peak incident heat flux to 700 $kW/m^2$; heat fluxes on the tower and normally unirradiated portions of the receiver will be limited to 25 $kW/m^2$.

The Collector System will respond to commands from the Solar Master Control System for emergency defocusing of the reflected energy or to protect the heliostat array against environmental extremes. The environmental conditions to be encountered and survived by the Collector System are described in Section 4.0; the Collector System must maintain structural integrity in any applicable combination of those conditions.

Heliostat design will provide for stored or safe position for use at night, during periodic maintenance, and during adverse weather conditions. Heliostat drive systems will be environmentally sealed, and will provide corrosion protection of all parts.

The foundations for the heliostats shall provide a stable support in order that the performance objectives specified in Section 3.4.2 will be met. The dimensions and design forces shall be based on data produced for the second generation heliostat design in the DOE Heliostat Development Program.

3.4.1 Collector Field

The collector field design will provide a heliostat layout consistent with the following requirements.

(1) The collector field will direct 42.00 $MW_t$ onto the receiver absorber surfaces at the design point (Equinox Noon) with a reference insolation of 0.95 $kW/m^2$.

(2) The collector field will produce an incident heat flux distribution on the receiver consistent with the requirements specified in Section 3.5.

(3) Heliostats will be located in an area north of the Cimarron River Station cooling towers as illustrated on Figure 3.4-1. No heliostats will be located within the right-of-way of the buried gas pipelines on the east side of the plant site.

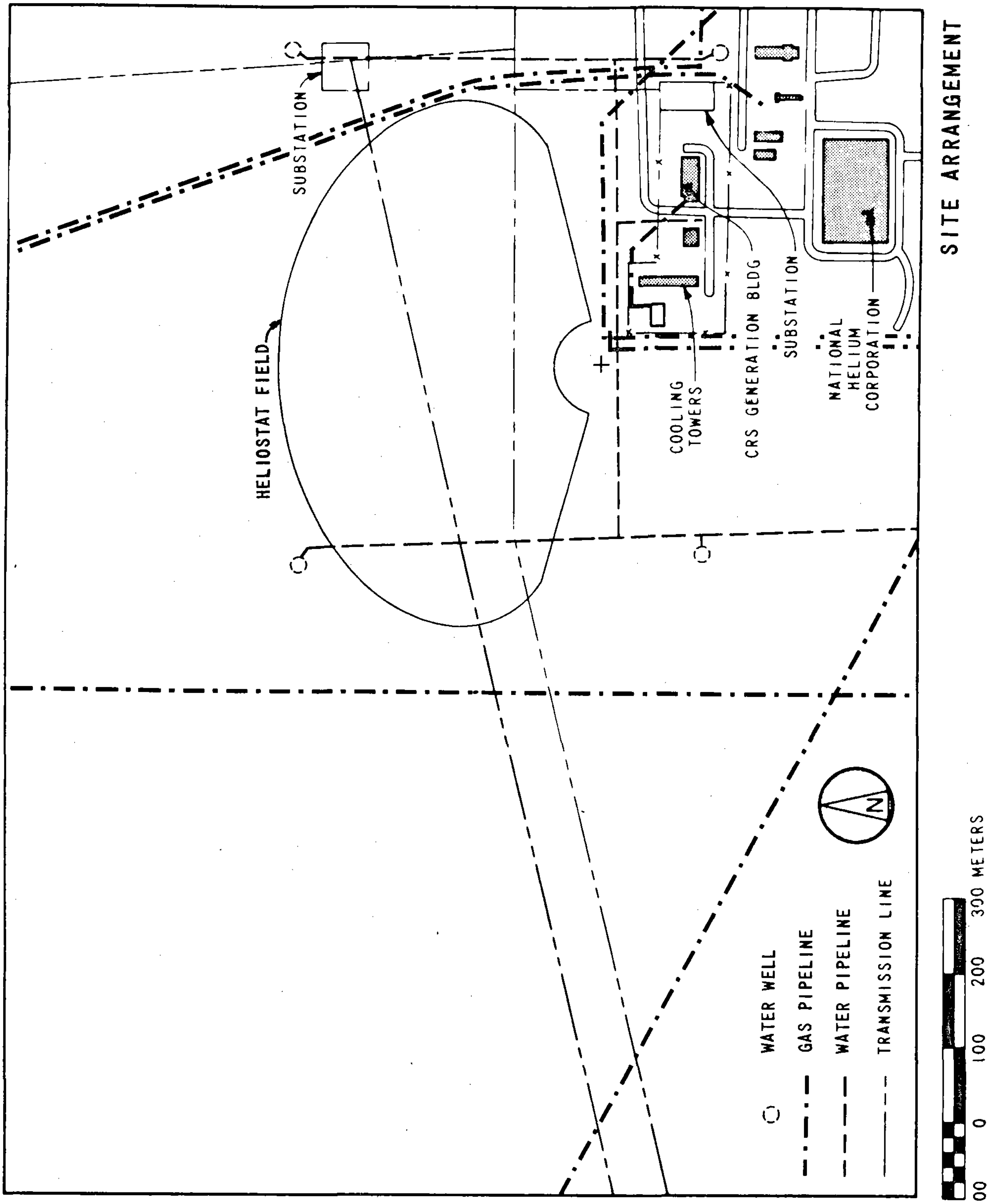
(4) The collector field will be graded to smooth the local terrain and fill will be compacted to permit the use of a standard heliostat foundation. Site grading will limit the maximum slope in any portion of the field to 4 per cent.

(5) The location of heliostats within the field will be determined to maximize the collector's annual performance per cost while satisfying the design point power and incident heat flux requirements specified above. Collector costs will include the following.

(a) Heliostat capital cost.
(b) Operation and maintenance cost.
(c) Field wiring cost.

Collector performance will include the annual effects of the following.

(a) Sun position.
(b) Direct normal insolation.
(c) Cosine effects.
(d) Shadowing and blocking.
(e) Mirror reflectivity.
(f) Atmospheric attenuation.
(g) Heliostat optical performance.
(h) Receiver size and elevation.
(i) Beam control strategy.




SITE ARRANGEMENT

FIGURE 3.4-1

3.4.2 <u>Heliostats</u>

The heliostats will meet or exceed the design and performance requirements given in Specification A10772 Issue D "Collector Subsystem Requirements" dated December 11, 1979. In addition, the heliostats will meet the environemental design requirements specified in Section 4.0.

3.5 RECEIVER SYSTEM

The Receiver System shall provide a means of transferring the incident solar radiation from the Collector System to the heat transfer fluid.

3.5.1 <u>Structural Design</u>

The receiver and tower will be designed to provide access for maintenance and inspection of tower structure, receiver, heat transfer fluid, instruments and controls, power conversion equipment (that may be located on the tower), utilities, etc. Consideration shall be given to ease of maintenance. Adequate provisions shall be made to ensure crew safety at all times for required operations, inspection, maintenance and repair. The receiver design will be in accordance with the intent of appropriate ASME Boiler codes.

3.5.2 <u>Receiver</u>

The Receiver will be an external receiver with closure doors. The receiver shall meet the following design requirements.

(1) Maximum flux at noon of equinox--0.70 $MWt/m^2$.

(2) Receiver incident power rating at noon of equinox--42.05 MWt.

(3) Water and steam receiver fluid.

(4) Receiver fluid mass flow rate at outlet of superheater 54,331 kg/h (119,800 lb/h).

(5) Receiver fluid inlet temperature--217 C (423 F).

(6) Receiver fluid outlet temperature--520 C (968 F).

(7) Receiver fluid outlet pressure--11.07 MPa (1,605 psia).

(8) Worst case tube life (fatigue life) per Section I ASME Boiler and Pressure Vessel Code.

(9) Construction technique is erection on the tower by parts.

(10) Overall receiver efficiency--88.3 per cent at equinox noon.

(11) Maximum allowable solar power incident on receiver--45.5 MWt.

(12) The receiver should be of the screen tube design with pump assisted circulation and three superheater passes with spray attemperation.

(13) Receiver Controls--The solar receiver shall be designed to provide the following types of controls.

(a) Feedwater flow control--To maintain proper water level in the drum.

- Normal operation--Feedwater flow demand established by measured steam flow and drum level.
- Start-up and shutdown--Feedwater flow based only on drum level. A high level dump valve is used to control drum level swell during start-up.

(b) Economizer Recirculating Valve Control--To provide a flow path from the recirculating pump discharge through the economizer panels at start-up and shutdown.

(c) Steam Temperature Control--To regulate the steam temperature at the superheater outlet through the use of water attemperation.

(d) Superheater Panel Bias Valve Control--To redistribute flow from cold panels to hot panels during transients. If modulation of the bias valve does not adequately control panel outlet temperatures, heliostats will be directed away from the hot panel(s).

(e) Controls to admit fossil generated steam from the EPGS to prewarm the receiver during startup.

3.5.3 <u>Receiver Fluid</u>

Receiver water quality shall be maintained as shown on Table 3-1.

Phosphate ($Na_3PO_4$) levels in the receiver drum will be checked approximately once a week. A small phosphate feed system located at the receiver equipment will be used to adjust the receiver drum phosphate level as required.

TABLE 3-1. RECEIVER WATER QUALITY

| | |
|---|---|
| Receiver Feedwater[a] | |
| Total Solids, ppm (max) | 0.15 |
| Hardness, ppm | 0.0 |
| Organic, ppm | 0.0 |
| Free Caustic, ppm | 0.0 |
| Oxygen, ppm | 0.007 |
| Total Silica (as $SiO_2$), ppm | 0.02 - 0.7 |
| Total Iron | 0.01 |
| Total Copper | 0.002 |
| pH | 8.8 - 9.2[b] |
| pH | 9.3 - 9.5[c] |
| Receiver Boiler Water | |
| Max Total Boiler Water Solids, ppm | 50 |
| Max Total Alkalinity, ppm | 10 |
| Max Chloride Ion Concentration, ppm | 5 |
| $NA_3PO_4$, ppm | 5 - 15 |
| $OH^-$ (max), ppm | 1 |
| pH (max) | 10.0 |
| Silica | As determined by drum pressure |
| $Na/PO_4$ Molar Ratio, Max. | 2.6 |

[a]There should be no sodium sulfite ($Na_2SO_3$) in the water to be used for spray attemperation of the superheater and it should be at least the quality of the feedwater.

[b]With copper alloys in feedwater heaters.

[c]With carbon steel in feedwater heaters.

3.5.4 Receiver Tower

The tower that supports the receiver, piping, and other elements of the Receiver System shall be designed to meet the following requirements.

(1) Tower height--74.37 m (244 ft) to receiver support level.

(2) Structural type--Bolted structural steel.

(3) Design wind, temperature, earthquake, snow, rain, and ice loadings shall be in accordance with Section 4.0, Environmental criteria.

(4) The tower foundation shall be designed to meet the following requirements.

(a) No uplift forces are allowed on any portion of the foundation under lateral loadings.

(b) The maximum settlement over the service life of the facility shall not exceed 0.025 m (1 in) total or 0.019 m (0.75 in) differential.

3.6 RECEIVER PIPING SYSTEM

The Receiver Piping System (RPS) will be designed in accordance with the ANSI Power Code B31.1. The receiver blowdown tank will be designed in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. All piping design pressures and temperatures will be based on the maximum sustained conditions at the piping inlet plus a suitable design margin.

The receiver booster pump will be sized to provide the receiver design flow at a head sufficient to overcome the additional pressure loss in the solar facility as compared to the Electric Power Generating System (EPGS).

Main steam and feedwater piping will be sized based on economic optimization. The condensate piping will be sized based on a reasonable pressure drop and velocity at the maximum expected return water conditions.

3.7 SOLAR MASTER CONTROL SYSTEM

A Solar Master Control System shall be provided to sense, detect, monitor and control all system and subsystem parameters necessary to ensure safe and proper operation of the solar energy producing portion of the solar cogenerating facility.

3.7.1 Operating Requirements

There will be two modes of operation; non-solar (fossil only) operation and combined fossil-solar (hybrid) operation. There will be a smooth transition between these two modes of operation.

During hybrid operation, all available solar energy will be utilized subject to any operational limitations of the solar equipment. The fossil boiler will always be operated above a minimum turndown level and there will be local and remote (dispatch) automatic load control throughout a restricted load range of the unit.

The solar equipment will be capable of operation by a single operator who will simultaneously operate the non-solar portions of the cogeneration facility. The mode of operation will be primarily automatic with manual override capability. All solar equipment will be operated from a centralized location in the existing control room for Unit 1. No operating personnel will be required in the receiver tower. The Solar Master Control System (SMCS) will be designed to support these operational criteria.

The SMCS will coordinate the independent controls of the other systems (Receiver, Collector, Receiver Piping, and Solar Auxiliary Electric Systems). The major control functions of the SMCS are as follows.

(1) Automated start-up of the solar equipment.

(2) Coordination of the collector and receiver during solar operation.

(3) Automated shutdown of the solar equipment.

(4) Emergency shutdown of the solar facility.

3.7.1.1 Automated Start-up. Because of the relatively large number of control actions necessary during the start-up of the solar equipment and because the equipment is to be operated by a single operator who will also have additional non-solar responsibilities, solar equipment start-up will be automated to minimize the required operator actions.

The automated start-up program will control all solar equipment. This program will be comprehensive in order to safely start the equipment during a large variation in available solar insolation conditions. The complexity will be equivalent to automatic turbine start-up programs which are routinely used in many new power plants.

The start-up sequence will be automated to the extent that the required operator participation will be limited to pushbutton initiation of each of these phases. The SMCS will keep the operator appraised of the status of the start-up through CRT messages on the control panel. The operator will be able to interrupt the automated sequence at any point and complete the start-up manually.

3.7.1.2 Coordination of Collector and Receiver Systems. The main responsibility of the Solar Master Control System is the prevention of over temperature conditions in the receiver panels while maintaining the largest possible number of heliostats on target.

The coordination requirements of the SMCS are minimal during solar operation. This is due to the receiver design and incorporation of receiver steam temperature controls in the Receiver System which will maintain the proper temperatures during all normal operating conditions. The SMCS will attempt to focus all available mirrors on the receiver to maximize the solar insolation. Should an abnormal condition arise in which the receiver controls are unable to maintain temperatures below critical limits in the receiver panels, the SMCS will automatically defocus mirrors according to a predetermined sequence to reduce the solar insolation to a point that the receiver controls are again able to control temperatures. When the abnormal condition has passed, the SMCS will automatically refocus all mirrors.

3.7.1.3 Automated Shutdown. An automated shutdown is required for the same reasons that an automated start-up is required. The shutdown program will safely shut down the solar equipment and place all equipment into an overnight storage condition.

As in the automated start-up program, the operator participation will be limited to the pushbutton initiation of each phase. Manual intervention at any point in the shutdown sequence will be possible.

3.7.1.4 Automated Emergency Shutdown. The SMCS will monitor critical solar equipment parameters and operating conditions of all critical plant equipment. Upon detection of any abnormal condition which would compromise the safety of personnel or integrity of the solar equipment, the SMCS will trigger an emergency shutdown of all solar equipment. The shutdown would consist of the following actions done in parallel.

(1) Command all mirrors to stow position.

(2) Close the receiver shutoff valve.

(3) Open all receiver superheater and steamline drain valves.

(4) Close the receiver piping system steam isolation valve.

(5) Start-up the emergency diesel generator (loss of power to heliostats only).

The main objectives of this emergency shutdown are to immediately remove all input energy from the system and prevent any possibility of water induction into the turbine.

This emergency shutdown system must function independently from all other elements in the SMCS.

The conditions that will automatically trigger an emergency shutdown are as follows.

(1) High receiver drum water level.

(2) Low receiver drum water level.

(3) Turbine trip.

(4) Fossil boiler trip.

(5) Loss of main source of electrical power to heliostat drive motors.

(6) Loss of one of the two redundant sources of uninterruptible control power.

(7) Recirculation pump failure.

The plant operator may also trigger an emergency shutdown from the main control room or the receiver tower.

3.7.1.5 Data Acquisition Requirements. The SMCS will include the capability to acquire plant data, analyze this data, display performance data to the operator, and store data for future detailed analysis.

(1) Data Acquisition--The SMCS will scan plant input data at individual point adjustable scan rates from once a second to once every 30 seconds. The SMCS will store the most current values of each input for further analysis and/or display. The estimated input count is as follows.

| Measurement | Quantity |
|---|---|
| Temperatures | 150 |
| Pressures | 20 |
| Flow rates | 10 |
| Valve positions | 50 |
| Water levels | 5 |
| Control valve positions | 15 |
| Miscellaneous discrete status inputs (level switches, breaker positions) | 50 |
| Heliostat status | 1,057 |

(2) Data Analysis--The SMCS will perform realtime input data processing on all inputs. This processing will consist of conversion to engineering units, detection of bad or unreasonable data, data averaging, and other required processing. The SMCS will also perform periodic performance calculations to determine facility performance.

(3) Data Display--The SMCS will display operational data to the plant operator. The displays will primarily consist of color cathode ray tube (CRT) displays and shall be updated at least once every 2 seconds.

(4) Data Storage--The SMCS will include long-term data storage capabilities. Both raw input data and computation results will be stored on magnetic media for off-site analysis.

3.7.2 Design Requirements

The SMCS equipment must meet the following design criteria.

(1) Reliability--The SMCS shall have an availability of over 99.5 per cent. This availability will be achieved through the use of simple designs, the use of proven highly reliable components, and the use of redundant elements whenever it is cost effective.

(3) Cost Effectiveness--The SMCS shall use commercially available equipment throughout. All equipment supplied shall be generically similar through the SMCS. The equipment configuration shall minimize cabling costs whenever feasible.

(4) Ease of Maintenance--All equipment shall be easily maintainable by normal power plant personnel. The equipment configuration shall consist of generically similar equipment wherever practical for ease of maintenance.

(5) Ease of Operation--All control panel displays shall be easily read from a distance of 3 m (10 ft). All manual controls shall be designed to allow a single plant operator to control all normal solar operating modes.

(6) Operating Environment--All equipment shall be capable of continuous operation over an ambient temperature range of 4 C (40 F) to 32 C (90 F) and a relative humidity of 5 per cent to 95 per cent. Electrical power for the SMCS will be a nominal 120 volt, single phase, 60 hertz alternating current.

(7) Expandability--The computer system shall have the capability of adding at least 25 per cent additional working memory for future expansion. The central processing units shall allow for a 25 per cent spare duty cycle under worst case loading conditions and 40 per cent spare duty cycle under normal loading conditions.

3.7.3 Interface Requirements

The SMCS will communicate with all other systems. The communications will consist of control commands from the SMCS to the other systems and status information from the other systems to the SMCS. The interface between the SMCS and the Collector System will consist of a digital data transmission link between the master control computers and the heliostat array controllers. The interface between the SMCS and the Receiver System and between the SMCS and the Receiver Piping System will consist of a digital data transmission link between the master control computers and the Receiver Control System. The interface between the SMCS and the Fossil Energy Delivery System will consist of signal cables between the control computer and the turbine and fossil steam generator control systems.

3.8 FOSSIL ENERGY DELIVERY SYSTEM

No modifications are required to the Fossil Energy Delivery System. However, the operation has been changed due to the change in the EPGS control system which will allow variable pressure operation.

## 3.9 ENERGY STORAGE SYSTEM

There is no requirement for an energy storage system.

## 3.10 ELECTRIC POWER GENERATING SYSTEM

The Electric Power Generating System (EPGS) shall provide for rapid response to variations in inlet working fluid conditions. The design of the EPGS shall provide for safe operation and for access for inspection, maintenance, and repair of system elements; e.g., piping and controls. The elements of the EPGS shall be so configured and located within or relative to other systems as to minimize adverse interfaces with or operations of the other systems.

The EPGS control system will be modified to permit variable pressure operation which is necessary to maintain boiler outlet steam at rated temperature during low load operation. Water from the existing service water system will be supplied for the receiver feedwater pump seals at a flow as required by the pump manufacturer. A hose connection will also be added to the existing demineralized water system which will be used for filling the heliostat wash vehicle. The connection will be sized to provide approximately 95 liters per minute (25 gpm). This will permit filling in a reasonable time.

## 3.11 PROCESS HEAT SYSTEM

The addition of solar to the cogeneration facility imposes no new requirements upon the Process Heat System.

## 3.12 SOLAR AUXILIARY ELECTRIC SYSTEM

The Solar Auxiliary Electric System shall provide for the distribution of electric power to solar system components. The system shall be designed to meet the power requirements of all loads during shutdown, start-up and operating modes of the solar plant.

The Solar Auxiliary Electric System can be divided into two categories.

(1) Normal ac power supply.

(2) Uninterruptible ac power supply.

### 3.12.1 Normal AC Power Supply

Normal ac power shall be used to supply power to the following types of loads.

(1) Heliostat drives and controls including field controllers.

(2) Receiver feedwater booster pump.

(3) Receiver circulating and blowdown pumps.

(4) All motor operated valves.

(5) Receiver tower elevator.

(6) Lighting including aviation obstruction lighting.

(7) Heating, ventilation and air conditioning.

In the event of a total loss of normal ac power, an emergency power supply shall be required to slew the heliostats away from the receiver in the shortest possible time to prevent damage to the receiver. This emergency power will be supplied by a fast-start diesel generator unit to be located in the Solar Auxiliaries Building near the base of the receiver tower. The emergency generator shall have enough power to selectively and progressively move all the heliostats from the focusing position to the standby position under worst wind loading conditions within the time limit required by the receiver design.

A reasonable level of reliability is desirable for the primary distribution system serving the heliostats. The system shall be designed such that it will normally operate as an open-loop system. Distribution switching will be provided at each transformer with load break elbows. In the event of a fault in a line section, the faulted section can be isolated quickly by opening both ends of the faulted section at the transformers. Service can be restored to all heliostats by closing the normally open elbows, while the repair work is carried out on the faulty section.

3.12.2 Uninterruptible AC Power Supply

Uninterruptible ac power shall be supplied to specific loads associated with the Solar Master Control System, where an interruption of power even for a few cycles can not be tolerated under any normal or abnormal operating conditions of the solar plant. The following are the typical loads which shall be fed from uninterruptible power supply.

(1) Solar Master Control System computers.

(2) Heliostat array controllers.

(3) Receiver controls.

(4) Multiplexing equipment at the receiver tower.

(5) Critical instrumentation.

(6) Solar Master Control System emergency shut down system.

(7) Heliostat array graphics.

Because of the critical nature of the loads under this category, redundant power supplies shall be provided for reliability.

In the event of a total loss of normal plant ac power, the uninterruptible power supply shall be capable of supplying the uninterruptible electrical loads for at least one hour.

3.13 SPECIALIZED EQUIPMENT

The solar repowered plant includes components unique to the utilization of solar energy. These unique components require specialized equipment for their service, maintenance, repair, or replacement. Conventional components included in the solar repowered plant (i.e., the pumps, motors, piping, and valves) will be maintained via the existing conventional equipment and facilities and thus do not require specialized equipment. The components unique to the solar repowered plant are the solar receiver of the Receiver System and the heliostats of the Collector System. The specialized equipment required by these components are described in the following paragraphs.

3.13.1 Specialized Solar Receiver Equipment

The solar receiver is designed for a 30 year lifetime and requires only a minimum of scheduled maintenance. However, the solar receiver does require specialized equipment in order to perform unscheduled (corrective) maintenance, such as the repair/replacement of failed boiler or superheater tubes or the recoating of the receiver's high-absorptivity coating.

Specialized equipment to be included with the solar receiver and receiver tower include a tower personnel elevator and a small equipment hoist.

3.13.2 Specialized Heliostat Equipment

The heliostats of the Collector System require scheduled maintenance, such as the periodic cleansing of the mirror surfaces and the lubrication of the drive mechanisms. The heliostats may also require unscheduled (corrective) maintenance, such as the replacement of damaged reflector panels or even the replacement of an entire heliostat, due to a lightning strike. These maintenance actions will involve the use of specialized equipment as follows.

(1) Heliostat washing vehicle.

(2) Heliostat installation equipment (i.e., leveling and lifting equipment).

(3) Heliostat alignment tools.

3.14 SERVICE LIFE

The systems added to the existing Cimarron River Station shall be designed for a service life of thirty years. Any major component replacement requirements during the service life of the plant shall be identified.

3.15 FACILITY AVAILABILITY AND RELIABILITY

The solar addition to the cogeneration facility shall have an availability of at least 85 per cent, exclusive of scheduled outages and insolation-related outages. The availability of the solar addition will be the product of the operational reliabilities of its principal systems: the Receiver System, the Collector System, the Receiver Piping System, the Solar Master Control System, and the Solar Auxiliary Electric System.

3.16 MAINTAINABILITY

The maintenance of the solar repowered plant modifications shall be compatible with existing plant maintenance requirements. General maintenance requirements are discussed below. Estimated maintenance schedules and spare parts requirements are presented in Section 5.3.3, Operations and Maintenance Cost Estimate.

3.16.1 Conventional Components

The conventional components of the solar facility, including the piping, pumps, valves, and motors, will be maintained using existing maintenance facilities. Maintenance of the conventional components of the solar repowered plant modifications will require no new skills or specialized equipment. An additional inventory of spare parts and replacement equipment may be required for the solar facility.

3.16.2 Solar Specific Components

The solar specific components of the solar repowered plant modifications, the solar receiver and the heliostats, will have special maintenance considerations.

3.16.2.1 Solar Receiver. The solar receiver is designed for a 30-year lifetime and, except for routine inspections, the receiver shall not require any scheduled maintenance. Maintenance may be required to repair the randomly occurring leaks and tube failures and to occasionally repaint absorber surfaces.

Excessive leakage from the receiver would necessitate repairs, primarily consisting of screen tube replacement or superheater panel replacement. An inventory of spare screen tubes and superheater panels will be kept for such corrective maintenance. Replacement of either involves the cutting and rewelding of steam piping, a process very similar to the repair of the existing steam generator and power conversion components. The receiver tower includes an elevator and a hoist to facilitate receiver maintenance.

3.16.2.2 Heliostats. The heliostats require scheduled maintenance as well as occasional corrective maintenance. The scheduled maintenance shall consist primarily of heliostat reflector washing.

The reflectors of the heliostats are washed to maintain the reflectivity, thereby keeping plant performance at a high level. Washing of the reflectors may be performed on a set schedule, or on an intermittent basis whenever heliostat reflectivity drops below a threshold value.

Heliostat washing requires the use of special washing equipment, consisting of a truck carrying high-pressure spray equipment and tanks of detergent and rinse solutions. Washing is accomplished by slowly driving by verticaly oriented heliostats, spraying detergents and rinsing as the truck passes in front of the reflectors.

The heliostats may be damaged intermittently, since they are exposed to the elements. An inventory of spare drive units, reflector panels, controllers, etc. shall be stored on site for corrective maintenance. Replacement of reflector panels and other heliostat components shall require the use of installation and alignment equipment.

3.16.3 Control Components

The control components of the solar addition will primarily require corrective maintenance. An adequate inventory of spare components shall be stored on site to facilitate corrective repairs.

3.17 SAFETY REQUIREMENTS

The equipment, materials, design and construction of the Solar Cogeneration Facility will comply with all federal, state, and local standards, regulations, codes, laws, and ordinances relating to the specific site and user. Section 2.0 of this report provides references to the standards, codes, laws and regulations which are currently applicable.

In all phases of design and construction, appropriate safety requirements will be applied. This will include plant and equipment safety, and human safety. Primary among plant safety requirements is the necessity to protect the receiver from thermal damage, which could occur from a loss of electrical power to the heliostat field. Reliability impacts on safety will be considered in the design to assure appropriate component redundancy.

Human safety requirements shall include provisions for radiation control and containment. A list of circumstances requiring safety provisions to control radiation redirected by the heliostat field follows.

(1) The construction phase requires heliostat control procedures to protect personnel working on the tower.

(2) During field maintenance, the protection of personnel from redirected radiation hazards due to heliostats and optical diccomfort of scattered radiation from a diffuse receiver surface requires safety procedures.

(3) Normal start-up and shut-down of the field requires a safe heliostat control strategy.

(4) A safe control strategy will be developed for emergency field shut-down.

(5) Safety provisions will be developed for the protection of on-site personnel during normal operation.

(6) Protection of off-site pedestrians, vehicular traffic, and air traffic from redirected radiation hazards during normal operation requires safety provisions.

In addition to human safety hazards from radiation, high temperature surfaces present safety hazards to plant personnel. Therefore, safety provisions such as thermal insulation will be applied to safeguard against thermal hazards.

This enumeration of safety requirements does not comprise a comprehensive list. Additional safety requirements will be identified during the detailed design of the facility.

3.18 ENVIRONMENTAL IMPACT REQUIREMENTS

The solar facility addition to the Cimarron River Station shall be designed to prevent or mitigate adverse environmental impacts. An environmental assessment of the proposed addition identified certain adverse impacts which must be considered in the conceptual and detailed design of the facility and other potential adverse impacts which should be addressed by further investigations and planning prior to detailed design or construction.

3.18.1 Identified Environmental Requirements

The environmental assessment indicated that the following environmental issues require consideration in the conceptual and detailed design of the facility.

(1) Soil erosion during construction.

(2) Surface water runoff during construction.

(3) Fugitive dust during construction.

(4) Permanent revegetation of the heliostat field following construction.

(5) Receiver tower lighting.

3.18.2 Potential Environmental Requirements

The following environmental issues require further study and analysis prior to detailed design or construction to determine whether there will be an adverse environmental impact.

(1) Paleontological, Archaeological, and Historical Resources.

(2) Terrestrial Ecosystems.

(3) Soils.

These studies shall include field investigations, literature searches, analyses of impacts, and development of mitigation measures, as necessary.

3.19 SPECIALIZED REQUIREMENTS

No specialized requirements have been identified.

# 4.0 ENVIRONMENTAL CRITERIA

## 4.1 FACILITY ENVIRONMENTAL DESIGN REQUIREMENTS

The following environmental criteria apply to all components of the Solar Cogeneration Facility except for the heliostats unless stated otherwise. Heliostat environmental criteria are provided in the Collector Subsystem Requirement Specification, A10772, Issue D, December 11, 1979.

### 4.1.1 Operating Requirements

The system shall be capable of operating in appropriate combinations of the following environments.

4.1.1.1 Temperature. The plant shall be able to operate in an ambient, dry bulb air temperature range from -26 C (-15 F) to 43 C (109 F), based on the extreme temperatures recorded at Dodge City, Kansas.* It should be noted that this design temperature range is a general criteria only; it does not have a direct bearing on the design wet bulb temperature for plant heat rejection or on the design HVAC temperatures.

4.1.1.2 Wind. The facility shall be capable of operating given the following approximate wind data.

Wind profile relationship:

$$V_z = V_{10} \left[\frac{Z}{10}\right]^{1/7}$$

where,

$V_z$ = velocity at height Z (m/s)

$V_{10}$ = velocity at 10 meters (32.8 feet) (m/s)

$Z$ = desired height (m)

Operating wind speed: $V_{10}$ = 16 m/s (35 mph)

4.1.1.3 Seismology. Peak ground accelerations shall be as presented below per applicable UBC Zone. This peak ground acceleration is combined with the response spectrum given by NRC Regulatory Guide 1.60 and the damping values given for the operating basis earthquake in NRC Regulatory Guide 1.61. UBC Zone 1 values should be used for the baseline design.

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*The first order National Weather Service Station nearest the plant site is at Dodge City, Kansas, located about 97 kilometers (60 miles) northeast of the plant site.

Maximum Operational Ground Accelerations

| UBC Zone | Peak Ground Acceleration Average or Firm Conditions |
|---|---|
| 1 | 0.02 g |

4.1.2 Survival Requirements

The system shall be capable of surviving appropriate combinations of the environments specified below.

4.1.2.1 Wind. The facility shall be designed considering prevailing wind directions and observed wind speeds. An annual wind rose is shown on Figure 4.1-1. The facility shall be designed to survive, without damage, winds with a basic speed of 40 m/s (90 mph), with gusts to 52 m/s (117 mph). This figure is based on a 100 year mean recurrence interval in accordance with requirements of ANSI A58.1-1972. A local wind vector variation of up to +10 degrees from the horizontal shall be assumed for the survival condition.

4.1.2.2 Wind Rise Rate. A maximum wind rise rate of 0.01 $m/s^2$ (1.3 mph/min) shall be used in calculating wind loads during heliostat stowage and for tower survival. However, the heliostats should withstand, without catastrophic failure, a maximum wind of 22 m/s (50 mph) from any direction, for any heliostat orientation, such as might result from unusually rapid wind rise rates, e.g., severe thunderstorm gust fronts.

4.1.2.3 Dust Devils. Dust devils with wind speeds up to 18 m/s (40 mph) shall be survived without damage to the facility.

4.1.2.4 Snow. The facility shall survive a static snow load of 960 Pa (20 $lb/ft^2$) and a snow deposition rate of 0.33 m (13 in.) in 24 hours, based on the recorded maximum.

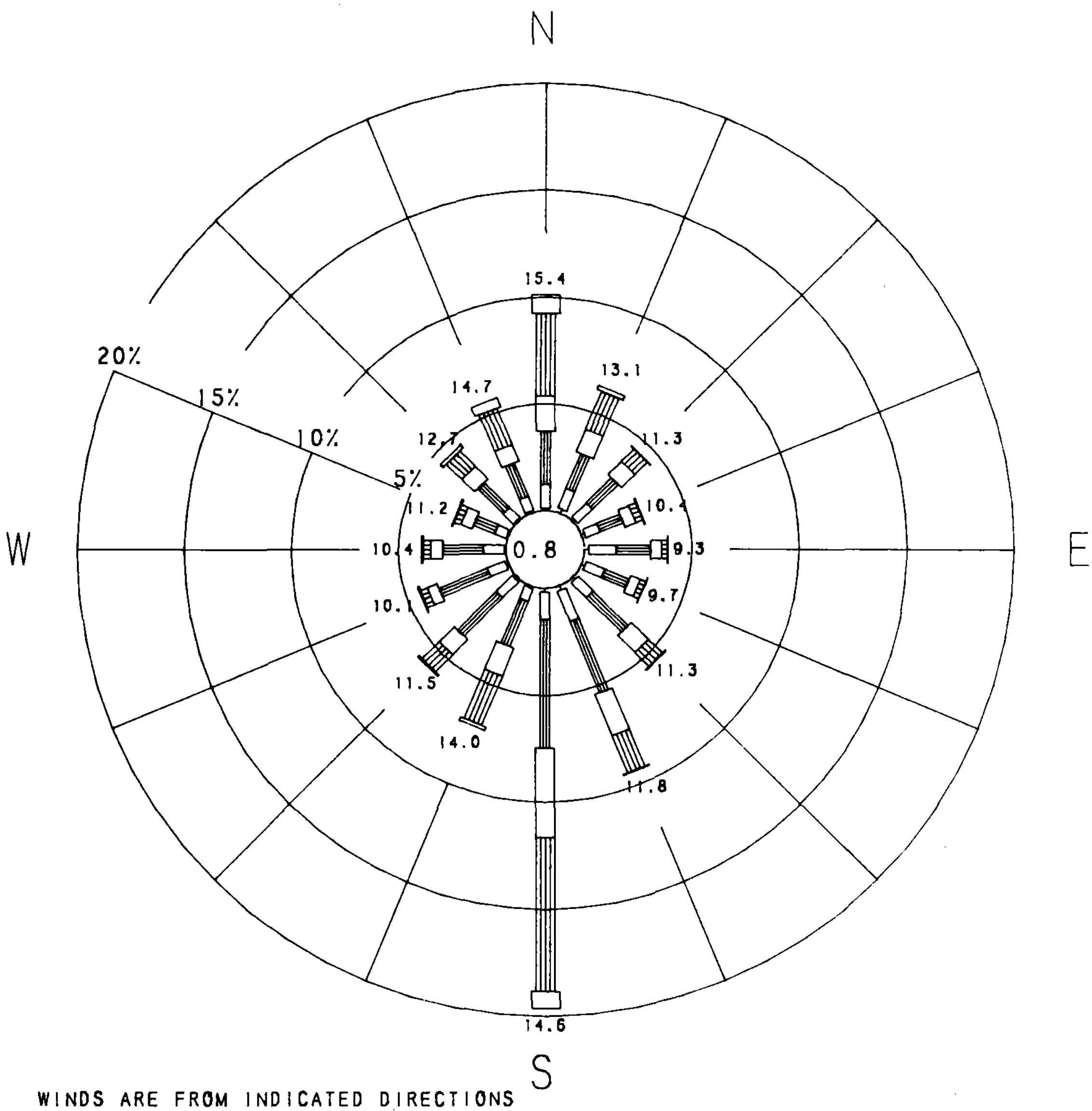
4.1.2.5 Rain. The facility shall survive the following rainfall conditions.

(1) Average annual--520 mm (20.6 in).

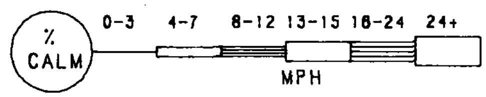
(2) Maximum 24-hr rate--140 mm (5.6 in).

4.1.2.6 Ice. The facility shall survive freezing rain and ice deposits in a layer 38 mm (1.5 in) thick.

4.1.2.7 Seismology. Peak ground accelerations shall be as presented below per applicable UBC Zone. This peak ground acceleration is combined




WINDS ARE FROM INDICATED DIRECTIONS




CALMS ARE DISTRIBUTED INTO THE 0-3 CATEGORY

AVERAGE WIND SPEEDS ARE SHOWN AT THE END OF EACH BAR

**HEIGHT ABOVE GROUND: 18 FEET**

PERIOD OF RECORD: 1969 - 1973 (8 OBSERVATIONS PER DAY)

**SOURCE: NATIONAL WEATHER SERVICE, DODGE CITY, KANSAS**

**ANNUAL WIND ROSE FOR DODGE CITY, KANSAS**

**FIGURE 4.1-1**

with the response spectrum given by NRC Regulatory Guide 1.60 and the damping values given for the operating basis earthquake in NRC Regulatory Guide 1.61. UBC Zone 1 values should be used for the baseline design.

Maximum Survival Ground Accelerations

| UBC Zone | Peak Ground Acceleration Average or Firm Conditions |
|---|---|
| 1 | 0.07 g |

4.1.2.8 Hail. The heliostats shall survive hail impact up to the following limits.

| | Any Orientation | Stowed |
|---|---|---|
| Diameter, mm (in) | 20 (0.75) | 25 (1.0) |
| Specific Gravity | 0.9 | 0.9 |
| Terminal Velocity, m/s (mph) | 20 (44) | 23 (51) |

4.1.2.9 Sandstorm Environment. The facility shall survive exposure to flowing dust comparable to the conditions described by Method 510 of MIL-STD-810C or other more appropriate conditions.

4.1.3 Lightning Considerations

The facility shall be designed in accordance with the following lightning considerations.

4.1.3.1 Protection. The facility shall be provided with a ligntning protection system, designed per the requirements of NFPA No. 78, Lightning Protection Code.

4.1.3.2 Direct Hit. Total destruction of a single heliostat and its controller when subjected to a direct lightning strike is acceptable.

4.1.3.3 Adjacent Strike. Damage to a heliostat adjacent to a direct lightning strike should be minimized. The central controller and the local controllers of heliostats adjacent to a direct lightning strike must be protected, or alternate control methods provided to minimize loss of collector system control.

4.1.4 Special Environmental Considerations

Heliostats shall withstand sustained winds (see 4.1.2) at the periphery of the heliostat field. If it is determined that wind loading on interior heliostats is significantly altered by peripheral heliostats, this factor should be considered. Adequate protection shall be provided against heliostat degradation from exposure to humidity, temperature (transients and steady state) and other environmental effects specified in Section 4.

4.2 ENVIRONMENTAL STANDARDS

The environmental standards to which the solar cogeneration facility shall be designed consist of ambient air quality standards and emissions limitations.

4.2.1 Ambient Air Quality Standards

(1) Federal Standards. Pursuant to a requirement in the Clean Air Act, the Environmental Protection Agency (EPA) has identified seven air pollutants which have an adverse effect upon public health or welfare and has issued air quality criteria for them. The seven air pollutants are as follows.

(a) Sulfur Oxides.
(b) Particulate Matter.
(c) Nitrogen Oxides.
(d) Carbon Monoxide.
(e) Photochemical Oxidants.
(f) Hydrocarbons.
(g) Lead.

The combustion gas produced by a fossil fuel fired steam generator may include sizable quantities of sulfur oxides, particulate matter, and nitrogen oxides. Since other pollutants will appear only in insignificant quantities only those three pollutants will be discussed. The national primary and secondary ambient air quality standards applicable to the Cimarron River Station are shown on Table 4-1.

(2) Kansas Standards. Kansas has not adopted ambient standards more stringent than federal standards, so those promulgated by EPA listed above are applicable.

4.2.2 Emission Limitations

There are no Federal Emission limits applicable to the Cimarron River Station. However, the Kansas Department of Health and Environment has

TABLE 4-1. APPLICABLE AIR QUALITY STANDARDS

| | 3-Hour Average* | 24-Hour Average* | Annual Average** |
|---|---|---|---|
| | $\mu g/m^3$ (ppm) | $\mu g/m^3$ (ppm) | $\mu g/m^3$ (ppm) |
| Sulfur Dioxide | | | |
| Primary Standard | -- | 365 (0.14) | 80 (0.03) |
| Secondary Standard | 1300 (0.50) | -- | -- |
| Particulate Matter | | | |
| Primary Standard | -- | 260 | 75 |
| Secondary Standard | -- | 150 | 60 |
| Nitrogen Dioxide | | | |
| Primary Standard | -- | -- | 100 (0.05) |
| Secondary Standard | -- | -- | 100 (0.05) |

*The maximum 3-hour and 24-hour concentrations are not to be exceeded more than once during a year.

**The annual average for particulate matter shall be computed as a geometric mean, whereas the annual average for sulfur and nitrogen dioxide shall be computed as arithmetic means.

established emission limitations for particulate matter, visible emissions, hydrocarbons, sulfur oxides, carbon monoxide, and nitorgen oxides applicable to all existing sources. Since emissions from fossil fuel steam generators do not include significant quantities of hydrocarbons or carbon monoxide, these will not be summarized. The Solar Cogeneration Project would not cause an emissions increase at the Cimarron River Station. Therefore, the unit should continue to be subject to the emission limitations applicable to existing units. These emission limitations are summarized below.

(1) Particulate Emission Limitations--Particulate emission rates from fuel-burning equipment from Kansas Regulation 28-19.31 are given below.

| Heat Input $10^6$ Btu/hr | Allowable* lb/hr/$10^6$ Btu | Heat Input $10^6$ Btu/hr | Allowable* lb/hr/$10^6$ Btu |
|---|---|---|---|
| 10 or less | 0.60 | 1,000 | 0.21 |
| 50 ....... | 0.41 | 2,000 | 0.17 |
| 100 ....... | 0.35 | 5,000 | 0.14 |
| 500 ....... | 0.24 | 7,500 | 0.13 |
| 700 ....... | 0.22 | 10,000 | 0.12 |

Kansas Regulation 28-19-50 limits the opacity of emissions to 20 per cent. However, the regulation allows deviations from the 20 per cent standard during the cleaning of a fire, building of a new fire, soot blowing, or other short-term occurrences. These deviations are limited to emissions of up to 60 per cent opacity for periods aggregating no more than 5 minutes in any 60 consecutive minutes.

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*The allowable emission rate for equipment having intermediate heat input between 10 x $10^6$ Btu and 10,000 x $10^6$ Btu may be determined by the formula.

$$A = \frac{1.026}{I^{0.233}}$$

where,

A = the allowable emission rate in lb/hr/$10^6$ Btu.

I = the total heat input in $10^6$ Btu/hr.

(2) Sulfur Dioxide Emission Limitations--Kansas regulations impose emissions limitations on sulfur dioxide to be less than or equal to 1.5 pounds of sulfur per million Btu of heat input per hour.

(3) Nitrogen Oxide Emission Limitations--Kansas regulations prohibit nitrogen oxide emissions (calculated as $NO_2$) that are more than 0.3 pounds per million Btu of heat input.

# 5.0 FACILITY DESIGN DATA

The data in this section provide design detail, performance estimates, cost and economic data, and simulation models for the system designed to meet the requirements of the System Specification.

## 5.1 FACILITY CHARACTERISTICS AND PERFORMANCE DATA

The following technical data will be used in determining the facility technical characteristics and performance.

### 5.1.1 Receiver Tower Data

The receiver tower has the following design characteristics.

(1) Tower height--74.37 m (244 ft) to receiver support level.

(2) Structural type--Bolted structural steel.

(3) Top dimensions--4.27 m x 4.27 m (14 ft x 14 ft).

(4) Base dimensions--7.32 m x 7.32 m (24 ft x 24 ft).

(5) Foundation--12.19 m x 12.19 m x 1.52 m (40 ft x 40 ft x 5 ft) reinforced concrete mat supported by 64 auger cast concrete piles.

(6) Material--ASTM A572 Grade 50 structural steel for columns. ASTM A36 structural steel for bracing.

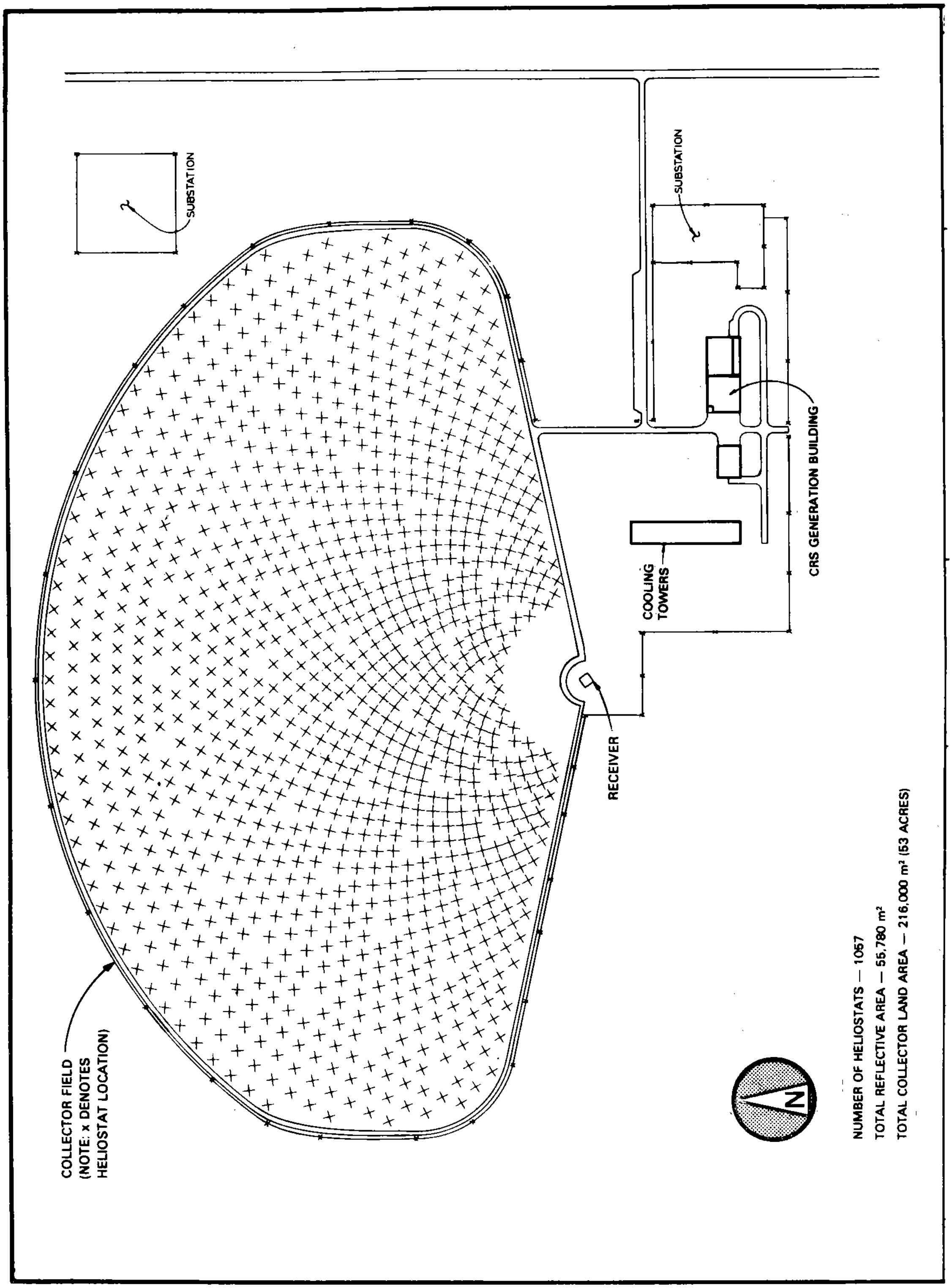
The receiver tower has four support legs, and X-bracing is provided to resist lateral loads.

### 5.1.2 Collector System Data

The Collector System has the following design and performance characteristics.

(1) Design Characteristics--Design and trade studies have identified the following Collector System design characteristics.

(a) The collector field lies north of the Cimarron River Station generation building and cooling towers as illustrated on Figure 5.1-1. The field consists of 1,057 heliostats (55,780 $m^2$ of reflective area) placed in 34 circular arcs, forming a 156 degree sector north of the receiver support tower. The inner and outer rows lie 66.1 m (217 ft) and




COLLECTOR FIELD LAYOUT

FIGURE 5.1-1

424 m (1,391 ft) from the tower centerline, respectively. Heliostats are arranged in a radial stagger pattern to allow close packing with a minimum of optical interference (blocking).

Table 5.1-1 lists the X, Y, and Z coordinates of the base of the heliostat pedestals; the heliostat elevation axis centerline is 4.04 m (13.25 ft) above the pedestal base. The X, Y, Z coordinates are given in meters, with positive X East, positive Y North, and positive Z above the base of the receiver support tower axis. The heliostats are numbered from 1 to 1,057 and are listed in order from the inner to the outer row, counting clockwise from the west end of the row to the east.

No contingency heliostats have been included in the collector design to replace those temporarily disabled during repair or routine maintenance.

(b) All 1,057 heliostats are identical in configuration, having nominal characteristics approximating those of the DOE second generation production heliostats. The physical characteristics are as follows.

- Dimensions--7.39 m wide, 7.44 m high.
- Reflective Area--52.772 $m^2$.
- Reflectivity--0.9 (average between washing).
- Reflected Beam Quality--±2 milliradians.
- Reflected Beam Pointing Accuracy--±1.5 milliradians.
- Mirror modules canted for individual slant ranges.
- Mirror module array approximates a spherical surface with focal length equal to slant range.

(c) Each heliostat is supported by a reinforced concrete foundation and pedestal. Below grade, the foundation is constructed as a drilled pier 0.76 m (30 in) in diameter, socketed 3.05 m (10 ft) into the soil. Above grade, the pedestal is

TABLE 5.1-1. HELIOSTAT LOCATIONS

| *HELIOSTAT* | *X* | *Y* | *Z* | *HELIOSTAT* | *X* | *Y* | *Z* |
|---|---|---|---|---|---|---|---|
| 1 | -59.52 | 28.76 | -.18 | 51 | -64.68 | 70.42 | 1.40 |
| 2 | -50.48 | 42.68 | .37 | 52 | -50.31 | 81.31 | 1.74 |
| 3 | -38.25 | 53.91 | 1.01 | 53 | -34.15 | 89.31 | 2.29 |
| 4 | -23.61 | 61.74 | 1.43 | 54 | -16.78 | 94.13 | 2.77 |
| 5 | -7.49 | 65.68 | 1.77 | 55 | 1.19 | 95.61 | 3.14 |
| 6 | 9.11 | 65.47 | 2.23 | 56 | 19.11 | 93.68 | 3.35 |
| 7 | 25.14 | 61.14 | 2.53 | 57 | 36.36 | 88.43 | 3.51 |
| 8 | 39.58 | 52.94 | 2.65 | 58 | 52.32 | 80.03 | 3.57 |
| 9 | 51.52 | 41.41 | 2.65 | 59 | 66.41 | 68.79 | 3.66 |
| 10 | 60.21 | 27.27 | 2.59 | 60 | 78.14 | 55.10 | 3.60 |
| 11 | -68.70 | 23.09 | -.46 | 61 | 87.10 | 39.45 | 3.44 |
| 12 | -60.78 | 39.47 | .15 | 62 | 92.95 | 22.40 | 3.17 |
| 13 | -49.03 | 53.37 | .88 | 63 | -95.64 | 35.53 | -.09 |
| 14 | -34.18 | 63.90 | 1.40 | 64 | -87.27 | 52.85 | .73 |
| 15 | -17.18 | 70.41 | 1.80 | 65 | -75.79 | 68.29 | 1.31 |
| 16 | .90 | 72.47 | 2.23 | 66 | -61.63 | 81.31 | 1.68 |
| 17 | 18.93 | 69.96 | 2.59 | 67 | -45.27 | 91.43 | 2.23 |
| 18 | 35.76 | 63.04 | 2.77 | 68 | -27.30 | 98.30 | 2.77 |
| 19 | 50.34 | 52.14 | 2.87 | 69 | -8.36 | 101.68 | 3.20 |
| 20 | 61.74 | 37.95 | 2.80 | 70 | 10.88 | 101.44 | 3.51 |
| 21 | 69.25 | 21.37 | 2.68 | 71 | 29.73 | 97.60 | 3.66 |
| 22 | -79.32 | 21.21 | -.61 | 72 | 47.52 | 90.28 | 3.81 |
| 23 | -73.93 | 35.72 | .00 | 73 | 63.63 | 79.75 | 3.93 |
| 24 | -65.91 | 48.97 | .52 | 74 | 77.47 | 66.39 | 3.90 |
| 25 | -43.21 | 69.82 | 1.49 | 75 | 88.55 | 50.67 | 3.78 |
| 26 | -29.33 | 76.69 | 1.83 | 76 | 96.49 | 33.14 | 3.23 |
| 27 | -14.41 | 80.83 | 2.26 | 77 | -106.30 | 33.87 | -.12 |
| 28 | 16.41 | 80.45 | 2.87 | 78 | -100.45 | 48.54 | .61 |
| 29 | 31.23 | 75.94 | 3.05 | 79 | -92.60 | 62.23 | 1.13 |
| 30 | 44.93 | 68.73 | 3.08 | 80 | -71.51 | 85.63 | 1.83 |
| 31 | 67.11 | 47.31 | 3.11 | 81 | -58.71 | 94.87 | 2.29 |
| 32 | 74.79 | 33.88 | 2.99 | 82 | -44.73 | 102.21 | 2.71 |
| 33 | 79.82 | 19.23 | 2.90 | 83 | -14.38 | 110.64 | 3.35 |
| 34 | -83.67 | 31.08 | -.27 | 84 | 1.39 | 111.56 | 3.63 |
| 35 | -76.35 | 46.24 | .40 | 85 | 17.12 | 110.24 | 3.81 |
| 36 | -66.31 | 59.75 | 1.01 | 86 | 47.25 | 101.07 | 4.11 |
| 37 | -53.92 | 71.14 | 1.46 | 87 | 61.04 | 93.38 | 4.18 |
| 38 | -39.60 | 79.99 | 1.83 | 88 | 73.62 | 83.83 | 4.21 |
| 39 | -23.88 | 86.00 | 2.32 | 89 | 94.11 | 59.91 | 4.15 |
| 40 | -7.31 | 88.96 | 2.74 | 90 | 101.63 | 46.03 | 3.99 |
| 41 | 9.52 | 88.75 | 3.05 | 91 | 107.11 | 31.22 | 3.81 |
| 42 | 26.01 | 85.39 | 3.23 | 92 | -115.31 | 27.93 | -.34 |
| 43 | 41.58 | 78.98 | 3.35 | 93 | -110.21 | 43.93 | .49 |
| 44 | 55.67 | 69.77 | 3.35 | 94 | -102.90 | 59.05 | 1.13 |
| 45 | 67.77 | 58.08 | 3.35 | 95 | -93.54 | 72.98 | 1.52 |
| 46 | 77.47 | 44.33 | 3.29 | 96 | -82.30 | 85.45 | 1.80 |
| 47 | 84.42 | 29.00 | 3.11 | 97 | -69.41 | 96.22 | 2.29 |
| 48 | -92.37 | 24.70 | -.49 | 98 | -55.13 | 105.05 | 2.74 |
| 49 | -86.09 | 41.60 | .21 | 99 | -39.75 | 111.78 | 3.08 |
| 50 | -76.75 | 57.02 | .88 | 100 | -23.58 | 116.28 | 3.44 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| *HELIOSTAT* | *X* | *Y* | *Z* | *HELIOSTAT* | *X* | *Y* | *Z* |
|---|---|---|---|---|---|---|---|
| 101 | -6.93 | 118.44 | 3.75 | 151 | -115.43 | 83.66 | 1.98 |
| 102 | 9.86 | 118.23 | 3.93 | 152 | -105.91 | 95.42 | 2.44 |
| 103 | 26.45 | 115.65 | 4.11 | 153 | -95.19 | 106.12 | 2.74 |
| 104 | 42.52 | 110.76 | 4.30 | 154 | -70.67 | 123.80 | 3.23 |
| 105 | 57.73 | 103.65 | 4.48 | 155 | -57.15 | 130.60 | 3.57 |
| 106 | 71.78 | 94.46 | 4.51 | 156 | -42.98 | 135.92 | 3.96 |
| 107 | 84.40 | 83.39 | 4.51 | 157 | -13.35 | 141.93 | 4.45 |
| 108 | 95.32 | 70.64 | 4.45 | 158 | 1.77 | 142.54 | 4.66 |
| 109 | 104.34 | 56.47 | 4.27 | 159 | 16.87 | 141.55 | 4.88 |
| 110 | 111.27 | 41.18 | 4.11 | 160 | 46.34 | 134.81 | 5.18 |
| 111 | -119.75 | 38.16 | .30 | 161 | 60.37 | 129.14 | 5.21 |
| 112 | -113.16 | 54.68 | 1.04 | 162 | 73.73 | 122.01 | 5.24 |
| 113 | -104.31 | 70.11 | 1.46 | 163 | 97.80 | 103.72 | 5.24 |
| 114 | -93.37 | 84.13 | 1.74 | 164 | 108.24 | 92.77 | 5.21 |
| 115 | -80.56 | 96.47 | 2.29 | 165 | 117.47 | 80.77 | 5.09 |
| 116 | -66.13 | 106.87 | 2.80 | 166 | 131.86 | 54.18 | 4.82 |
| 117 | -50.39 | 115.14 | 3.11 | 167 | 136.86 | 39.89 | 4.57 |
| 118 | -33.63 | 121.10 | 3.47 | 168 | -145.45 | 37.97 | 1.01 |
| 119 | -16.20 | 124.63 | 3.51 | 169 | -140.61 | 53.18 | 1.40 |
| 120 | 1.56 | 125.67 | 4.08 | 170 | -134.18 | 67.79 | 1.68 |
| 121 | 19.29 | 124.19 | 4.27 | 171 | -126.23 | 81.63 | 2.04 |
| 122 | 36.62 | 120.23 | 4.54 | 172 | -116.87 | 94.56 | 2.53 |
| 123 | 53.23 | 113.85 | 4.66 | 173 | -106.18 | 106.41 | 2.80 |
| 124 | 68.77 | 105.20 | 4.72 | 174 | -94.30 | 117.07 | 3.05 |
| 125 | 82.93 | 94.44 | 4.79 | 175 | -81.35 | 126.41 | 3.29 |
| 126 | 95.43 | 81.78 | 4.72 | 176 | -67.49 | 134.33 | 3.72 |
| 127 | 106.02 | 67.49 | 4.72 | 177 | -52.87 | 140.72 | 4.08 |
| 128 | 114.49 | 51.85 | 4.42 | 178 | -37.65 | 145.54 | 4.39 |
| 129 | 120.66 | 35.17 | 4.18 | 179 | -22.01 | 148.71 | 4.66 |
| 130 | -129.19 | 31.29 | .09 | 180 | -6.12 | 150.20 | 4.79 |
| 131 | -123.48 | 49.22 | 1.04 | 181 | 9.84 | 150.01 | 5.03 |
| 132 | -115.30 | 66.16 | 1.46 | 182 | 25.69 | 148.12 | 5.27 |
| 133 | -104.80 | 81.77 | 1.74 | 183 | 41.25 | 144.56 | 5.36 |
| 134 | -92.21 | 95.75 | 2.32 | 184 | 56.35 | 139.37 | 5.43 |
| 135 | -77.77 | 107.80 | 2.77 | 185 | 70.81 | 132.61 | 5.43 |
| 136 | -61.77 | 117.70 | 3.11 | 186 | 84.47 | 124.35 | 5.46 |
| 137 | -44.54 | 125.24 | 3.51 | 187 | 97.18 | 114.70 | 5.49 |
| 138 | -26.41 | 130.28 | 3.87 | 188 | 108.79 | 103.75 | 5.49 |
| 139 | -7.76 | 132.70 | 4.18 | 189 | 119.18 | 91.63 | 5.33 |
| 140 | 11.05 | 132.47 | 4.45 | 190 | 128.22 | 78.47 | 5.18 |
| 141 | 29.64 | 129.58 | 4.69 | 191 | 135.82 | 64.44 | 5.00 |
| 142 | 47.64 | 124.10 | 4.88 | 192 | 141.88 | 49.67 | 4.79 |
| 143 | 64.68 | 116.13 | 4.94 | 193 | 146.35 | 34.35 | 4.51 |
| 144 | 80.42 | 105.84 | 4.97 | 194 | -150.88 | 48.08 | 1.40 |
| 145 | 94.56 | 93.43 | 5.00 | 195 | -144.93 | 63.80 | 1.74 |
| 146 | 106.80 | 79.14 | 4.91 | 196 | -137.35 | 78.81 | 2.13 |
| 147 | 116.90 | 63.27 | 4.82 | 197 | -128.22 | 92.93 | 2.62 |
| 148 | 124.66 | 46.14 | 4.54 | 198 | -117.64 | 106.00 | 2.87 |
| 149 | -135.83 | 43.28 | 1.01 | 199 | -105.74 | 117.88 | 3.11 |
| 150 | -130.47 | 57.44 | 1.40 | 200 | -92.65 | 128.43 | 3.44 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| HELIOSTAT | X | Y | Z | HELIOSTAT | X | Y | Z |
|---|---|---|---|---|---|---|---|
| 201 | -78.51 | 137.52 | 3.81 | 251 | -102.53 | 142.12 | 4.08 |
| 202 | -63.48 | 145.07 | 4.18 | 252 | -86.88 | 152.19 | 4.42 |
| 203 | -47.74 | 150.99 | 4.48 | 253 | -70.25 | 160.54 | 4.69 |
| 204 | -31.47 | 155.20 | 4.75 | 254 | -52.84 | 167.09 | 5.03 |
| 205 | -14.83 | 157.66 | 5.03 | 255 | -34.82 | 171.75 | 5.40 |
| 206 | 1.97 | 158.34 | 5.30 | 256 | -16.42 | 174.47 | 5.64 |
| 207 | 18.74 | 157.24 | 5.46 | 257 | 2.18 | 175.23 | 5.79 |
| 208 | 35.31 | 154.37 | 5.55 | 258 | 20.74 | 174.01 | 5.94 |
| 209 | 51.48 | 149.76 | 5.64 | 259 | 39.08 | 170.83 | 6.10 |
| 210 | 67.07 | 143.45 | 5.70 | 260 | 56.97 | 165.72 | 6.25 |
| 211 | 81.90 | 135.53 | 5.73 | 261 | 74.22 | 158.75 | 6.28 |
| 212 | 95.81 | 126.09 | 5.73 | 262 | 90.63 | 149.99 | 6.28 |
| 213 | 108.64 | 115.22 | 5.73 | 263 | 106.03 | 139.53 | 6.25 |
| 214 | 120.24 | 103.05 | 5.61 | 264 | 120.22 | 127.50 | 6.10 |
| 215 | 130.49 | 89.72 | 5.40 | 265 | 133.06 | 114.04 | 5.88 |
| 216 | 139.27 | 75.38 | 5.18 | 266 | 144.40 | 99.29 | 5.70 |
| 217 | 146.47 | 60.19 | 4.94 | 267 | 154.12 | 83.42 | 5.33 |
| 218 | 152.03 | 44.32 | 4.72 | 268 | 162.09 | 66.60 | 5.03 |
| 219 | -161.25 | 42.10 | 1.40 | 269 | 168.24 | 49.04 | 4.63 |
| 220 | -155.88 | 58.96 | 1.77 | 270 | -178.17 | 46.51 | 1.83 |
| 221 | -148.75 | 75.15 | 2.23 | 271 | -172.23 | 65.14 | 2.44 |
| 222 | -139.94 | 90.50 | 2.65 | 272 | -164.35 | 83.03 | 2.77 |
| 223 | -129.56 | 104.83 | 2.90 | 273 | -154.62 | 99.99 | 3.14 |
| 224 | -117.71 | 117.97 | 3.20 | 274 | -143.15 | 115.82 | 3.47 |
| 225 | -104.54 | 129.79 | 3.54 | 275 | -130.06 | 130.35 | 3.81 |
| 226 | -90.19 | 140.14 | 3.93 | 276 | -115.51 | 143.40 | 4.21 |
| 227 | -74.82 | 148.91 | 4.30 | 277 | -99.65 | 154.84 | 4.51 |
| 228 | -58.61 | 156.01 | 4.60 | 278 | -82.67 | 164.53 | 4.79 |
| 229 | -41.74 | 161.34 | 4.88 | 279 | -64.76 | 172.37 | 5.15 |
| 230 | -24.40 | 164.86 | 5.18 | 280 | -46.12 | 178.27 | 5.49 |
| 231 | -6.78 | 166.52 | 5.46 | 281 | -26.96 | 182.15 | 5.73 |
| 232 | 10.91 | 166.30 | 5.64 | 282 | -7.49 | 183.98 | 5.94 |
| 233 | 28.48 | 164.20 | 5.76 | 283 | 12.06 | 183.74 | 6.19 |
| 234 | 45.73 | 160.26 | 5.82 | 284 | 31.47 | 181.43 | 6.34 |
| 235 | 62.47 | 154.51 | 5.94 | 285 | 50.53 | 177.07 | 6.49 |
| 236 | 78.50 | 147.01 | 5.97 | 286 | 69.02 | 170.71 | 6.61 |
| 237 | 93.64 | 137.86 | 5.97 | 287 | 86.73 | 162.43 | 6.64 |
| 238 | 107.73 | 127.15 | 5.91 | 288 | 103.47 | 152.32 | 6.55 |
| 239 | 120.61 | 115.01 | 5.79 | 289 | 119.03 | 140.49 | 6.37 |
| 240 | 132.12 | 101.58 | 5.70 | 290 | 133.26 | 127.08 | 6.19 |
| 241 | 142.15 | 87.00 | 5.43 | 291 | 145.98 | 112.23 | 5.91 |
| 242 | 150.57 | 71.43 | 5.12 | 292 | 157.06 | 96.12 | 5.64 |
| 243 | 157.30 | 55.07 | 4.85 | 293 | 166.36 | 78.93 | 5.18 |
| 244 | 162.25 | 38.08 | 4.48 | 294 | 173.79 | 60.84 | 4.75 |
| 245 | -166.97 | 53.20 | 1.83 | 295 | 179.27 | 42.07 | 4.18 |
| 246 | -160.39 | 70.61 | 2.32 | 296 | -188.64 | 43.93 | 1.95 |
| 247 | -152.00 | 87.22 | 2.74 | 297 | -184.55 | 58.81 | 2.53 |
| 248 | -141.89 | 102.84 | 3.05 | 298 | -179.28 | 73.31 | 2.77 |
| 249 | -130.19 | 117.31 | 3.32 | 299 | -165.38 | 100.82 | 3.32 |
| 250 | -117.02 | 130.45 | 3.69 | 300 | -156.83 | 113.67 | 3.60 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| HELIOSTAT | X | Y | Z | HELIOSTAT | X | Y | Z |
|---|---|---|---|---|---|---|---|
| 301 | -147.29 | 125.79 | 3.90 | 351 | 171.95 | 108.40 | 5.82 |
| 302 | -125.46 | 147.56 | 4.45 | 352 | 180.03 | 94.37 | 5.40 |
| 303 | -113.32 | 157.08 | 4.66 | 353 | 186.97 | 79.74 | 4.88 |
| 304 | -100.46 | 165.60 | 4.88 | 354 | 192.73 | 64.61 | 4.42 |
| 305 | -72.91 | 179.44 | 5.33 | 355 | 197.26 | 49.07 | 3.81 |
| 306 | -58.40 | 184.68 | 5.67 | 356 | -207.66 | 48.36 | 2.65 |
| 307 | -43.52 | 188.74 | 5.88 | 357 | -203.15 | 64.73 | 2.96 |
| 308 | -13.02 | 193.25 | 6.25 | 358 | -197.35 | 80.69 | 3.26 |
| 309 | 2.40 | 193.68 | 6.40 | 359 | -190.30 | 96.15 | 3.66 |
| 310 | 17.81 | 192.87 | 6.55 | 360 | -182.05 | 110.99 | 3.96 |
| 311 | 48.19 | 187.60 | 6.80 | 361 | -172.64 | 125.12 | 4.11 |
| 312 | 62.97 | 183.17 | 6.92 | 362 | -162.13 | 138.47 | 4.48 |
| 313 | 77.34 | 177.58 | 6.98 | 363 | -150.60 | 150.93 | 4.72 |
| 314 | 104.54 | 163.06 | 6.98 | 364 | -138.11 | 162.44 | 5.03 |
| 315 | 117.19 | 154.22 | 6.86 | 365 | -124.74 | 172.91 | 5.27 |
| 316 | 129.09 | 144.40 | 6.86 | 366 | -110.58 | 182.29 | 5.49 |
| 317 | 150.36 | 122.09 | 6.16 | 367 | -95.73 | 190.52 | 5.79 |
| 318 | 159.60 | 109.74 | 5.88 | 368 | -80.26 | 197.53 | 6.10 |
| 319 | 167.83 | 96.69 | 5.58 | 369 | -64.28 | 203.29 | 6.25 |
| 320 | 181.05 | 68.83 | 4.79 | 370 | -47.90 | 207.76 | 6.40 |
| 321 | 185.95 | 54.20 | 4.36 | 371 | -31.21 | 210.91 | 6.61 |
| 322 | -195.98 | 53.95 | 2.59 | 372 | -14.33 | 212.73 | 6.86 |
| 323 | -191.06 | 69.38 | 2.83 | 373 | 2.65 | 213.20 | 7.04 |
| 324 | -184.93 | 84.36 | 3.14 | 374 | 19.61 | 212.31 | 7.16 |
| 325 | -177.63 | 98.81 | 3.47 | 375 | 36.44 | 210.07 | 7.25 |
| 326 | -169.21 | 112.64 | 3.78 | 376 | 53.04 | 206.51 | 7.38 |
| 327 | -159.70 | 125.75 | 4.08 | 377 | 69.31 | 201.63 | 7.47 |
| 328 | -149.19 | 138.06 | 4.33 | 378 | 85.14 | 195.48 | 7.53 |
| 329 | -137.73 | 149.49 | 4.60 | 379 | 100.43 | 188.08 | 7.50 |
| 330 | -125.39 | 159.98 | 4.82 | 380 | 115.08 | 179.49 | 7.47 |
| 331 | -112.26 | 169.45 | 5.06 | 381 | 129.00 | 169.76 | 7.38 |
| 332 | -98.42 | 177.85 | 5.27 | 382 | 142.10 | 158.96 | 7.22 |
| 333 | -83.96 | 185.12 | 5.61 | 383 | 154.30 | 147.14 | 6.86 |
| 334 | -68.96 | 191.21 | 5.88 | 384 | 165.52 | 134.40 | 6.43 |
| 335 | -53.52 | 196.10 | 6.07 | 385 | 175.69 | 120.80 | 6.13 |
| 336 | -37.74 | 199.73 | 6.25 | 386 | 184.75 | 106.43 | 5.64 |
| 337 | -21.73 | 202.10 | 6.43 | 387 | 192.63 | 91.39 | 5.06 |
| 338 | -5.57 | 203.19 | 6.61 | 388 | 199.29 | 75.77 | 4.57 |
| 339 | 10.62 | 202.99 | 6.80 | 389 | 204.69 | 59.67 | 3.99 |
| 340 | 26.74 | 201.50 | 6.92 | 390 | -215.53 | 59.33 | 3.05 |
| 341 | 42.69 | 198.73 | 7.04 | 391 | -210.12 | 76.30 | 3.44 |
| 342 | 58.37 | 194.71 | 7.16 | 392 | -203.38 | 92.78 | 3.87 |
| 343 | 73.68 | 189.44 | 7.25 | 393 | -195.36 | 108.67 | 4.11 |
| 344 | 88.53 | 182.98 | 7.25 | 394 | -186.09 | 123.87 | 4.48 |
| 345 | 102.81 | 175.35 | 7.25 | 395 | -175.64 | 138.29 | 4.66 |
| 346 | 116.44 | 166.61 | 7.22 | 396 | -164.07 | 151.83 | 4.97 |
| 347 | 129.33 | 156.82 | 7.07 | 397 | -151.47 | 164.41 | 5.24 |
| 348 | 141.40 | 146.03 | 6.77 | 398 | -137.90 | 175.94 | 5.49 |
| 349 | 152.57 | 134.31 | 6.43 | 399 | -123.46 | 186.36 | 5.79 |
| 350 | 162.78 | 121.74 | 6.16 | 400 | -108.24 | 195.59 | 6.10 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| *HELIOSTAT* | *X* | *Y* | *Z* |
|---|---|---|---|
| 401 | -92.33 | 203.59 | 6.31 |
| 402 | -75.84 | 210.29 | 6.49 |
| 403 | -58.86 | 215.66 | 6.61 |
| 404 | -41.51 | 219.66 | 6.89 |
| 405 | -23.89 | 222.27 | 7.10 |
| 406 | -6.13 | 223.46 | 7.25 |
| 407 | 11.68 | 223.24 | 7.41 |
| 408 | 29.41 | 221.60 | 7.53 |
| 409 | 46.95 | 218.56 | 7.65 |
| 410 | 64.19 | 214.13 | 7.74 |
| 411 | 81.03 | 208.34 | 7.77 |
| 412 | 97.36 | 201.23 | 7.77 |
| 413 | 113.06 | 192.85 | 7.71 |
| 414 | 128.05 | 183.24 | 7.62 |
| 415 | 142.23 | 172.46 | 7.47 |
| 416 | 155.51 | 160.60 | 7.22 |
| 417 | 167.79 | 147.71 | 6.86 |
| 418 | 179.02 | 133.89 | 6.43 |
| 419 | 189.11 | 119.22 | 6.04 |
| 420 | 197.99 | 103.79 | 5.36 |
| 421 | 205.63 | 87.70 | 4.79 |
| 422 | 211.95 | 71.06 | 4.18 |
| 423 | 216.94 | 53.96 | 3.51 |
| 424 | -228.19 | 53.14 | 3.14 |
| 425 | -223.24 | 71.13 | 2.07 |
| 426 | -216.87 | 88.67 | 4.11 |
| 427 | -209.12 | 105.65 | 4.36 |
| 428 | -200.05 | 121.96 | 4.63 |
| 429 | -189.71 | 137.50 | 4.88 |
| 430 | -178.16 | 152.16 | 5.15 |
| 431 | -165.49 | 165.85 | 5.49 |
| 432 | -151.76 | 178.50 | 5.82 |
| 433 | -137.08 | 190.01 | 6.19 |
| 434 | -121.52 | 200.32 | 6.34 |
| 435 | -105.19 | 209.35 | 6.49 |
| 436 | -88.20 | 217.06 | 6.68 |
| 437 | -70.64 | 223.39 | 6.95 |
| 438 | -52.64 | 228.31 | 7.16 |
| 439 | -34.30 | 231.77 | 7.32 |
| 440 | -15.75 | 233.77 | 7.47 |
| 441 | 2.91 | 234.28 | 7.62 |
| 442 | 21.55 | 233.30 | 7.77 |
| 443 | 40.04 | 230.85 | 7.99 |
| 444 | 58.29 | 226.93 | 8.17 |
| 445 | 76.17 | 221.57 | 8.23 |
| 446 | 93.56 | 214.81 | 8.23 |
| 447 | 110.36 | 206.68 | 8.20 |
| 448 | 126.46 | 197.24 | 8.08 |
| 449 | 141.75 | 186.55 | 7.77 |
| 450 | 156.15 | 174.68 | 7.59 |
| 451 | 169.56 | 161.69 | 7.22 |
| 452 | 181.89 | 147.69 | 6.80 |
| 453 | 193.06 | 132.74 | 6.37 |
| 454 | 203.02 | 116.96 | 5.76 |
| 455 | 211.68 | 100.43 | 5.03 |
| 456 | 219.00 | 83.26 | 4.42 |
| 457 | 224.93 | 65.57 | 3.69 |
| 458 | -236.68 | 65.16 | 3.72 |
| 459 | -230.74 | 83.79 | 4.21 |
| 460 | -223.34 | 101.88 | 4.51 |
| 461 | -214.53 | 119.34 | 4.75 |
| 462 | -204.35 | 136.03 | 4.79 |
| 463 | -192.87 | 151.86 | 5.40 |
| 464 | -180.17 | 166.73 | 5.76 |
| 465 | -166.33 | 180.54 | 6.19 |
| 466 | -151.44 | 193.21 | 6.40 |
| 467 | -135.58 | 204.65 | 6.55 |
| 468 | -118.86 | 214.79 | 6.71 |
| 469 | -101.39 | 223.57 | 6.92 |
| 470 | -83.28 | 230.93 | 7.16 |
| 471 | -64.63 | 236.82 | 7.32 |
| 472 | -45.58 | 241.21 | 7.53 |
| 473 | -26.24 | 244.08 | 7.68 |
| 474 | -6.73 | 245.39 | 7.86 |
| 475 | 12.82 | 245.15 | 8.08 |
| 476 | 32.29 | 243.35 | 8.29 |
| 477 | 51.56 | 240.01 | 8.47 |
| 478 | 70.49 | 235.14 | 8.56 |
| 479 | 88.98 | 228.79 | 8.69 |
| 480 | 106.91 | 220.98 | 8.69 |
| 481 | 124.16 | 211.77 | 8.53 |
| 482 | 140.62 | 201.22 | 8.29 |
| 483 | 156.19 | 189.39 | 8.02 |
| 484 | 170.76 | 176.36 | 7.62 |
| 485 | 184.26 | 162.21 | 7.22 |
| 486 | 196.58 | 147.03 | 6.74 |
| 487 | 207.66 | 130.91 | 5.94 |
| 488 | 217.42 | 113.97 | 5.33 |
| 489 | 225.80 | 96.31 | 4.72 |
| 490 | 232.75 | 78.03 | 4.05 |
| 491 | 238.22 | 59.26 | 3.20 |
| 492 | -249.22 | 63.30 | 4.02 |
| 493 | -245.00 | 78.07 | 4.30 |
| 494 | -239.90 | 92.56 | 4.57 |
| 495 | -227.15 | 120.50 | 5.03 |
| 496 | -219.55 | 133.85 | 5.27 |
| 497 | -211.17 | 146.72 | 5.58 |
| 498 | -192.17 | 170.85 | 6.19 |
| 499 | -181.62 | 182.02 | 6.40 |
| 500 | -170.43 | 192.54 | 6.55 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| *HELIOSTAT* | *X* | *Y* | *Z* | *HELIOSTAT* | *X* | *Y* | *Z* |
|---|---|---|---|---|---|---|---|
| 501 | -146.26 | 211.49 | 6.80 | 551 | 38.08 | 266.57 | 8.99 |
| 502 | -133.37 | 219.85 | 6.92 | 552 | 53.93 | 263.82 | 9.11 |
| 503 | -120.00 | 227.42 | 7.04 | 553 | 69.59 | 260.13 | 9.17 |
| 504 | -92.03 | 240.10 | 7.41 | 554 | 85.00 | 255.51 | 9.21 |
| 505 | -77.53 | 245.17 | 7.56 | 555 | 100.11 | 249.98 | 9.21 |
| 506 | -62.75 | 249.36 | 7.65 | 556 | 114.85 | 243.56 | 9.17 |
| 507 | -32.57 | 255.06 | 7.99 | 557 | 129.19 | 236.26 | 9.14 |
| 508 | -17.28 | 256.55 | 8.17 | 558 | 143.07 | 228.13 | 9.05 |
| 509 | -1.93 | 257.13 | 8.32 | 559 | 156.44 | 219.18 | 8.90 |
| 510 | 28.74 | 255.52 | 8.63 | 560 | 169.25 | 209.44 | 8.69 |
| 511 | 43.95 | 253.35 | 8.75 | 561 | 181.46 | 198.96 | 8.35 |
| 512 | 59.00 | 250.28 | 8.84 | 562 | 193.01 | 187.77 | 8.02 |
| 513 | 88.42 | 241.46 | 8.93 | 563 | 203.88 | 175.91 | 7.62 |
| 514 | 102.68 | 235.75 | 8.93 | 564 | 214.02 | 163.42 | 7.16 |
| 515 | 116.57 | 229.19 | 8.93 | 565 | 223.40 | 150.35 | 6.64 |
| 516 | 143.07 | 213.66 | 8.75 | 566 | 231.98 | 136.74 | 6.19 |
| 517 | 155.57 | 204.73 | 8.47 | 567 | 239.73 | 122.64 | 5.40 |
| 518 | 167.52 | 195.08 | 8.47 | 568 | 246.63 | 108.10 | 4.88 |
| 519 | 189.58 | 173.72 | 7.56 | 569 | 252.64 | 93.18 | 4.27 |
| 520 | 199.62 | 162.08 | 7.16 | 570 | 257.76 | 77.93 | 3.66 |
| 521 | 208.94 | 149.87 | 6.74 | 571 | 261.95 | 62.40 | 2.87 |
| 522 | 225.32 | 123.89 | 5.64 | 572 | -273.27 | 69.40 | 4.54 |
| 523 | 232.32 | 110.22 | 5.06 | 573 | -268.64 | 85.60 | 4.82 |
| 524 | 238.48 | 96.15 | 4.54 | 574 | -263.04 | 101.49 | 5.15 |
| 525 | 248.25 | 67.03 | 3.32 | 575 | -256.51 | 117.02 | 5.49 |
| 526 | -262.86 | 58.46 | 4.18 | 576 | -249.07 | 132.13 | 5.79 |
| 527 | -258.90 | 74.05 | 4.42 | 577 | -240.73 | 146.76 | 6.10 |
| 528 | -254.01 | 89.38 | 4.66 | 578 | -231.54 | 160.88 | 6.40 |
| 529 | -248.22 | 104.39 | 4.97 | 579 | -221.52 | 174.42 | 6.61 |
| 530 | -241.54 | 119.03 | 5.24 | 580 | -210.71 | 187.33 | 6.92 |
| 531 | -234.01 | 133.24 | 5.55 | 581 | -199.14 | 199.58 | 7.04 |
| 532 | -225.63 | 146.98 | 5.94 | 582 | -186.87 | 211.12 | 7.16 |
| 533 | -216.45 | 160.19 | 6.22 | 583 | -173.93 | 221.90 | 7.38 |
| 534 | -206.50 | 172.83 | 6.40 | 584 | -160.37 | 231.89 | 7.56 |
| 535 | -195.81 | 184.85 | 6.61 | 585 | -146.23 | 241.06 | 7.74 |
| 536 | -184.42 | 196.22 | 6.83 | 586 | -131.58 | 249.36 | 7.86 |
| 537 | -172.37 | 206.88 | 6.95 | 587 | -116.45 | 256.77 | 7.99 |
| 538 | -159.71 | 216.80 | 7.01 | 588 | -100.91 | 263.27 | 8.08 |
| 539 | -146.48 | 225.95 | 7.16 | 589 | -85.01 | 268.82 | 8.23 |
| 540 | -132.72 | 234.30 | 7.32 | 590 | -68.80 | 273.42 | 8.38 |
| 541 | -118.50 | 241.81 | 7.56 | 591 | -52.35 | 277.04 | 8.56 |
| 542 | -103.84 | 248.45 | 7.62 | 592 | -35.71 | 279.67 | 8.75 |
| 543 | -88.82 | 254.21 | 7.77 | 593 | -18.95 | 281.31 | 8.84 |
| 544 | -73.48 | 259.06 | 7.92 | 594 | -2.12 | 281.94 | 8.99 |
| 545 | -57.88 | 262.99 | 8.08 | 595 | 14.73 | 281.56 | 9.08 |
| 546 | -42.07 | 265.97 | 8.23 | 596 | 31.51 | 280.18 | 9.24 |
| 547 | -26.11 | 268.01 | 8.44 | 597 | 48.19 | 277.79 | 9.36 |
| 548 | -10.06 | 269.09 | 8.56 | 598 | 64.69 | 274.42 | 9.54 |
| 549 | 6.02 | 269.21 | 8.75 | 599 | 80.96 | 270.07 | 9.66 |
| 550 | 22.09 | 268.37 | 8.84 | 600 | 96.95 | 264.75 | 9.72 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| *HELIOSTAT* | *X* | *Y* | *Z* | *HELIOSTAT* | *X* | *Y* | *Z* |
|---|---|---|---|---|---|---|---|
| 601 | 112.58 | 258.49 | 9.72 | 651 | 185.51 | 229.57 | 9.21 |
| 602 | 127.82 | 251.30 | 9.60 | 652 | 198.89 | 218.08 | 8.87 |
| 603 | 142.60 | 243.22 | 9.42 | 653 | 211.56 | 205.81 | 8.44 |
| 604 | 156.87 | 234.27 | 9.24 | 654 | 223.47 | 192.81 | 8.41 |
| 605 | 170.58 | 224.49 | 9.05 | 655 | 234.59 | 179.12 | 7.56 |
| 606 | 183.68 | 213.90 | 8.78 | 656 | 244.87 | 164.79 | 6.95 |
| 607 | 196.13 | 202.55 | 8.38 | 657 | 254.27 | 149.88 | 6.40 |
| 608 | 207.87 | 190.47 | 8.08 | 658 | 262.77 | 134.42 | 5.70 |
| 609 | 218.88 | 177.72 | 7.62 | 659 | 270.33 | 118.49 | 4.97 |
| 610 | 229.10 | 164.33 | 7.10 | 660 | 276.92 | 102.14 | 4.36 |
| 611 | 238.50 | 150.36 | 6.55 | 661 | 282.52 | 85.42 | 3.69 |
| 612 | 247.06 | 135.85 | 5.94 | 662 | 287.12 | 68.39 | 2.83 |
| 613 | 254.73 | 120.85 | 5.18 | 663 | -299.44 | 76.06 | 5.09 |
| 614 | 261.49 | 105.42 | 4.57 | 664 | -294.36 | 93.80 | 5.52 |
| 615 | 267.32 | 89.62 | 4.05 | 665 | -288.23 | 111.21 | 5.85 |
| 616 | 272.20 | 73.50 | 3.20 | 666 | -281.08 | 128.22 | 6.13 |
| 617 | -288.12 | 64.08 | 4.66 | 667 | -272.92 | 144.78 | 6.49 |
| 618 | -283.77 | 81.17 | 5.00 | 668 | -263.79 | 160.82 | 6.86 |
| 619 | -278.42 | 97.97 | 5.30 | 669 | -253.71 | 176.28 | 7.13 |
| 620 | -272.07 | 114.42 | 5.70 | 670 | -242.73 | 191.12 | 7.41 |
| 621 | -264.75 | 130.47 | 6.00 | 671 | -230.89 | 205.28 | 7.65 |
| 622 | -256.49 | 146.04 | 6.28 | 672 | -218.22 | 218.70 | 7.86 |
| 623 | -247.31 | 161.10 | 6.58 | 673 | -204.77 | 231.34 | 8.11 |
| 624 | -237.25 | 175.58 | 6.92 | 674 | -190.59 | 243.15 | 8.26 |
| 625 | -226.34 | 189.44 | 7.10 | 675 | -175.72 | 254.10 | 8.41 |
| 626 | -214.62 | 202.61 | 7.32 | 676 | -160.24 | 264.14 | 8.53 |
| 627 | -202.14 | 215.07 | 7.59 | 677 | -144.18 | 273.24 | 8.69 |
| 628 | -188.94 | 226.76 | 7.77 | 678 | -127.60 | 281.36 | 8.87 |
| 629 | -175.06 | 237.64 | 7.92 | 679 | -110.57 | 288.48 | 8.99 |
| 630 | -160.55 | 247.67 | 8.05 | 680 | -93.15 | 294.57 | 9.08 |
| 631 | -145.48 | 256.81 | 8.20 | 681 | -75.39 | 299.60 | 9.24 |
| 632 | -129.88 | 265.04 | 8.32 | 682 | -57.36 | 303.57 | 9.30 |
| 633 | -113.82 | 272.32 | 8.44 | 683 | -39.13 | 306.46 | 9.45 |
| 634 | -97.36 | 278.64 | 8.63 | 684 | -20.76 | 308.25 | 9.66 |
| 635 | -80.54 | 283.95 | 8.75 | 685 | -2.32 | 308.94 | 9.78 |
| 636 | -63.44 | 288.26 | 8.90 | 686 | 16.14 | 308.52 | 9.97 |
| 637 | -46.12 | 291.53 | 9.05 | 687 | 34.53 | 307.01 | 10.12 |
| 638 | -28.62 | 293.76 | 9.14 | 688 | 52.80 | 304.40 | 10.27 |
| 639 | -11.03 | 294.95 | 9.24 | 689 | 70.89 | 300.70 | 10.39 |
| 640 | 6.60 | 295.08 | 9.45 | 690 | 88.72 | 295.93 | 10.49 |
| 641 | 24.21 | 294.16 | 9.60 | 691 | 106.23 | 290.11 | 10.55 |
| 642 | 41.74 | 292.19 | 9.75 | 692 | 123.37 | 283.24 | 10.58 |
| 643 | 59.11 | 289.18 | 9.97 | 693 | 140.06 | 275.37 | 10.49 |
| 644 | 76.27 | 285.13 | 10.15 | 694 | 156.26 | 266.52 | 10.30 |
| 645 | 93.17 | 280.07 | 10.24 | 695 | 171.89 | 256.71 | 10.06 |
| 646 | 109.72 | 274.00 | 10.24 | 696 | 186.92 | 245.99 | 9.75 |
| 647 | 125.89 | 266.96 | 10.21 | 697 | 201.27 | 234.38 | 9.30 |
| 648 | 141.61 | 258.97 | 10.06 | 698 | 214.91 | 221.95 | 8.93 |
| 649 | 156.82 | 250.05 | 9.78 | 699 | 227.78 | 208.72 | 8.44 |
| 650 | 171.47 | 240.24 | 9.48 | 700 | 239.84 | 194.74 | 8.05 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| *HELIOSTAT* | *X* | *Y* | *Z* | *HELIOSTAT* | *X* | *Y* | *Z* |
|---|---|---|---|---|---|---|---|
| 701 | 251.04 | 180.07 | 7.47 | 751 | 296.14 | 129.81 | 4.51 |
| 702 | 261.34 | 164.76 | 6.80 | 752 | 303.36 | 111.89 | 3.81 |
| 703 | 270.72 | 148.86 | 6.19 | 753 | 309.50 | 93.57 | 2.93 |
| 704 | 279.12 | 132.42 | 5.43 | 754 | 314.54 | 74.92 | 5.79 |
| 705 | 286.53 | 115.52 | 4.72 | 755 | -327.96 | 83.29 | 6.00 |
| 706 | 292.92 | 98.20 | 4.11 | 756 | -323.90 | 97.90 | 6.55 |
| 707 | 298.26 | 80.53 | 3.20 | 757 | -313.83 | 126.50 | 6.89 |
| 708 | 302.54 | 62.58 | 5.18 | 758 | -307.85 | 140.44 | 7.16 |
| 709 | -315.63 | 70.20 | 5.70 | 759 | -301.25 | 154.09 | 7.65 |
| 710 | -310.87 | 88.92 | 5.97 | 760 | -286.25 | 180.43 | 7.92 |
| 711 | -305.01 | 107.33 | 6.25 | 761 | -277.88 | 193.08 | 7.86 |
| 712 | -298.05 | 125.35 | 6.61 | 762 | -268.95 | 205.33 | 8.63 |
| 713 | -290.04 | 142.92 | 7.04 | 763 | -249.49 | 228.58 | 8.84 |
| 714 | -280.98 | 159.99 | 7.35 | 764 | -239.00 | 239.53 | 9.02 |
| 715 | -270.93 | 176.48 | 7.65 | 765 | -228.03 | 249.99 | 9.45 |
| 716 | -259.90 | 192.35 | 7.92 | 766 | -204.74 | 269.40 | 9.54 |
| 717 | -247.95 | 207.53 | 8.17 | 767 | -192.46 | 278.30 | 9.60 |
| 718 | -235.12 | 221.96 | 8.38 | 768 | -179.80 | 286.65 | 9.81 |
| 719 | -221.44 | 235.61 | 8.66 | 769 | -153.42 | 301.59 | 9.88 |
| 720 | -206.98 | 248.41 | 8.84 | 770 | -139.76 | 308.16 | 9.91 |
| 721 | -191.77 | 260.33 | 8.99 | 771 | -125.81 | 314.11 | 10.09 |
| 722 | -175.89 | 271.32 | 9.21 | 772 | -97.19 | 324.11 | 10.21 |
| 723 | -159.37 | 281.34 | 9.30 | 773 | -82.57 | 328.14 | 10.27 |
| 724 | -142.28 | 290.35 | 9.45 | 774 | -67.79 | 331.51 | 10.45 |
| 725 | -124.69 | 298.33 | 9.54 | 775 | -37.84 | 336.25 | 10.52 |
| 726 | -106.65 | 305.24 | 9.60 | 776 | -22.74 | 337.61 | 10.58 |
| 727 | -88.23 | 311.07 | 9.72 | 777 | -7.59 | 338.29 | 10.73 |
| 728 | -69.50 | 315.78 | 9.91 | 778 | 22.72 | 337.61 | 10.79 |
| 729 | -50.52 | 319.37 | 10.06 | 779 | 37.82 | 336.25 | 11.06 |
| 730 | -31.36 | 321.82 | 10.21 | 780 | 52.85 | 334.22 | 11.67 |
| 731 | -12.08 | 323.11 | 10.27 | 781 | 82.55 | 328.15 | 11.80 |
| 732 | 7.23 | 323.26 | 10.52 | 782 | 97.17 | 324.12 | 11.86 |
| 733 | 26.53 | 322.25 | 10.61 | 783 | 111.59 | 319.44 | 11.80 |
| 734 | 45.72 | 320.09 | 10.76 | 784 | 139.74 | 308.17 | 11.67 |
| 735 | 64.76 | 316.79 | 11.06 | 785 | 153.40 | 301.60 | 11.43 |
| 736 | 83.56 | 312.36 | 11.28 | 786 | 166.76 | 294.42 | 10.85 |
| 737 | 102.06 | 306.81 | 11.28 | 787 | 192.44 | 278.32 | 10.52 |
| 738 | 120.20 | 300.17 | 11.22 | 788 | 204.72 | 269.42 | 10.21 |
| 739 | 137.91 | 292.45 | 10.97 | 789 | 216.58 | 259.97 | 9.54 |
| 740 | 155.13 | 283.69 | 10.58 | 790 | 238.98 | 239.54 | 9.05 |
| 741 | 171.80 | 273.92 | 10.27 | 791 | 249.48 | 228.60 | 8.63 |
| 742 | 187.85 | 263.18 | 9.97 | 792 | 259.47 | 217.19 | 7.71 |
| 743 | 203.23 | 251.49 | 9.57 | 793 | 277.87 | 193.09 | 7.22 |
| 744 | 217.88 | 238.90 | 9.02 | 794 | 286.24 | 180.45 | 6.61 |
| 745 | 231.76 | 225.47 | 8.47 | 795 | 294.03 | 167.45 | 5.58 |
| 746 | 244.81 | 211.22 | 7.96 | 796 | 313.83 | 126.52 | 5.00 |
| 747 | 256.99 | 196.23 | 7.41 | 797 | 319.18 | 112.34 | 4.45 |
| 748 | 268.25 | 180.53 | 6.31 | 798 | 327.95 | 83.32 | 3.14 |
| 749 | 278.55 | 164.19 | 5.91 | 799 | -341.13 | 94.83 | 6.10 |
| 750 | 287.86 | 147.26 | 5.24 | 800 | -336.54 | 110.01 | 6.43 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| *HELIOSTAT* | *X* | *Y* | *Z* | *HELIOSTAT* | *X* | *Y* | *Z* |
|---|---|---|---|---|---|---|---|
| 801 | -331.28 | 124.98 | 6.80 | 851 | 303.67 | 182.06 | 7.22 |
| 802 | -325.34 | 139.69 | 7.10 | 852 | 311.52 | 168.28 | 6.55 |
| 803 | -318.76 | 154.13 | 7.35 | 853 | 318.75 | 154.15 | 5.91 |
| 804 | -311.53 | 168.26 | 7.62 | 854 | 325.33 | 139.72 | 5.40 |
| 805 | -303.68 | 182.04 | 7.92 | 855 | 331.27 | 125.00 | 4.72 |
| 806 | -295.22 | 195.47 | 8.23 | 856 | 336.53 | 110.03 | 4.30 |
| 807 | -286.17 | 208.50 | 8.53 | 857 | 341.13 | 94.85 | 3.75 |
| 808 | -276.54 | 221.11 | 8.84 | 858 | -349.45 | 122.96 | 6.98 |
| 809 | -266.36 | 233.27 | 9.08 | 859 | -343.59 | 138.50 | 7.25 |
| 810 | -255.64 | 244.97 | 9.36 | 860 | -337.04 | 153.75 | 7.56 |
| 811 | -244.41 | 256.18 | 9.60 | 861 | -329.81 | 168.70 | 7.89 |
| 812 | -232.69 | 266.87 | 9.75 | 862 | -321.93 | 183.30 | 8.29 |
| 813 | -220.50 | 277.03 | 9.91 | 863 | -313.39 | 197.54 | 10.15 |
| 814 | -207.86 | 286.63 | 10.03 | 864 | -304.23 | 211.38 | 8.96 |
| 815 | -194.81 | 295.65 | 10.15 | 865 | -294.45 | 224.80 | 9.24 |
| 816 | -181.37 | 304.08 | 10.21 | 866 | -284.08 | 237.76 | 9.54 |
| 817 | -167.57 | 311.90 | 10.27 | 867 | -273.15 | 250.25 | 9.78 |
| 818 | -153.43 | 319.10 | 10.30 | 868 | -261.66 | 262.24 | 9.97 |
| 819 | -138.98 | 325.65 | 10.36 | 869 | -249.65 | 273.70 | 10.21 |
| 820 | -124.25 | 331.55 | 10.45 | 870 | -237.14 | 284.61 | 10.30 |
| 821 | -109.27 | 336.78 | 10.52 | 871 | -224.15 | 294.95 | 10.39 |
| 822 | -94.07 | 341.34 | 10.58 | 872 | -210.71 | 304.69 | 10.45 |
| 823 | -78.69 | 345.21 | 10.61 | 873 | -196.85 | 313.83 | 10.58 |
| 824 | -63.14 | 348.39 | 10.67 | 874 | -182.59 | 322.33 | 10.70 |
| 825 | -47.47 | 350.87 | 10.70 | 875 | -167.97 | 330.19 | 10.76 |
| 826 | -31.70 | 352.64 | 10.73 | 876 | -153.01 | 337.38 | 10.82 |
| 827 | -15.87 | 353.71 | 10.76 | 877 | -137.74 | 343.90 | 10.88 |
| 828 | -.01 | 354.07 | 10.82 | 878 | -122.19 | 349.72 | 10.91 |
| 829 | 15.85 | 353.71 | 10.97 | 879 | -106.40 | 354.84 | 10.97 |
| 830 | 31.68 | 352.65 | 11.19 | 880 | -90.40 | 359.25 | 10.97 |
| 831 | 47.45 | 350.87 | 11.43 | 881 | -74.22 | 362.94 | 11.00 |
| 832 | 63.12 | 348.40 | 11.73 | 882 | -57.88 | 365.90 | 11.03 |
| 833 | 78.66 | 345.22 | 12.04 | 883 | -41.43 | 368.13 | 11.09 |
| 834 | 94.05 | 341.35 | 12.25 | 884 | -24.90 | 369.62 | 11.16 |
| 835 | 109.25 | 336.79 | 12.34 | 885 | -8.31 | 370.36 | 11.25 |
| 836 | 124.23 | 331.56 | 12.41 | 886 | 8.29 | 370.36 | 11.37 |
| 837 | 138.96 | 325.66 | 12.34 | 887 | 24.87 | 369.62 | 11.52 |
| 838 | 153.41 | 319.11 | 12.19 | 888 | 41.41 | 368.13 | 11.73 |
| 839 | 167.55 | 311.91 | 12.01 | 889 | 57.86 | 365.91 | 12.04 |
| 840 | 181.35 | 304.10 | 11.80 | 890 | 74.19 | 362.95 | 12.41 |
| 841 | 194.80 | 295.67 | 11.49 | 891 | 90.38 | 359.26 | 11.28 |
| 842 | 207.85 | 286.64 | 11.16 | 892 | 106.38 | 354.85 | 11.49 |
| 843 | 220.48 | 277.04 | 10.82 | 893 | 122.17 | 349.73 | 11.58 |
| 844 | 232.67 | 266.89 | 10.36 | 894 | 137.72 | 343.90 | 11.52 |
| 845 | 244.39 | 256.20 | 10.03 | 895 | 152.99 | 337.39 | 11.34 |
| 846 | 255.62 | 244.99 | 9.63 | 896 | 167.95 | 330.20 | 11.16 |
| 847 | 266.34 | 233.29 | 9.14 | 897 | 182.57 | 322.34 | 10.88 |
| 848 | 276.53 | 221.12 | 8.66 | 898 | 196.83 | 313.84 | 10.58 |
| 849 | 286.16 | 208.51 | 8.14 | 899 | 210.69 | 304.71 | 10.27 |
| 850 | 295.21 | 195.49 | 7.71 | 900 | 224.13 | 294.96 | 11.46 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| *HELIOSTAT* | *X* | *Y* | *Z* | *HELIOSTAT* | *X* | *Y* | *Z* |
|---|---|---|---|---|---|---|---|
| 901 | 237.12 | 284.62 | 11.00 | 951 | 183.40 | 341.42 | 13.20 |
| 902 | 249.63 | 273.71 | 10.61 | 952 | 198.51 | 332.86 | 12.80 |
| 903 | 261.64 | 262.26 | 10.15 | 953 | 213.22 | 323.63 | 12.50 |
| 904 | 273.13 | 250.27 | 9.66 | 954 | 227.51 | 313.75 | 12.07 |
| 905 | 284.07 | 237.78 | 9.24 | 955 | 241.33 | 303.25 | 11.67 |
| 906 | 294.44 | 224.82 | 8.69 | 956 | 254.68 | 292.13 | 11.25 |
| 907 | 304.21 | 211.40 | 8.11 | 957 | 267.51 | 280.43 | 10.76 |
| 908 | 313.38 | 197.56 | 7.56 | 958 | 279.80 | 268.16 | 10.18 |
| 909 | 321.91 | 183.32 | 7.16 | 959 | 291.54 | 255.36 | 9.66 |
| 910 | 329.80 | 168.72 | 6.40 | 960 | 302.68 | 242.04 | 9.24 |
| 911 | 337.03 | 153.77 | 5.85 | 961 | 313.22 | 228.24 | 8.69 |
| 912 | 343.58 | 138.52 | 5.18 | 962 | 323.13 | 213.98 | 8.08 |
| 913 | 349.44 | 122.99 | 4.63 | 963 | 332.40 | 199.28 | 7.53 |
| 914 | -356.12 | 152.91 | 7.77 | 964 | 340.99 | 184.19 | 7.07 |
| 915 | -348.91 | 168.71 | 8.23 | 965 | 348.90 | 168.73 | 6.31 |
| 916 | -341.00 | 184.17 | 8.63 | 966 | 356.11 | 152.93 | 5.79 |
| 917 | -332.41 | 199.26 | 8.99 | 967 | -352.29 | 200.59 | 9.33 |
| 918 | -323.15 | 213.95 | 9.27 | 968 | -342.95 | 216.18 | 9.66 |
| 919 | -313.24 | 228.22 | 9.66 | 969 | -332.93 | 231.32 | 10.09 |
| 920 | -302.70 | 242.02 | 9.97 | 970 | -322.23 | 246.01 | 10.33 |
| 921 | -291.55 | 255.34 | 10.24 | 971 | -310.88 | 260.19 | 10.52 |
| 922 | -279.82 | 268.14 | 10.36 | 972 | -298.91 | 273.86 | 10.73 |
| 923 | -267.53 | 280.41 | 10.49 | 973 | -286.35 | 286.98 | 10.97 |
| 924 | -254.70 | 292.11 | 10.67 | 974 | -273.20 | 299.52 | 11.25 |
| 925 | -241.35 | 303.23 | 10.82 | 975 | -259.51 | 311.46 | 11.49 |
| 926 | -227.53 | 313.74 | 11.06 | 976 | -245.29 | 322.77 | 11.73 |
| 927 | -213.24 | 323.62 | 11.19 | 977 | -230.59 | 333.43 | 11.83 |
| 928 | -198.53 | 332.85 | 11.28 | 978 | -215.42 | 343.43 | 11.98 |
| 929 | -183.42 | 341.41 | 11.40 | 979 | -199.82 | 352.74 | 12.04 |
| 930 | -167.94 | 349.28 | 11.55 | 980 | -183.81 | 361.33 | 12.13 |
| 931 | -152.12 | 356.45 | 11.58 | 981 | -167.44 | 369.21 | 12.28 |
| 932 | -136.00 | 362.91 | 11.61 | 982 | -150.73 | 376.34 | 12.28 |
| 933 | -119.61 | 368.64 | 11.67 | 983 | -133.72 | 382.71 | 12.31 |
| 934 | -102.97 | 373.63 | 11.73 | 984 | -116.44 | 388.32 | 12.31 |
| 935 | -86.13 | 377.87 | 11.80 | 985 | -98.93 | 393.14 | 12.28 |
| 936 | -69.11 | 381.35 | 11.80 | 986 | -81.22 | 397.18 | 12.28 |
| 937 | -51.96 | 384.06 | 11.83 | 987 | -63.34 | 400.42 | 12.25 |
| 938 | -34.70 | 386.00 | 11.83 | 988 | -45.34 | 402.86 | 12.25 |
| 939 | -17.38 | 387.17 | 11.83 | 989 | -27.24 | 404.48 | 12.25 |
| 940 | -.01 | 387.56 | 11.86 | 990 | -9.10 | 405.30 | 12.25 |
| 941 | 17.35 | 387.17 | 11.98 | 991 | 9.07 | 405.30 | 12.28 |
| 942 | 34.68 | 386.00 | 12.16 | 992 | 27.22 | 404.49 | 12.41 |
| 943 | 51.94 | 384.06 | 12.50 | 993 | 45.31 | 402.86 | 12.71 |
| 944 | 69.09 | 381.35 | 12.89 | 994 | 63.31 | 400.43 | 13.29 |
| 945 | 86.10 | 377.87 | 13.41 | 995 | 81.19 | 397.19 | 13.93 |
| 946 | 102.95 | 373.63 | 13.62 | 996 | 98.90 | 393.15 | 14.48 |
| 947 | 119.58 | 368.65 | 13.78 | 997 | 116.42 | 388.33 | 14.60 |
| 948 | 135.98 | 362.92 | 13.78 | 998 | 133.70 | 382.72 | 14.57 |
| 949 | 152.10 | 356.46 | 13.62 | 999 | 150.71 | 376.35 | 14.48 |
| 950 | 167.92 | 349.29 | 13.47 | 1000 | 167.42 | 369.22 | 14.17 |

TABLE 5.1-1 (Continued). HELIOSTAT LOCATIONS

| *HELIOSTAT* | *X* | *Y* | *Z* | *HELIOSTAT* | *X* | *Y* | *Z* |
|---|---|---|---|---|---|---|---|
| 1001 | 183.79 | 361.35 | 13.84 | 1030 | -112.65 | 408.76 | 12.95 |
| 1002 | 199.79 | 352.75 | 13.59 | 1031 | -94.23 | 413.40 | 12.89 |
| 1003 | 215.40 | 343.44 | 13.26 | 1032 | -75.61 | 417.20 | 12.83 |
| 1004 | 230.57 | 333.45 | 12.80 | 1033 | -56.85 | 420.17 | 12.77 |
| 1005 | 245.27 | 322.79 | 12.44 | 1034 | -37.97 | 422.30 | 12.71 |
| 1006 | 259.49 | 311.47 | 11.92 | 1035 | -19.01 | 423.57 | 12.68 |
| 1007 | 273.18 | 299.54 | 11.43 | 1036 | -.01 | 424.00 | 12.68 |
| 1008 | 286.33 | 287.00 | 10.82 | 1037 | 18.98 | 423.57 | 12.71 |
| 1009 | 298.90 | 273.88 | 10.21 | 1038 | 37.94 | 422.30 | 12.83 |
| 1010 | 310.87 | 260.21 | 9.66 | 1039 | 56.82 | 420.18 | 13.53 |
| 1011 | 322.21 | 246.03 | 9.24 | 1040 | 75.59 | 417.21 | 14.63 |
| 1012 | 332.91 | 231.34 | 8.63 | 1041 | 94.20 | 413.40 | 15.21 |
| 1013 | 342.94 | 216.20 | 8.02 | 1042 | 112.63 | 408.77 | 15.36 |
| 1014 | 352.28 | 200.62 | 7.47 | 1043 | 130.83 | 403.31 | 15.33 |
| 1015 | -342.69 | 249.68 | 10.64 | 1044 | 148.76 | 397.05 | 15.18 |
| 1016 | -331.16 | 264.78 | 10.91 | 1045 | 166.40 | 389.98 | 14.84 |
| 1017 | -318.97 | 279.35 | 11.28 | 1046 | 183.71 | 382.14 | 14.54 |
| 1018 | -306.13 | 293.36 | 11.58 | 1047 | 200.64 | 373.52 | 14.20 |
| 1019 | -292.68 | 306.78 | 11.86 | 1048 | 217.17 | 364.16 | 13.81 |
| 1020 | -278.65 | 319.58 | 12.07 | 1049 | 233.27 | 354.06 | 13.44 |
| 1021 | -264.05 | 331.74 | 12.19 | 1050 | 248.90 | 343.26 | 12.98 |
| 1022 | -248.92 | 343.24 | 12.31 | 1051 | 264.03 | 331.76 | 12.65 |
| 1023 | -233.29 | 354.05 | 12.50 | 1052 | 278.62 | 319.60 | 12.13 |
| 1024 | -217.20 | 364.14 | 12.68 | 1053 | 292.66 | 306.80 | 11.49 |
| 1025 | -200.67 | 373.51 | 12.80 | 1054 | 306.11 | 293.38 | 10.82 |
| 1026 | -183.73 | 382.12 | 12.89 | 1055 | 318.95 | 279.37 | 10.24 |
| 1027 | -166.43 | 389.97 | 12.95 | 1056 | 331.14 | 264.80 | 9.69 |
| 1028 | -148.79 | 397.04 | 12.95 | 1057 | 342.68 | 249.70 | 7.62 |
| 1029 | -130.85 | 403.30 | 12.95 | | | | |

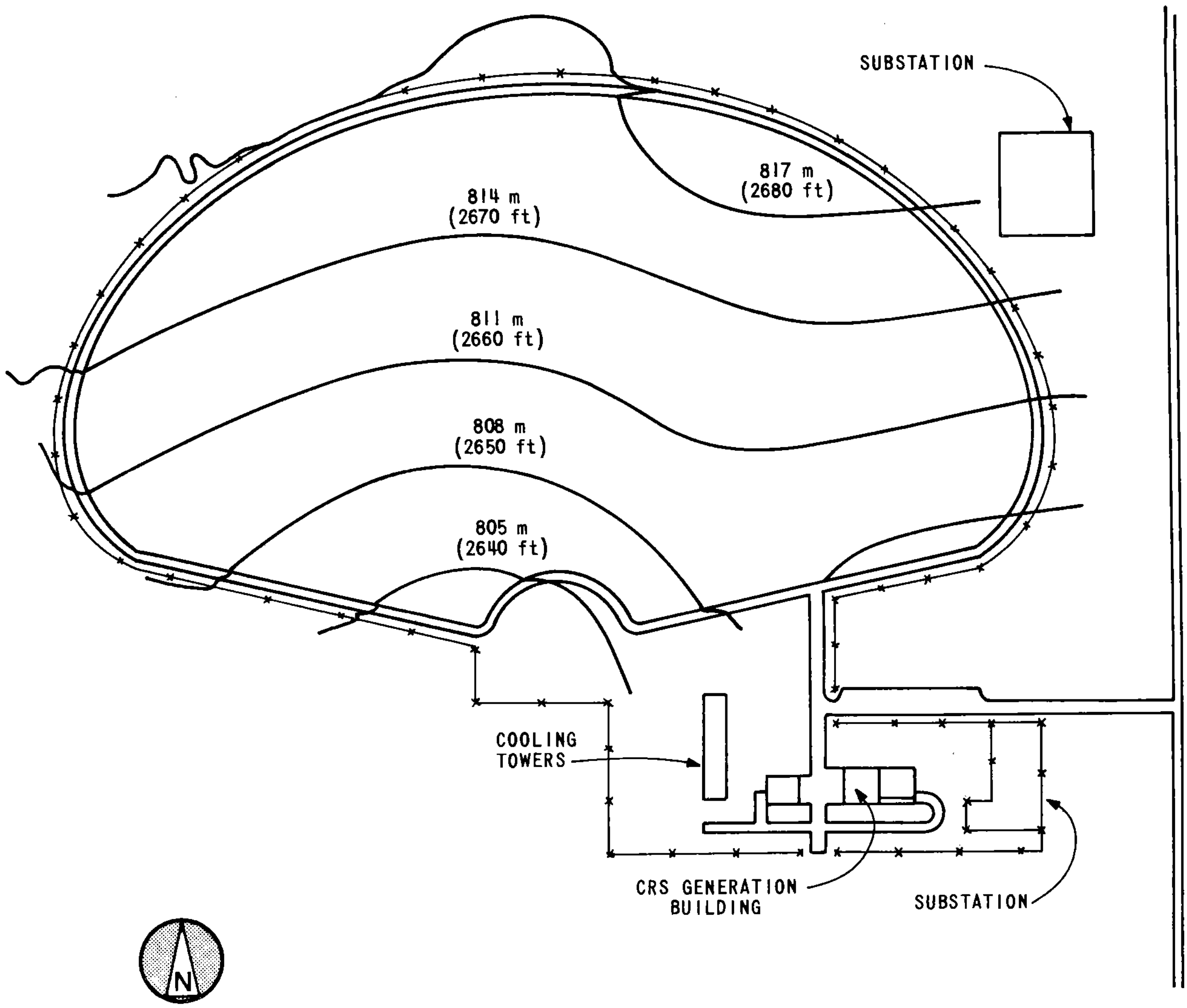
constructed as a circular column that has a diameter and height compatible with the heliostat chosen for this project. A reinforcing cage extends the full height of the foundation and pedestal. The dimensions and design forces are based on data produced for the second generation heliostat design in the DOE Heliostat Development Program.

(d) The collector field is graded to smooth the local terrain. The final field topography, illustrated in Figure 5.1-2, has a gently rolling contour with an overall downward slope to the south that reflects the underlying features of the existing site topography.

(2) Performance Characteristics--A detailed breakdown of the collector system performance at the design point (Equinox Noon) is presented in the stairstep chart in Figure 5.1-3. The collector delivers 42.05 MWt to the receiver absorber surfaces at the design point, with a reference solar radiation of 0.95 $kW/m^2$. Similarly, Figure 5.1-3 presents the annual energy stairstep based on a reference insolation of 6.1 $kWh/m^2$ day. The reference insolation is an annual average-day value based on the clear air insolation model described in Section 5.5.1, and on per cent sunshine data collected for Dodge City, Kansas.

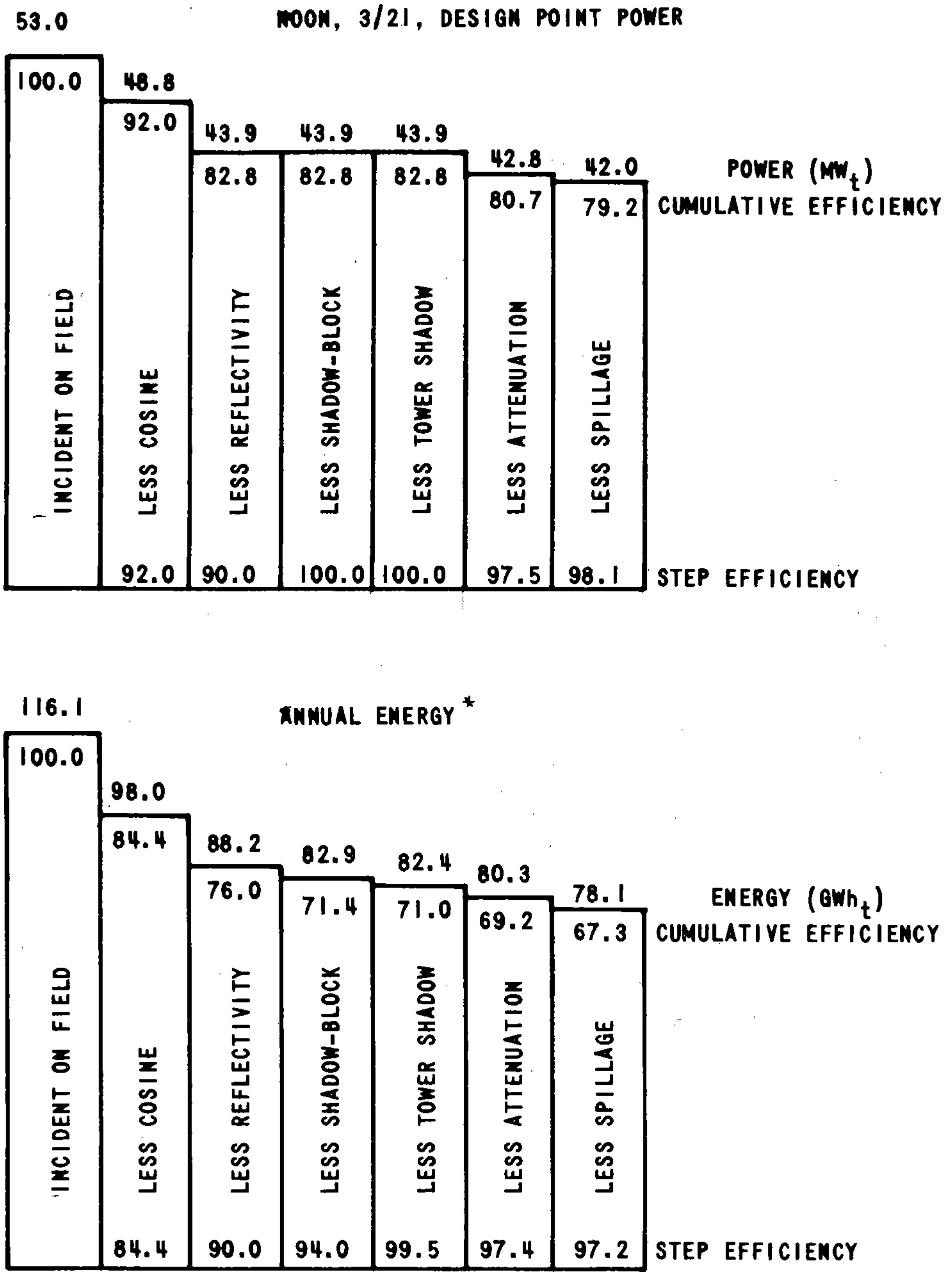
Figure 5.1-4 presents the overall field efficiency values in graphical and tabular form for various sun azimuths and elevations. Field efficiency is defined such that its product with direct normal insolation and total field mirror area yields the total power incident on the receiver surface. The values shown here include the combined effects of cosine, tower shadow, heliostat shading and blocking, mirror reflectivity, atmospheric attentuation, and spillage.

The baseline heliostat design is composed of 12 curved mirror panels attached to a single frame; the orientations of the panels on the frame are adjusted (canted) to form a segmented surface with an overall effective curvature. The performance




COLLECTOR SITE GRADING PLAN

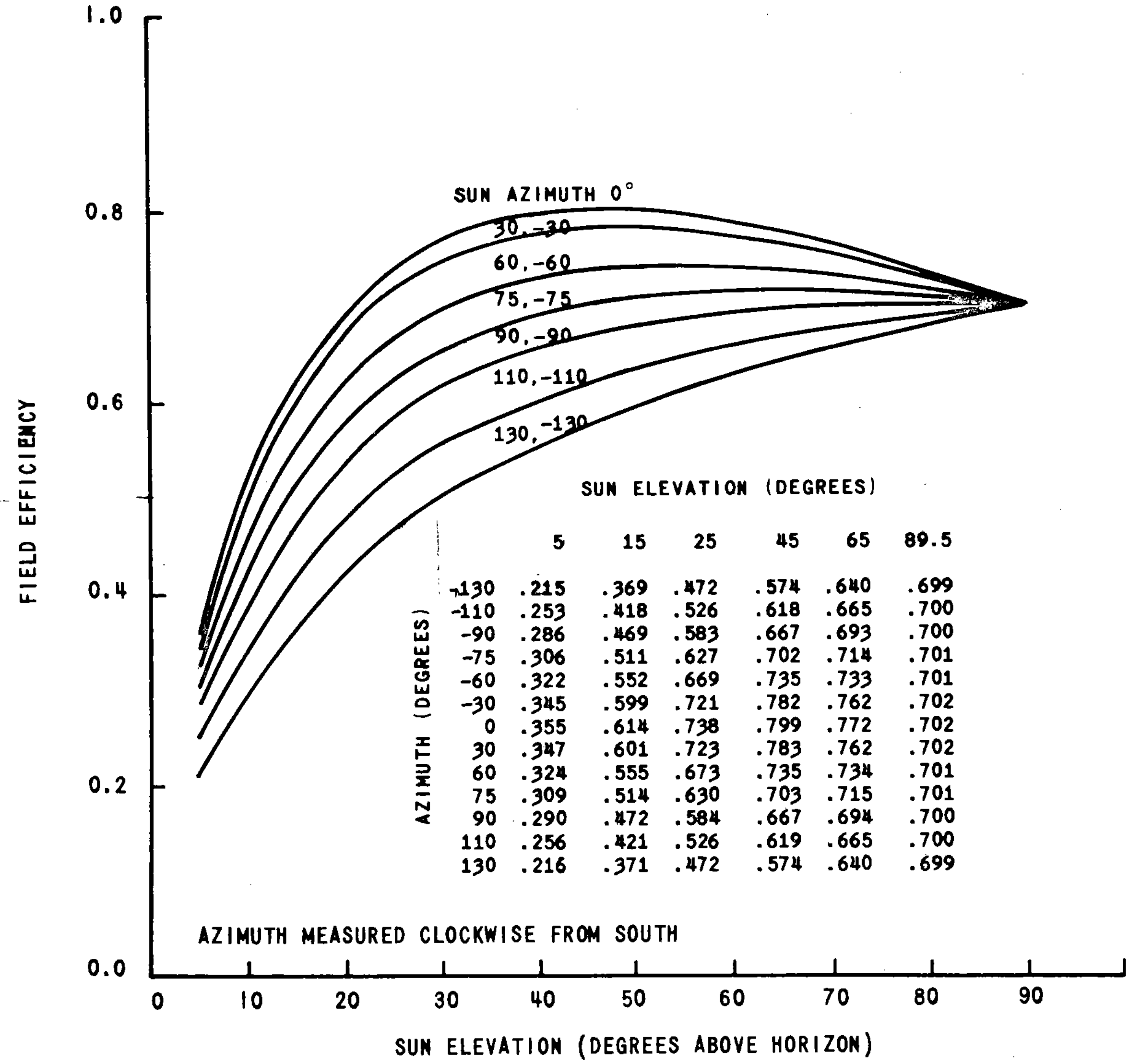
FIGURE 5.1-2




* INCLUDES THREE WEEK SCHEDULED ANNUAL OUTAGE.

COLLECTOR SYSTEM EFFICIENCY STAIR STEPS

FIGURE 5.1-3




SUN ELEVATION (DEGREES)

| AZIMUTH (DEGREES) | 5 | 15 | 25 | 45 | 65 | 89.5 |
|---|---|---|---|---|---|---|
| -130 | .215 | .369 | .472 | .574 | .640 | .699 |
| -110 | .253 | .418 | .526 | .618 | .665 | .700 |
| -90 | .286 | .469 | .583 | .667 | .693 | .700 |
| -75 | .306 | .511 | .627 | .702 | .714 | .701 |
| -60 | .322 | .552 | .669 | .735 | .733 | .701 |
| -30 | .345 | .599 | .721 | .782 | .762 | .702 |
| 0 | .355 | .614 | .738 | .799 | .772 | .702 |
| 30 | .347 | .601 | .723 | .783 | .762 | .702 |
| 60 | .324 | .555 | .673 | .735 | .734 | .701 |
| 75 | .309 | .514 | .630 | .703 | .715 | .701 |
| 90 | .290 | .472 | .584 | .667 | .694 | .700 |
| 110 | .256 | .421 | .526 | .619 | .665 | .700 |
| 130 | .216 | .371 | .472 | .574 | .640 | .699 |

COLLECTOR FIELD EFFICIENCIES

FIGURE 5.1-4

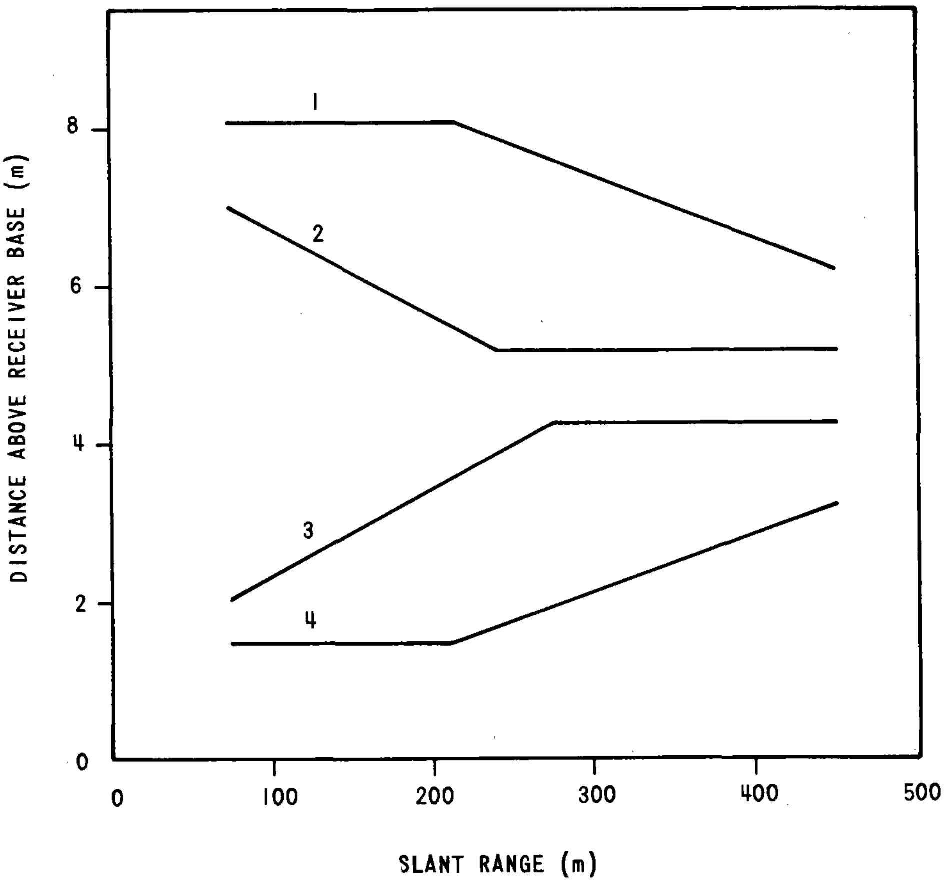
characteristics presented here assume the focal lengths of the individual panels and the overall focal length produced by on-axis canting were both equal to the heliostat's slant range, the distance from mirror to target. On-axis canting refers to perfect focusing when the sun, heliostat, and aim point lie on the same line.

The collector system redirects power to the receiver using an aim strategy which assigns a unique aim point location to each heliostat in the field. All heliostats redirect their images toward the vertical axis of the receiver cylinder (i.e., no circumferential shift); vertical distribution is achieved using four aim points on the receiver surface as illustrated in Figure 5.1-5. The vertical separation between aim points is a function of the heliostat's slant range, and is tailored to meet the incident flux requirements of the receiver specified in Section 3.5. By spreading the beams vertically, incident power is more evenly distributed along the absorber surface without significantly increasing the total spillage loss.

A simple algorithm is presented here to generate the aim point coordinates (XA, YA, ZA) of each heliostat based on the field coordinate (X, Y, Z) and identification numbers (NH) listed on Table 5.1-1. Heliostats were assigned identification numbers from 1 to 1,057 by numbering them from the inner row to the outer, and from the west end of the row clockwise to the east.

The algorithm computes an aim point number (NA) from one to four corresponding to the numbered curve of the aim strategy diagram in Figure 5.1-5. It then computes the heliostat slant range (S) and uses it to calculate the coordinates (XA, YA, ZA) of the aim point in meters from the base of the tower.

The FORTRAN statements below perform the aim point coordinate calculations.




FOUR POINT AIM STRATEGY

FIGURE 5.1-5

```
    NA = 1 + MOD ((NA - 1), 4)
    R  = (X * X + Y * Y) ** 0.5
    S  = ((R - 3.353) ** 2 + (80.09 - Z) ** 2) ** 0.5
    XA = 3.353 * X/R
    YA = 3.353 * Y/R
If (NA.EQ.1) ZA = 84.13 + AMIN1 (3.3, 4.913 - 0.00749 * S)
If (NA.EQ.2) ZA = 84.13 + AMAX1 (0.472, 3.1 - 0.01094 * S)
If (NA.EQ.3) ZA = 84.13 + AMIN1 (-0.472, -3.5 + 0.01094 * S)
If (NA.EQ.4) ZA = 84.13 + AMIN1 (-3.3, -4.913 + 0.00749 * S)
```

The functions MOD, AMIN1, and AMAX1 are FORTRAN-supplied functions. MOD produces the remainder resulting from division of its first argument with its second. AMAX1 returns the larger of its two arguments. AMIN1 returns the smaller of its two arguments.

(3) Operating Characteristics--The baseline heliostat and its control electronics are representative of the second generation heliostat configurations developed in the DOE Heliostat Development Program. The following data describe the operating characteristics expected for the design.

(a) In the normal operating mode, each heliostat tracks the sun, redirecting sunlight to an aim point on the receiver surface. In the standby mode, heliostats track the sun in a similar manner, redirecting sunlight to one of two stationary points in space. Heliostats in the east half of the collector field are assigned a standby position northwest of the tower, allowing all heliostats on that side of the field to be brought from standby to the receiver without tracking across the normally unirradiated portion of the south side of the receiver. Similarly, heliostats in the west half of the field are assigned a standby position northeast of the tower.

Heliostats may assume a directed position for cleaning, maintenance, or storage on command from the Heliostat Array

Controller or from local manual command at the Heliostat Controller.

Control software provides time-sequenced commands to the heliostats to execute predefined procedures such as start-up, shutdown, and emergency defocusing. In normal start-up, groups of heliostats are brought from stow position to standby by moving their beams from ground level up a vertical safety corridor to standby position. Then, upon command, the beams are moved from standby to the receiver surface as needed. Evening shutdown follows the reverse sequence, with beams redirected from the target to standby, then down the safety corridor to ground level.

Under emergency conditions requiring the immediate removal of power from the receiver surface, all heliostats are directed to standby and wait for operator command to return to the target or to the stow position.

Upon loss of command from the Heliostat Array Controller, the Heliostat Controllers initiate a stow sequence using preprogrammed instructions to bring the beam down safely. Upon loss of power, the heliostats fail in place.

(b) Each heliostat has two electric motors requiring a 110 volt ac power supply, and is expected to consume 380 watt-hours of energy per 12-hour day. The peak motor current for both motors combined is 5 amps; the peak inrush is 18 amps rms.

The Heliostat Controllers, Field Controllers, and Heliostat Array Controllers require a 120 volt supply with average currents of 0.24 ampere, 0.07 ampere, and 20 ampere, respectively. The Heliostat Array Controller has an identical backup system in hot standby which also requires 20 ampere.

The total installed power rating of equipment in the Collector System (based on 1,057 Heliostats, 34 Field Controllers, and two Heliostat Array Controllers) is 542 kW, and is broken down as follows.

| | Total Installed Power |
|---|---|
| Heliostat Motors | 507 kW |
| Heliostat Controllers | 30.4 kW |
| Heliostat Field Controllers | 0.2 kW |
| Heliostat Array Controllers | 4.8 kW |

Only a portion of the heliostats are repositioned at a time. The average operating power required by the collector system is 33.5 kW.

(c) Control system characteristics--Heliostat control is accomplished by a digital computer system which interprets operator commands, generates steering instructions for each heliostat individually, and performs monitoring and self-test routines.

Executive control is exercised by the Heliostat Array Controller (HAC) which interfaces with the Solar Master Control System (SMCS) and interprets commands entered by the operator via CRT. The HAC performs sun position calculations using the ephemeris tables and time inputs synchronized with Coordinated Universal Time through radio station WWV. The calculations use barometric pressure and temperature to make corrections to the sun position due to atmospheric refraction.

The HAC interfaces with the heliostat field by sequentially addressing the 34 Heliostat Field Controllers (HFC), and transmitting the sun position data and command information. Through the HFC's, the HAC is capable of addressing individual heliostats, groups of heliostats, or the entire field.

The HFC controls up to 32 heliostats by accepting sun position and command data from the HAC and sequentially transmitting the information to the individual Heliostat Controllers (HC). The HFC also accepts status information from the HC's and transmits it to the HAC.

The HC is a microprocessor controller which receives data from the HFC and calculates the azimuth and elevation angles of the heliostat based on sun position and on the heliostat and aim point coordinates stored in the microprocessor memory. The HC also services the ac motor control loop, advancing the motors until the calculated gimbal angles are reached. In addition, the HC has a self-check system which signals the HAC in the event of a failure. If command from the HAC is lost, the HC is capable of directing the heliostat to the stow position.

(d) The operating and survival limits of the collector system are identical to those defined for the DOE second generation heliostats.

5.1.3 Receiver System Data

(1) Receiver design characteristics--The results of conceptual design and trade studies have identified the following receiver system characteristics.

(a) The receiver is an external, water/steam type with closure doors, of the proprietary B&W screen tube design, applying pumped assisted circulation. The receiver is located atop a support tower north of the CRS turbine building and cooling tower.

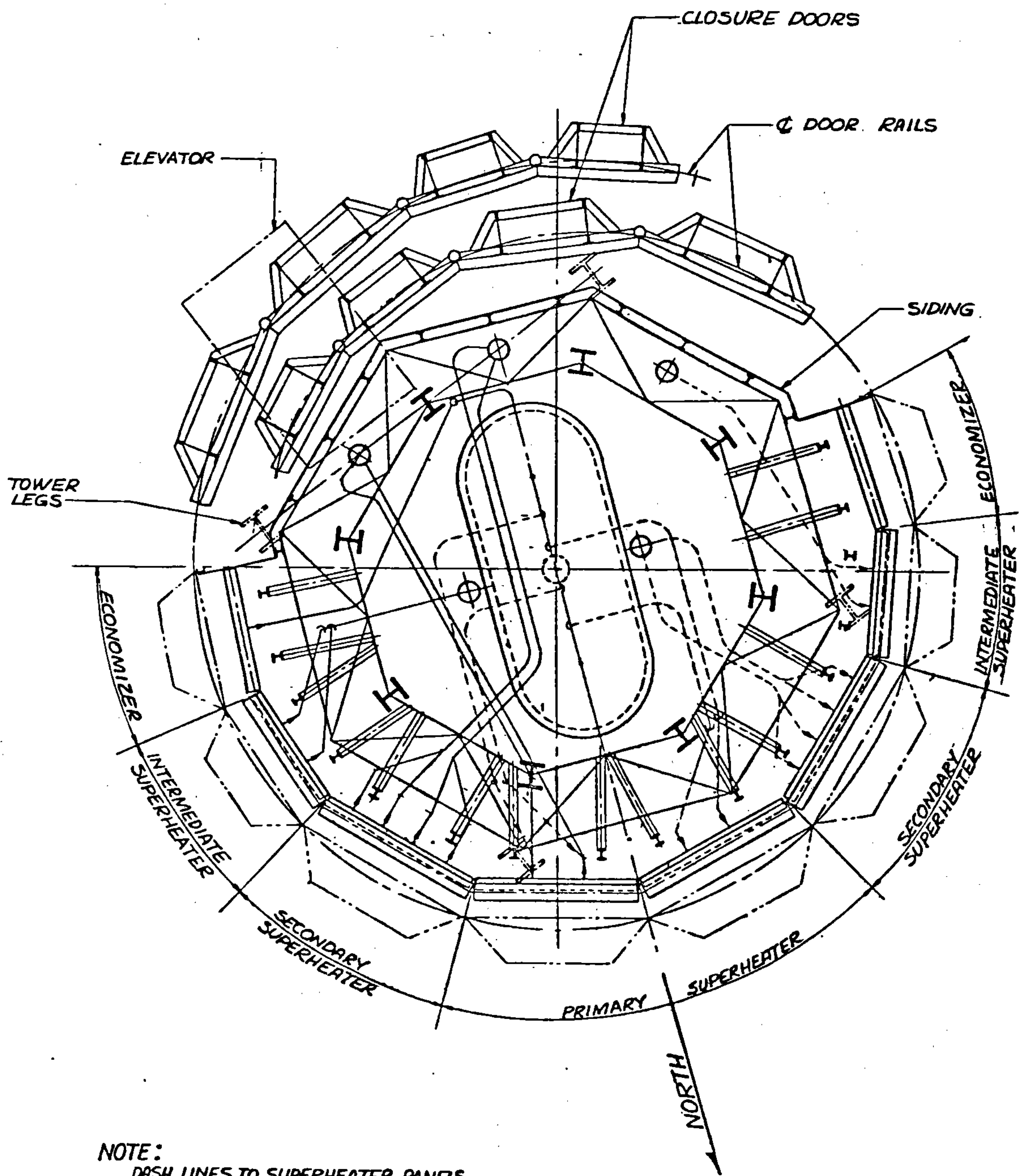
(b) The physical characteristics of the receiver are as follows.

- Diameter--6.7 m (22 ft).
- Height--9.45 m (31 ft).
- Centerline of receiver above grade--84.12 m (276 ft).
- Active surface--3.665 radians (210 degrees).
- Receiver geometry--See Figure 5.1-6.

(c) Absorber tubes and panels are as follows.

- Typical Assembly of Superheater Panel--See Figure 5.1-7.
- Materials, sizes, and numbers--See Table 5.1-2.
- Number of tubes, spacing, and flow--See Table 5.1-3.

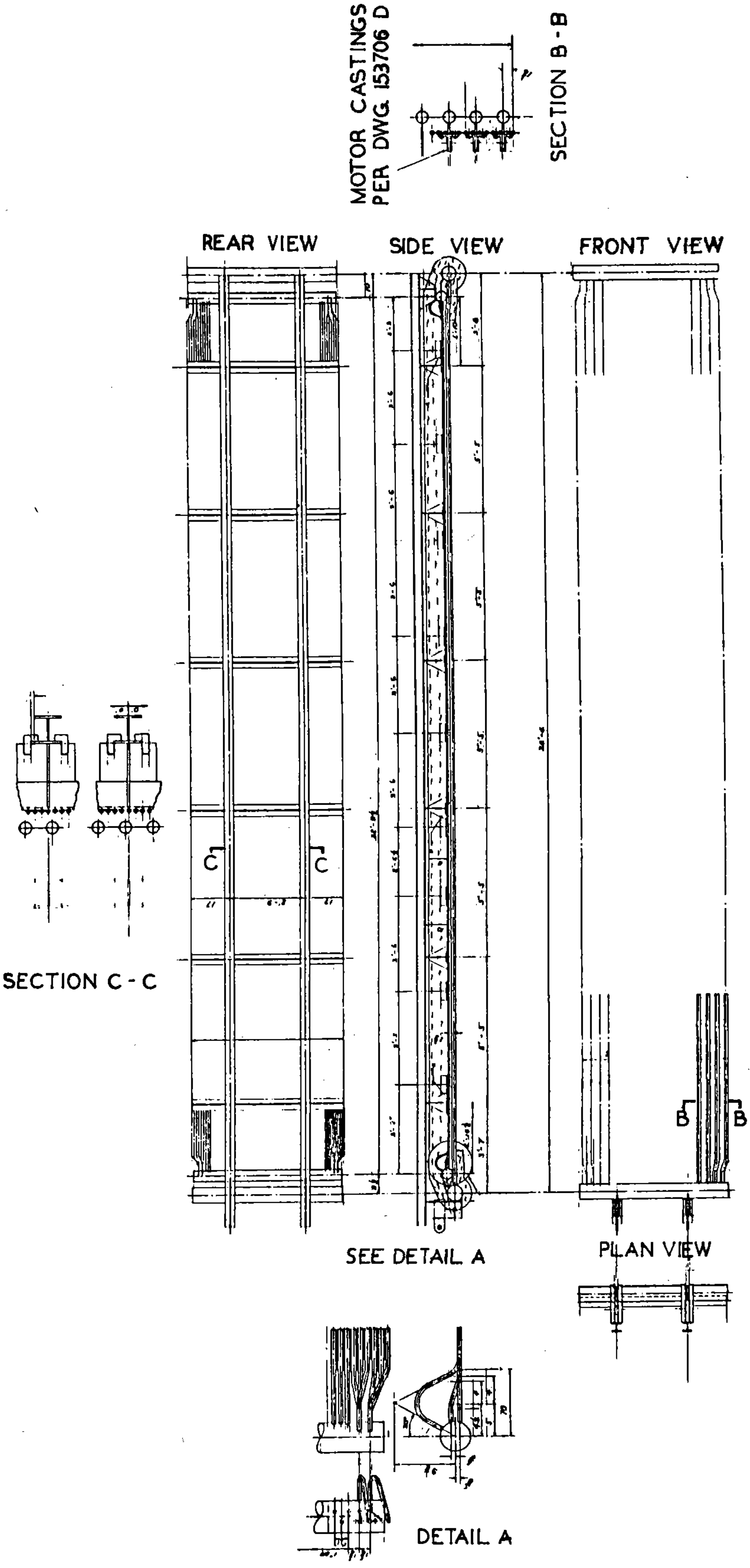
(d) Receiver valves--See Table 5.1-4.




NOTE:
DASH LINES TO SUPERHEATER PANELS ARE STEAM SUPPLY PIPES.
SOLID LINES FROM PANELS ARE DISCHARGE PIPES.

**SOLAR RECEIVER LAYOUT--PLAN VIEW**

FIGURE 5.1-6




SOLAR RECEIVER MEMBRANE PANEL

FIGURE 5.1-7

TABLE 5.1-2. GENERAL DESIGN DATA FOR SOLAR RECEIVER PANELS
External Type, Diameter 6.71 m (22 ft),
Active Height 9.45 m (31 ft)

| | |
|---|---|
| Membrane (Superheater) | |
| Tube and Membrane Material | 800H |
| Tube Wall Thickness | 2.54 mm (0.100 in) |
| Active Tube Length | 9.45 m (31 ft) |
| Total Tube Length | 9.9 m (32.5 ft) |
| Membrane Thickness | 4.76 mm (0.187 in) |
| Inlet Header OD | 0.114 m (4.5 in) |
| Outlet Header OD | 0.114 m (4.5 in) |
| Header Material | 800H |
| Design Pressure | 13.8 MPa (2,000 psia) |
| Screen Tubes (Multi-Lead Internal Ribs) | |
| Tube Material | SA-213-T2 |
| Tube Wall Thickness | 3.76 mm (0.148 in) |
| Active Tube Length | 9.45 m (31 ft) |
| Total Tube Length | 10.2 m (33.4 ft) |
| Inlet Header OD | 0.168 m (6.625 in) |
| Outlet Header OD | 0.168 m (6.625 in) |
| Header Material | SA-210C |
| Membrane (Economizer) | |
| Tubes and Membrane Material | SA-210-A1 |
| Tube Wall Thickness | 3.43 mm (0.135 in) |
| Active Tube Length | 9.45 m (31 ft) |
| Total Tube Length | 9.9 m (32.5 ft) |
| Membrane Thickness | 6.25 mm (0.250 in) |
| Inlet Header OD | 0.168 m (6.625 in) |
| Outlet Header OD | 0.168 m (6.625 in) |
| Header Material | SA-106-C |
| Design Pressure | 14.1 MPa (2,050 psia) |

TABLE 5.1-3. EXTERNAL RECEIVER PANEL DATA

| Panel Number | Width | Screen Tubes (Boiler) | | | Membrane Tube | | | |
|---|---|---|---|---|---|---|---|---|
| | m (ft) | No. | Spacing m (in) | OD m (in) | Type* | No. | Spacing m (in) | OD m (in) |
| 1 | 1.74 (5.72) | 17 | 0.101 (4.0) | 0.048 (1.875) | SH1 | 68 | 0.0254 (1.0) | 0.016 (0.625) |
| 2 | 1.74 (5.72) | 8 | 0.101 (4.0) | 0.051 (2.0) | SH3 | 68 | 0.0254 (1.0) | 0.016 (0.625) |
| | | 9 | 0.101 (4.0) | 0.049 (1.938) | | | | |
| 3 | 1.30 (4.32) | 6 | 0.0762 (3.0) | 0.041 (1.625) | SH2 | 34 | 0.0254 (1.0) | 0.016 (0.625) |
| | | 5 | 0.0762 (3.0) | 0.038 (1.50) | SH2 | 15 | 0.0286 (1.125) | 0.019 (0.750) |
| 4 | 1.30 (4.32) | 0 | -- | -- | ECON | 34 | 0.0331 (1.50) | 0.025 (1.00) |

*SH1 = Primary Superheater; SH2 = Intermediate Superheater; SH3 = Secondary Superheater; ECON = Economizer.

TABLE 5.1-4. LIST OF RECEIVER VALVES

| Service | Type | Operator* | Size m (in) | Quantity |
|---|---|---|---|---|
| Economizer Drain | Globe | Motor | 0.025 (1) | 1 |
| Economizer Pressure Test | Globe | -- | 0.025 (1) | 2 |
| Economizer Vent | Globe | -- | 0.025 (1) | 2 |
| Drum Atmospheric Vent | Globe | Motor | 0.025 (1) | 2 |
| Drum Safety Valve | Safety | Spring | 0.076 (3) | 1 |
| Drum Pressure Test | Globe | -- | 0.025 (1) | 2 |
| Drum Pressure | Globe | -- | 0.025 (1) | 2 |
| Drum Nitrogen | Globe | Motor | 0.025 (1) | 1 |
| Steam Sampling | Globe | -- | 0.025 (1) | 2 |
| Continuous Blowdown | Globe | Motor | 0.025 (1) | 2 |
| Chemical Feed | Globe | -- | 0.025 (1) | 2 |
| Water Sampling | Globe | -- | 0.025 (1) | 2 |
| Remote Level Transmitter | Globe | -- | 0.013 (1/2) | 4 |
| Water Gage Glass | Globe | -- | 0.013 (1/2) | 2 |
| Water Gage Drain | Globe | -- | 0.013 (1/2) | 2 |
| Drum Level Dump Shut-Off | Gate | Motor | 0.051 (2) | 1 |
| Drum Level Dump | Globe | Control | 0.051 (2) | 1 |
| Pump Auxiliary | Globe | -- | 0.025 (1) | 20 |
| Sparger Check | Nonreturn | Motor | 0.038 (1-1/2) | 3 |
| Sparger | Globe | Control | 0.038 (1-1/2) | 1 |
| Receiver Blowdown | Globe | Motor | 0.025 (1) | 3 |
| Economizer Circulation | Nonreturn | Motor | 0.025 (1) | 1 |
| Attemperator Block | Gate | Motor | 0.025 (1) | 1 |
| Attemperator Spray | Globe | Control | 0.025 (1) | 4 |
| Attemperator Check | Nonreturn | -- | 0.025 (1) | 4 |
| PSH Panel | Butterfly | Control | 0.064 (2-1/2) | 4 |
| ISH Panel | Butterfly | Control | 0.064 (2-1/2) | 6 |
| SSH Panel | Butterfly | Control | 0.064 (2-1/2) | 6 |
| SH Vents | Globe | Motor | 0.025 (1) | 6 |

TABLE 5.1-4 (Continued). LIST OF RECEIVER VALVES

| Service | Type | Operator* | Size m (in) | Quantity |
|---|---|---|---|---|
| SH Vent Shut-Off | Globe | Motor | 0.051 (2) | 1 |
| SH Nitrogen | Globe | Motor | 0.025 (1) | 2 |
| SH Drain | Globe | Motor | 0.025 (1) | 6 |
| SH Drain Shut-Off | Globe | Motor | 0.038 (1-1/2) | 1 |
| SH Trap | Trap | -- | 0.025 (1) | 6 |
| MS Pressure Test | Globe | -- | 0.025 (1) | 2 |
| MS Safety Valve | Safety | Spring | 0.064 (2-1/2) | 1 |
| MS Electromagnetic Shut-Off | Gate | Motor | 0.061 (2-1/2) | 1 |
| MS Electromatic | Relief | Electric | 0.064 (2-1/2) | 1 |
| MS Stop Valve | Gate | Motor | 0.153 (6) | 1 |
| Warm-Up, Shut-Off Valve | Gate | Motor | 0.064 (2-1/2) | 1 |
| Warm-Up Valve | Globe | Control | 0.064 (2-1/2) | 1 |

*Manual if not otherwise denoted.

PSH--Primary Superheater, ISH--Intermediate Superheater, SSH--Secondary Superheater, SH-Superheater, MS--Main Steam

(e) Weight of external receiver with closure doors.

- Boiler mountings--56,800 kg (125,000 lb).
- Circulating pump and motor--4,100 kg (9,000 lb).
- Economizer--4,100 kg (9,000 lb).
- Superheater and piping--49,100 kg (108,000 lb).
- Controls--13,600 kg (30,000 lb).
- Insulation and lagging--22,700 kg (50,000 lb).
- Structural steel, platforms, and siding--70,400 kg (155,000 lb).
- Closure door (with insulation)--25,000 kg (55,000 lb).
- Receiver fluid--5,000 kg (11,000 lb).
- Total--250,900 kg (552,000 lb).

(f) Receiver surface coating--Pyromark with absorptivity of 0.95 and emissivity of 0.9.

(g) Closure Doors--Two curved, insulated, tambour type, sliding doors.

(h) Circulation System--See Figure 5.1-8 and Table 5.1-5.

(i) Maximum receiver steam outlet pressure--11.07 MPa (1,605 psia). Receiver design pressure--13.4 MPa (1,945 psia). Steam output at design point (equinox noon)--54,331 kg/h (119,800 lb/h).

(j) Steam outlet temperature--520 C (968 F). Receiver heat transfer coefficients--See Table 5.1-6.

(2) Receiver operating characteristics are as follows.

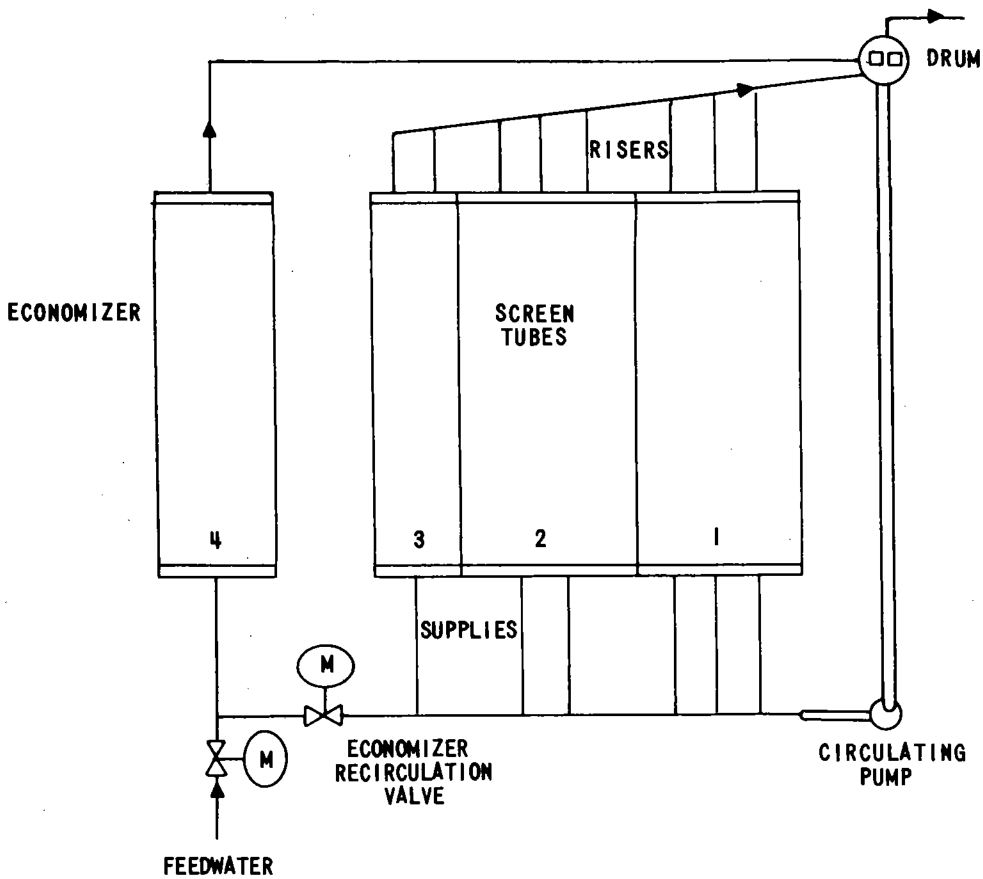
(a) Receiver incident power density--See Table 5.1-7.

(b) Receiver absorbed power--See Table 5.1-7.

(c) Flux map at 8 AM, 10 AM and design point--See Figures 5.1-9, 5.1-10, and 5.1-11.

(d) Receiver losses--See Table 5.1-7. Overall receiver efficiency--88.3 per cent at the design point.

(e) Tube material temperatures--See Figure 5.1-12. Working stresses are below Code allowable with at least 8.5 per cent safety margin. Receiver can withstand at least 10,000 cold start-ups and 50,000 cycles from complete and partial cloud cover. Expected lifetime is 30 years.




RECEIVER CIRCULATION SYSTEM

FIGURE 5.1-8

TABLE 5.1-5. RECEIVER CIRCULATING SYSTEM DATA

| Panel No. | Screen Tube (Boiler) No. | Supplies No. | Supplies OD m (in) | Supplies Thickness m (in) | Risers No. | Risers OD m (in) | Risers Thickness m (in) | Downcomer No. | Downcomer OD m (in) | Downcomer Thickness m (in) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 17 | 3 | 0.076 (3) | 0.0046 (0.18) | 3 | 0.076 (3) | 0.0046 (0.18) | 0 | -- | -- |
| 2 | 17 | 3 | 0.076 (3) | 0.0046 (0.18) | 3 | 0.076 (3) | 0.0046 (0.18) | 1 | 0.2731 (10.75) | 0.0214 (0.843) |
| 3 | 11 | 1 | 0.076 (3) | 0.0046 (0.18) | 2 | 0.076 (3) | 0.0046 (0.18) | 0 | -- | -- |

NOTES:

1. Due to symmetrical arrangement, only half of the receiver is listed here.
2. The dimensions of the screen tubes are shown on Table 5.1-3.
3. Only one downcomer is needed for entire receiver.
4. The steam drum is 1.37 m (54 in) ID, 0.10 m (4.0 in) thick, 2.29 m (7.5 ft) long with hemispherical heads, material SA-515.

TABLE 5.1-6. RECEIVER HEAT TRANSFER COEFFICIENTS

| | Avg. Fluid Temperature | | Avg. Heat Transfer Coeff. | |
| --- | --- | --- | --- | --- |
| | C | F | $kW/m^2/C$ | $Btu/h/ft^2/F$ |
| Economizer | 228 | 442 | 8.92 | 1,570 |
| Boiler (Screen Tubes) | 327 | 620 | 62.50 | 11,000 |
| Primary SH | 372 | 701 | 7.82 | 1,376 |
| Intermediate SH | 384 | 724 | 7.76 | 1,366 |
| Secondary SH | 464 | 868 | 6.16 | 1,085 |

TABLE 5.1-7. RECEIVER POWER DISTRIBUTION DATA

| Panel No. | Type | Avg. Power Density | Peak Over Average Ratio | Power Incident | Power Absorbed | Loss |
|---|---|---|---|---|---|---|
| | | $kW/m^2$ | | MW | MW | MW |
| 1 | Primary SH | 534.3 | 1.29 | 8.93 | 7.93 | 1.00 |
| 2 | Secondary SH | 479.6 | 1.41 | 7.93 | 7.01 | 0.92 |
| 3 | Intermediate SH | 281.2 | 2.02 | 3.48 | 3.0 | 0.48 |
| 4 | Economizer | 52.7 | 1.76 | 0.66 | 0.63 | 0.13 |

NOTES:

1. The power absorbed is the sum of the power absorbed by the screen and membrane tubes.
2. Due to the symmetrical arrangement, only half of receiver is listed here.

OUTPUT SUMMARY FOR FLUXCYLINDER **

THE TIME POINT UNDER TEST IS: DAY = 80, HOUR = 8
TOTAL POWER WAS 27.509 MEGAWATTS
26.802 MW HIT THE CYLINDER
.707 MW MISSED THE CYLINDER
INSOLATION = 0.76991 KW/SQM

MAP OF THE INCIDENT FLUX (KW/SQ METER) AS VIEWED FROM THE FIELD IS

| METERS ABOVE BASE OF CYLINDER | ° CW FROM NORTH | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 353 | 338 | 323 | 308 | 293 | 278 | 263 | 248 | 233 | 218 | 203 | 188 | 173 | 158 | 143 | 128 | 113 | 98 | 83 | 68 | 53 | 38 | 23 | 8 |
| 8.98 | 179 | 174 | 164 | 198 | 147 | 41 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 18 | 53 | 74 | 127 | 150 | 177 | 174 |
| 8.03 | 380 | 398 | 345 | 407 | 332 | 109 | 30 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 18 | 76 | 129 | 174 | 260 | 321 | 314 |
| 7.09 | 438 | 412 | 438 | 362 | 369 | 134 | 30 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 10 | 26 | 79 | 144 | 217 | 306 | 365 | 425 |
| 6.14 | 405 | 478 | 455 | 486 | 334 | 160 | 33 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 13 | 30 | 76 | 142 | 202 | 306 | 309 | 412 |
| 5.20 | 478 | 476 | 413 | 402 | 289 | 167 | 40 | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 10 | 25 | 71 | 136 | 205 | 299 | 405 | 384 |
| 4.25 | 473 | 509 | 422 | 435 | 284 | 139 | 40 | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 18 | 25 | 74 | 187 | 220 | 331 | 357 | 410 |
| 3.31 | 458 | 446 | 463 | 412 | 329 | 149 | 48 | 13 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 18 | 43 | 106 | 126 | 250 | 314 | 354 | 456 |
| 2.36 | 438 | 436 | 398 | 435 | 317 | 131 | 23 | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 7 | 23 | 78 | 134 | 250 | 276 | 372 | 380 |
| 1.42 | 324 | 364 | 405 | 349 | 276 | 119 | 20 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 21 | 53 | 111 | 141 | 218 | 276 | 299 |
| 0.47 | 145 | 160 | 109 | 131 | 129 | 23 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 12 | 33 | 58 | 81 | 106 | 157 | 93 |

**FLUX MAP AT 8 AM, MARCH 21**

**FIGURE 5.1-9**

*OUTPUT SUMMARY FOR FLUXCYLINDER ***

*THE TIME POINT UNDER TEST IS:* DAY = 80, *HOUR* = 10
*TOTAL POWER WAS* 39.799 *MEGAWATTS*
39.109 *MW HIT THE CYLINDER*
.690 *MW MISSED THE CYLINDER*
*INSOLATION* = 0.91993 *KW/SQM*

*MAP OF THE INCIDENT FLUX (KW/SQ METER) AS VIEWED FROM THE FIELD IS*

| METERS ABOVE BASE OF CYLINDER | ° CW FROM NORTH | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 353 | 338 | 323 | 308 | 293 | 278 | 263 | 248 | 233 | 218 | 203 | 188 | 173 | 158 | 143 | 128 | 113 | 98 | 83 | 68 | 53 | 38 | 23 | 8 |
| 8.98 | 232 | 237 | 210 | 225 | 175 | 69 | 19 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 14 | 41 | 110 | 170 | 187 | 201 | 206 |
| 8.03 | 502 | 519 | 588 | 536 | 378 | 151 | 22 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 41 | 62 | 208 | 371 | 459 | 512 | 514 |
| 7.09 | 638 | 648 | 562 | 528 | 435 | 148 | 36 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 12 | 43 | 93 | 285 | 476 | 519 | 560 | 667 |
| 6.14 | 610 | 691 | 641 | 595 | 435 | 179 | 67 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 43 | 120 | 268 | 464 | 476 | 540 | 593 |
| 5.20 | 629 | 591 | 574 | 516 | 337 | 187 | 57 | 7 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 5 | 19 | 29 | 136 | 246 | 361 | 433 | 483 | 662 |
| 4.25 | 569 | 619 | 605 | 493 | 347 | 196 | 48 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 41 | 115 | 227 | 380 | 502 | 571 | 610 |
| 3.31 | 636 | 679 | 660 | 550 | 433 | 155 | 31 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 38 | 120 | 304 | 373 | 505 | 593 | 631 |
| 2.36 | 655 | 619 | 583 | 631 | 430 | 187 | 38 | 10 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 10 | 43 | 155 | 285 | 452 | 495 | 571 | 660 |
| 1.42 | 567 | 485 | 514 | 567 | 332 | 122 | 22 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 33 | 93 | 230 | 361 | 461 | 469 | 502 |
| 0.47 | 203 | 148 | 246 | 160 | 170 | 45 | 10 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 55 | 93 | 153 | 175 | 206 | 151 |

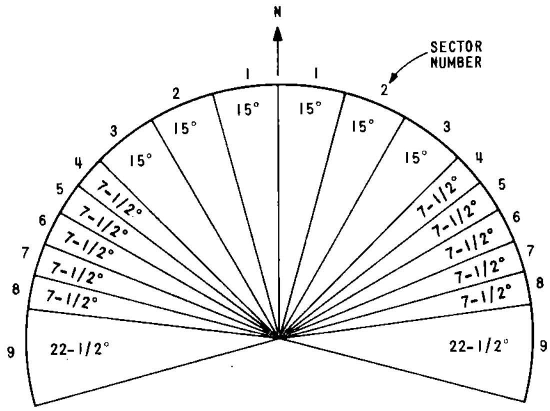
**FLUX MAP AT 10 AM, MARCH 21**

**FIGURE 5.1-10**

**SECTOR NUMBER**

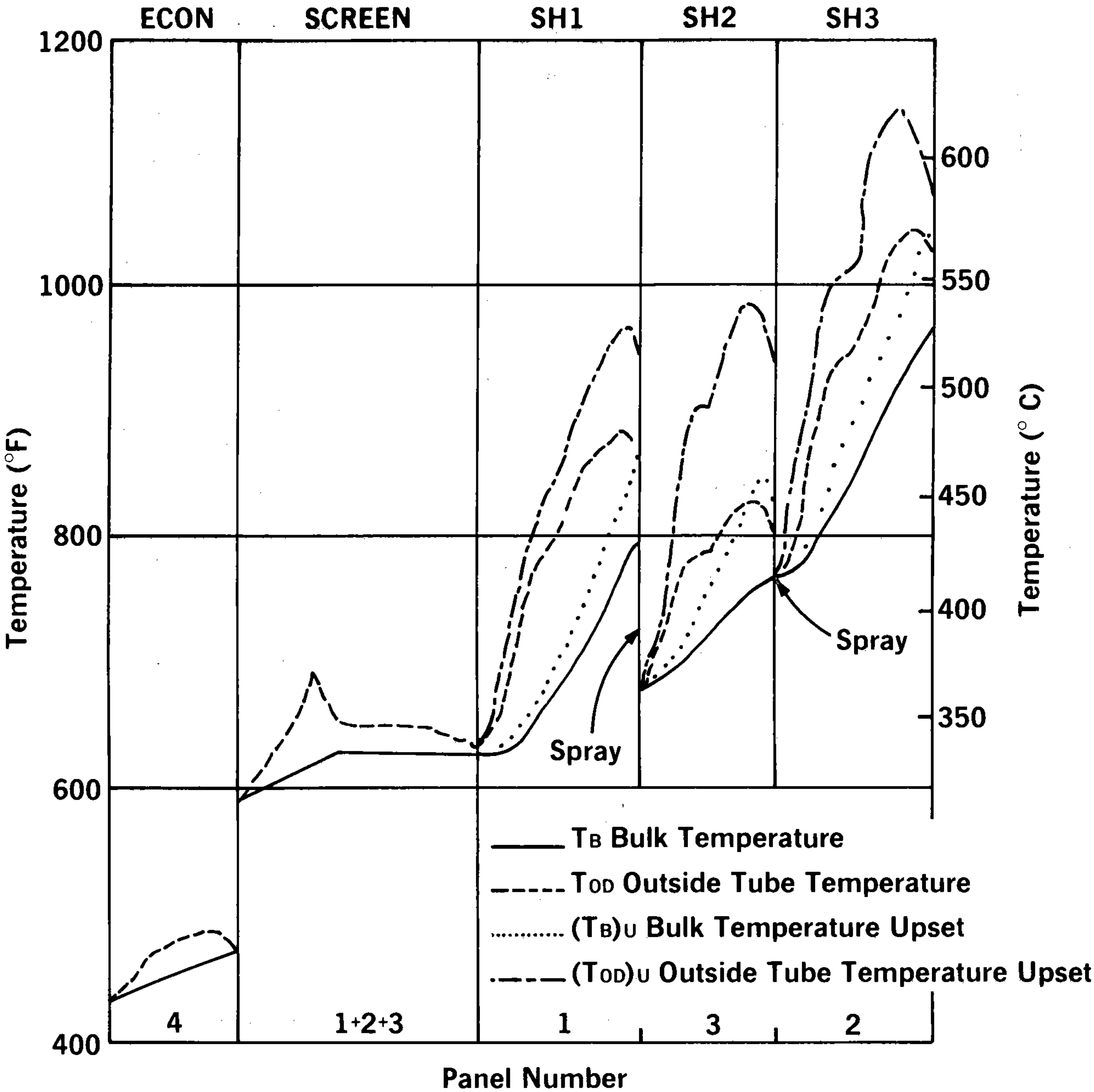
| Meters Above Base of Cylinder | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9.71 | 9 | 50 | 90 | 94 | 115 | 150 | 123 | 124 | 124 | 124 | 124 | 123 | 150 | 115 | 94 | 90 | 50 | 9 |
| 8.74 | 28 | 94 | 223 | 262 | 265 | 263 | 299 | 315 | 281 | 281 | 315 | 299 | 263 | 255 | 262 | 223 | 94 | 78 |
| 8.27 | 54 | 132 | 255 | 393 | 387 | 468 | 408 | 475 | 463 | 463 | 475 | 468 | 469 | 367 | 393 | 255 | 132 | 54 |
| 7.80 | 42 | 206 | 275 | 382 | 474 | 471 | 510 | 519 | 547 | 547 | 519 | 510 | 471 | 470 | 382 | 275 | 206 | 42 |
| 7.32 | 33 | 153 | 296 | 480 | 379 | 559 | 487 | 585 | 510 | 510 | 535 | 487 | 559 | 379 | 480 | 296 | 153 | 33 |
| 6.85 | 56 | 223 | 333 | 417 | 521 | 584 | 550 | 601 | 587 | 587 | 601 | 550 | 584 | 521 | 417 | 333 | 223 | 56 |
| 6.38 | 62 | 230 | 335 | 421 | 514 | 565 | 655 | 673 | 634 | 634 | 673 | 655 | 555 | 514 | 421 | 335 | 230 | 62 |
| 5.51 | 61 | 252 | 327 | 392 | 454 | 592 | 641 | 554 | 590 | 590 | 554 | 641 | 592 | 454 | 392 | 327 | 252 | 61 |
| 5.43 | 93 | 212 | 327 | 491 | 473 | 549 | 644 | 551 | 585 | 585 | 551 | 644 | 549 | 473 | 491 | 327 | 212 | 93 |
| 4.96 | 71 | 223 | 333 | 444 | 495 | 513 | 630 | 628 | 529 | 529 | 628 | 630 | 513 | 495 | 444 | 333 | 223 | 71 |
| 4.49 | 86 | 213 | 340 | 430 | 493 | 552 | 612 | 657 | 672 | 572 | 657 | 612 | 552 | 493 | 430 | 340 | 213 | 66 |
| 4.02 | 67 | 183 | 314 | 393 | 535 | 559 | 523 | 613 | 662 | 662 | 613 | 523 | 559 | 535 | 393 | 314 | 183 | 67 |
| 3.54 | 81 | 202 | 309 | 441 | 519 | 471 | 617 | 635 | 669 | 659 | 635 | 617 | 471 | 519 | 441 | 309 | 202 | 81 |
| 3.07 | 64 | 236 | 375 | 460 | 511 | 551 | 675 | 633 | 642 | 642 | 633 | 675 | 551 | 511 | 460 | 375 | 235 | 64 |
| 2.60 | 62 | 227 | 290 | 524 | 540 | 587 | 609 | 675 | 679 | 679 | 675 | 609 | 587 | 549 | 524 | 290 | 227 | 62 |
| 2.13 | 53 | 223 | 279 | 486 | 567 | 549 | 648 | 643 | 647 | 647 | 643 | 648 | 549 | 557 | 486 | 279 | 223 | 53 |
| 1.65 | 48 | 228 | 355 | 405 | 492 | 552 | 531 | 585 | 626 | 626 | 585 | 531 | 552 | 492 | 405 | 355 | 228 | 48 |
| 1.18 | 32 | 141 | 258 | 370 | 384 | 483 | 478 | 504 | 542 | 542 | 504 | 478 | 483 | 384 | 370 | 258 | 141 | 32 |
| 0.71 | 27 | 108 | 187 | 231 | 265 | 262 | 285 | 330 | 281 | 281 | 330 | 285 | 262 | 255 | 231 | 187 | 108 | 27 |
| 0.24 | 11 | 52 | 84 | 123 | 91 | 168 | 157 | 123 | 129 | 129 | 123 | 157 | 168 | 51 | 123 | 84 | 52 | 11 |

NOTE: The time point under test is: Day = 80, Hour = 12; Total power was 43.749 megawatts; 41.935 MW hit the cylinder; .814 MW missed the cylinder; Insolation = 0.95 kW/SQM; Map of the Incident Flux (kW/SQ Meter)




# DESIGN POINT RECEIVER FLUX MAP

FIGURE 5.1-11




FLUID AND METAL TEMPERATURE PROFILE OF RECEIVER

FIGURE 5.1-12

(f) Receiver circulating pump performance data--See Figure 5.1-13.

(g) Receiver Cooldown--Cooldown rate curves with and without closure doors are shown on Figure 5.1-14.

(h) Energy required for receiver warm-up--See Figure 5.1-15. For each pressure, two curves are provided, one curve for heating the receiver when the doors are closed and the other curve for the occasion when the doors are not closed during receiver preheating. The graph does not include the energy required to heat the piping system below the receiver.

(i) Receiver Heat Capacity.

- Boiler filled with water--12.7 kWh/C (24,000 Btu/F).
- Drum with water at normal level--4.9 kWh/C (9,300 Btu/F).
- Superheater (excluding fluid)--5.8 kWh/C (11,000 Btu/F).

(j) Thermal performance--See Figure 5.1-16 and Table 5.1-8. Receiver heat losses--See Figure 5.1-17, as calculated per Sandia Report No. SAND 79-8166 on Solar Advanced Steam Water Receiver, Appendix C. Effect of wind speed and ambient temperature on thermal performance--See Figure 5.1-18.

(k) Start-up procedures.

- Morning Start-up (receiver cold)--See Figure 5.1-19 and start-up sequence below.
  - -- Vent and fill to slightly above normal water level with feedwater (mix as required to match within 65 C (150 F) of bottom lower drum metal temperatures).
  - -- Open economizer circulation valve E,* superheater drains, and trap system H. Superheater steam vent valve F remains closed until drum is warmed to saturation 100 C (212 F).
  - -- Start boiler circulating pumps.

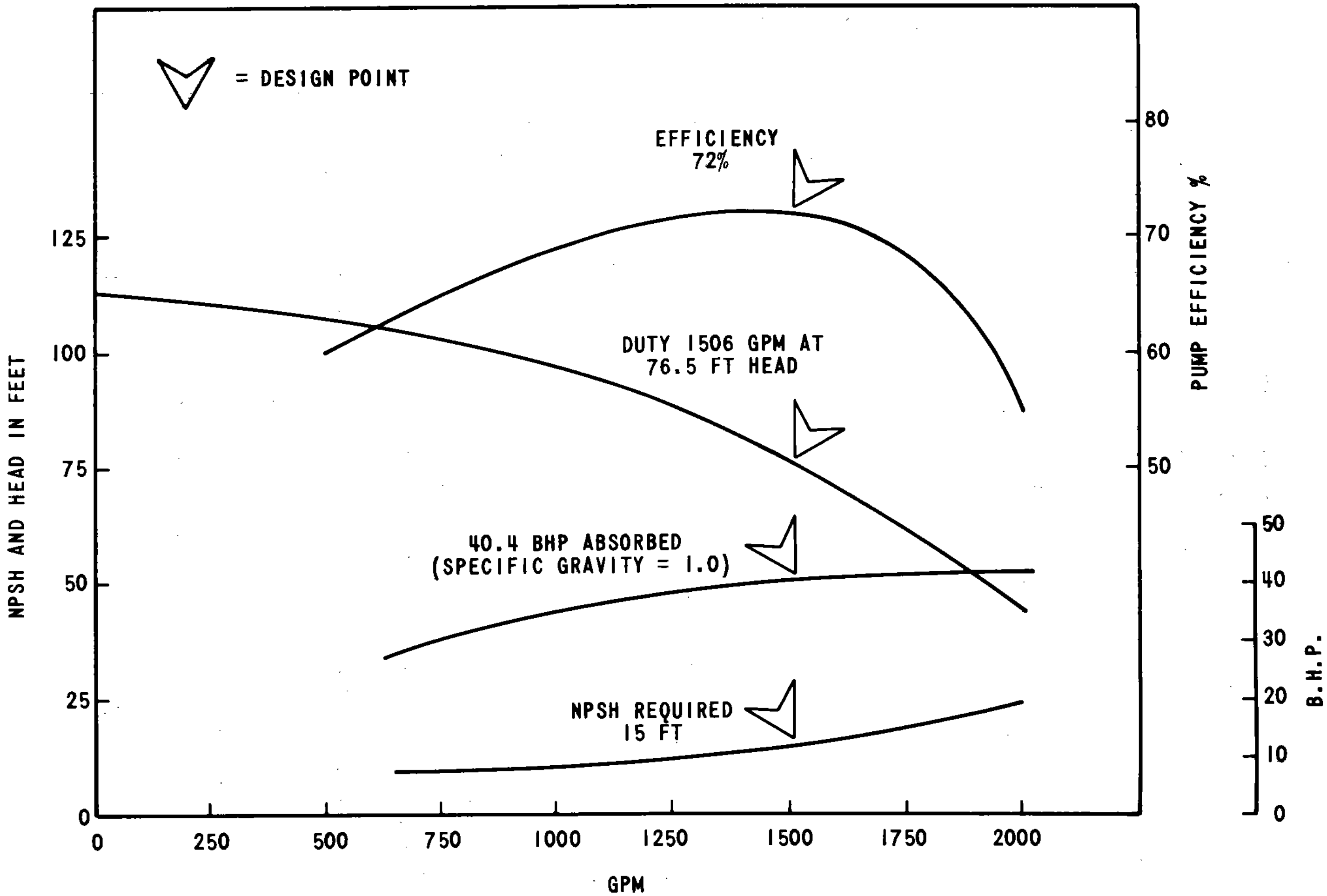
*Lettered valves are identified on Figure 5.1-20.

SYSTEM SPECIFICATION

FACILITY DESIGN DATA

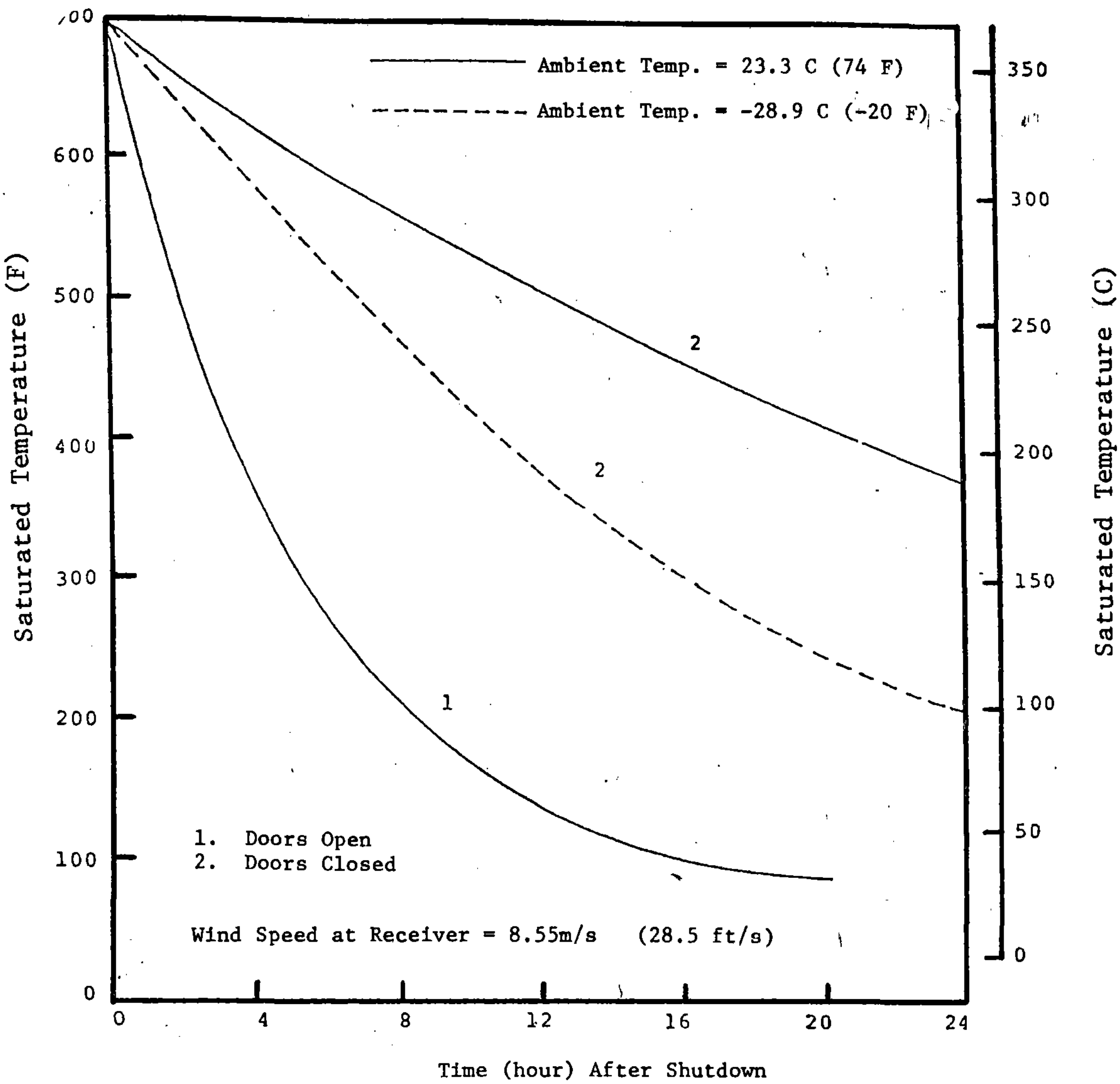
FILE NO. 9470.41.0200

SCF CRS 080781



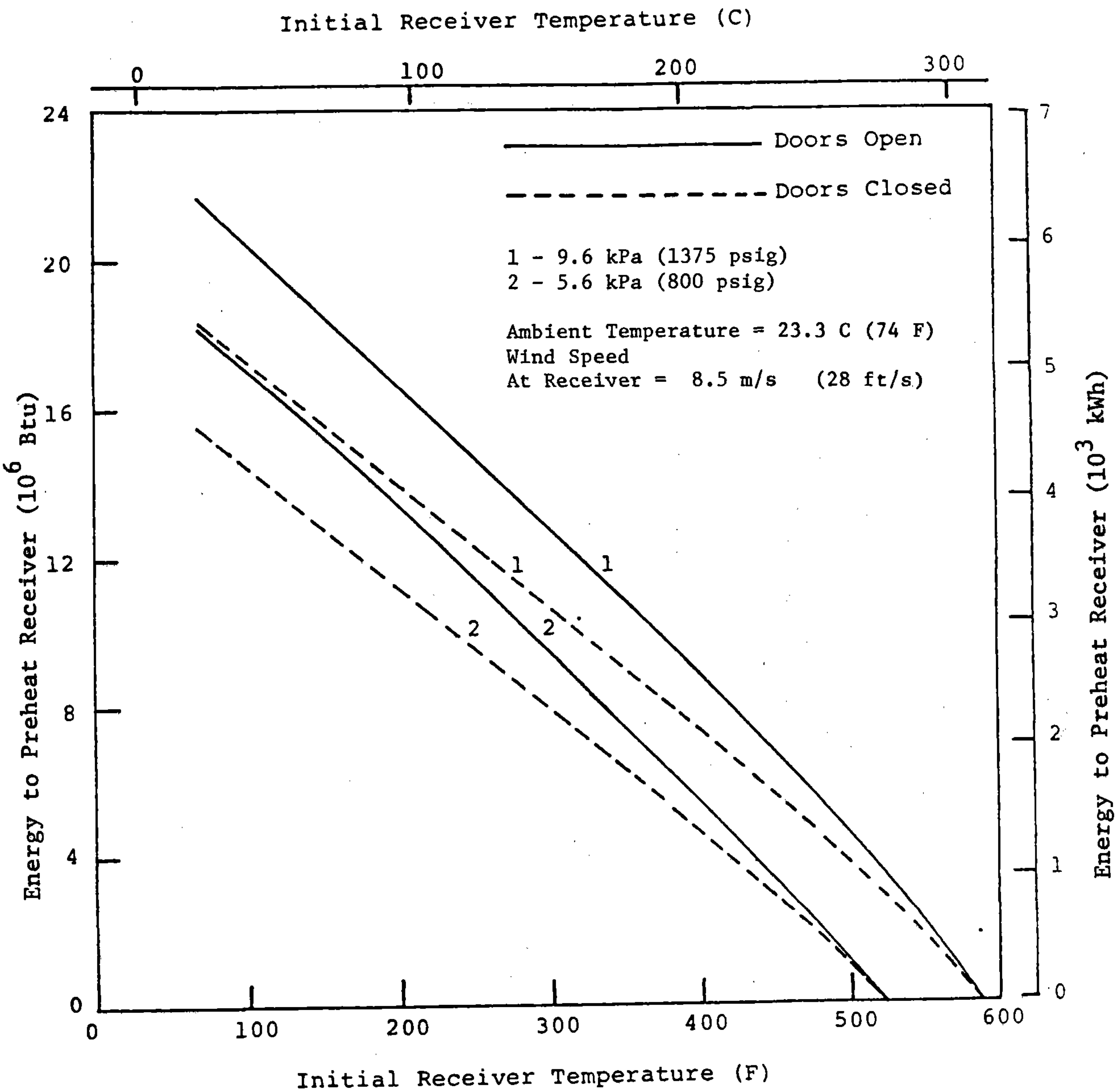

RECEIVER CIRCULATING PUMP CURVES

FIGURE 5.1-13



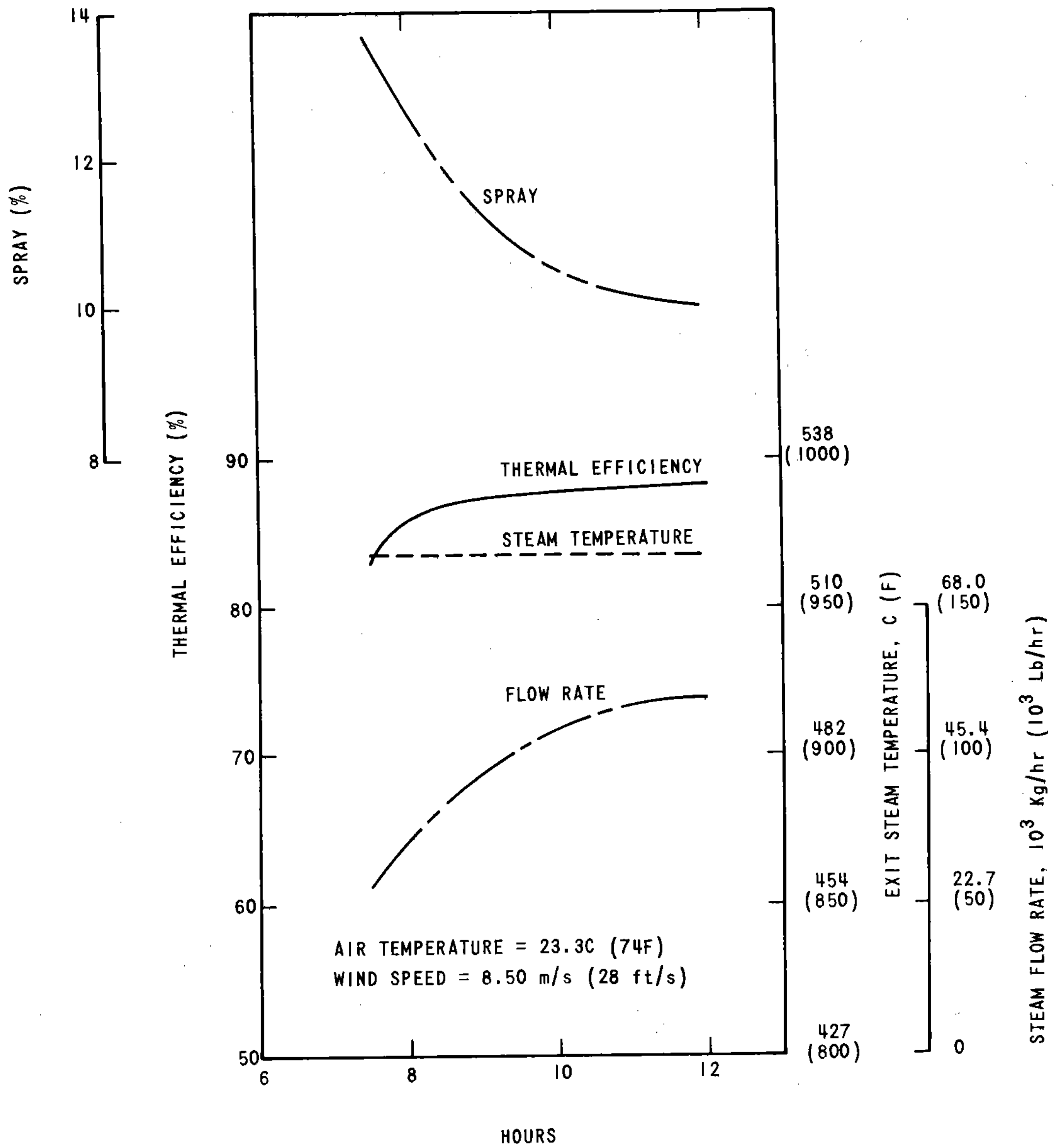

RECEIVER COOL DOWN RATE

FIGURE 5.1-14




**ENERGY REQUIRED FOR RECEIVER WARM-UP**

FIGURE 5.1-15




THERMAL PERFORMANCE OF SOLAR RECEIVER DURING EQUINOX DAY

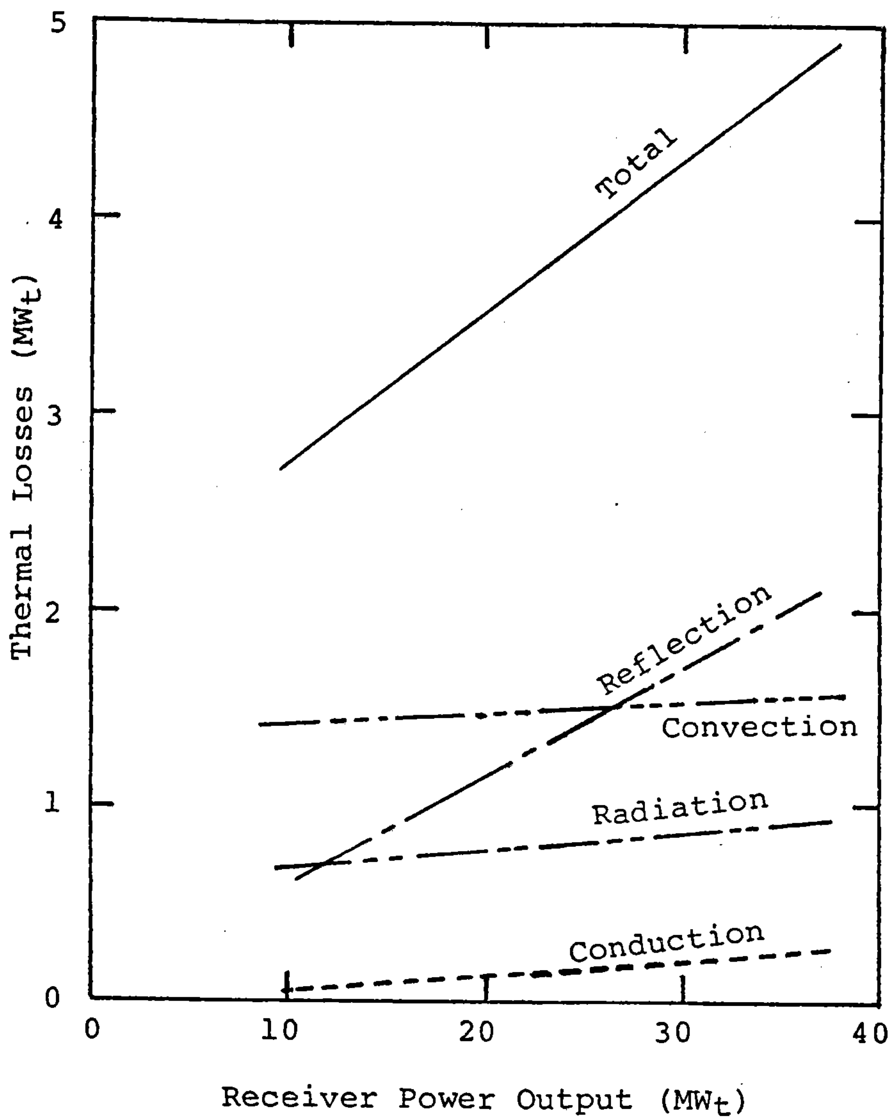
FIGURE 5.1-16

TABLE 5.1-8. PERFORMANCE OF SOLAR RECEIVER AT DESIGN POINT

| | | | |
|---|---|---|---|
| Superheater Outlet | | | |
| Pressure | MPa (psia) | 11.07 | (1,605) |
| Temperature | C (F) | 520 | (968) |
| Pressure Drop Through Superheater | MPa (psia) | 1.59 | (231) |
| Drum Pressure | MPa (psia) | 12.66 | (1,836) |
| Flow Rate | kg/h (lb/h) | 54,331 | (119,800) |
| Primary Superheater (or Preheater) | | 48,926 | (106,251) |
| Spray Attemperator 1 | | 5,500 | (12,210) |
| Intermediate Superheater | | 54,331 | (119,800) |
| Spray Attemperator 2 | | 0 | |
| Secondary Superheater | | 54,331 | (119,800) |
| % Spray | | 10.31 | |
| Circulation Flow | | 227,200 | 500,500 |
| Circulation Ratio | | 4.2 | |
| Circulation Pump Power | kW | 24.8 | |
| Feedwater Temperature | C (F) | 218.3 | (425) |
| Incident Power | MWt (MBtu/h) | 42.05 | (143.57) |
| Radiation Loss | MWt (MBtu/h) | 0.93 | (3.18) |
| Convection Loss | MWt (MBtu/h) | 1.58 | (5.39) |
| Conduction Loss | MWt (MBtu/h) | 0.25 | (.85) |
| Reflection Loss | MWt (MBtu/h) | 2.16 | (7.40) |
| Absorbed Power | MWt (MBtu/h) | 37.13 | (126.75) |
| Efficiency | | 88.3 | |
| Power Absorbed by Components | | | |
| Preheater | MW (MBtu/h) | 1.05 | (3.596) |
| Evaporator | MW (MBtu/h) | 22.25 | (75.951) |
| Primary Superheater | MW (MBtu/h) | 5.96 | (20.342) |
| Intermediate Superheater | MW (MBtu/h) | 2.77 | (9.464) |
| Secondary Superheater | MW (MBtu/h) | 4.94 | (16.755) |

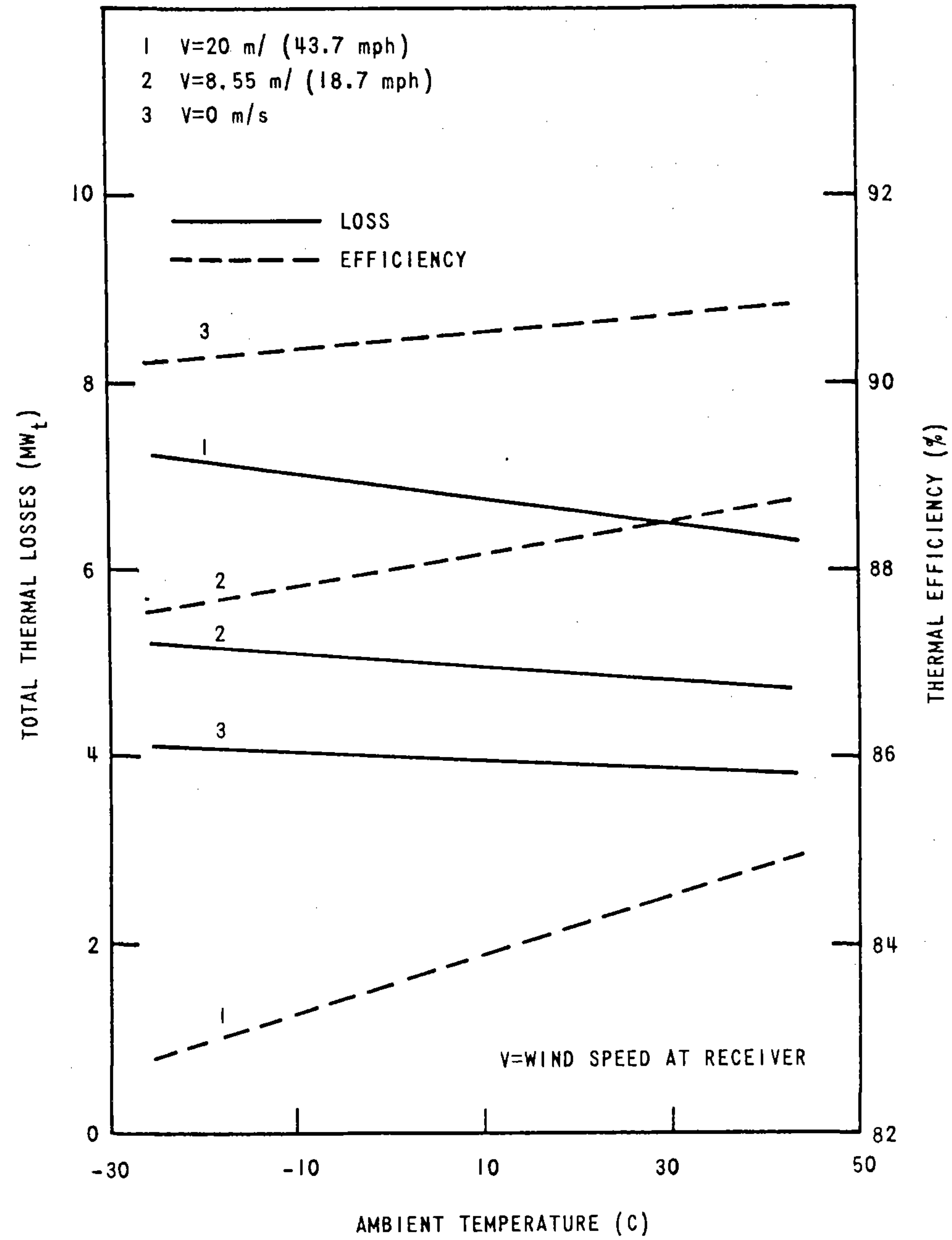
TABLE 5.1-8 (Continued). PERFORMANCE OF SOLAR RECEIVER AT DESIGN POINT

| | | | |
|---|---|---|---|
| Peak Flux at Equinox Noon | $kW/m^2$ ($KBtu/h\text{-}ft^2$) | 690 | (218.7) |
| Average Flux at Equinox Noon | $kW/m^2$ ($KBtu/h\text{-}ft^2$) | 361 | (114.7) |
| Peak Superheater Tube OD Temperature | C (F) | 820 | (1,508) |
| Peak Screen Tube OD Temperature | C (F) | 374 | (705) |
| Maximum Steam Temperature Leaving Tube | C (F) | 567 | (1,051) |
| Maximum Upset Tube OD Temperature | C (F) | 618 | (1,144) |



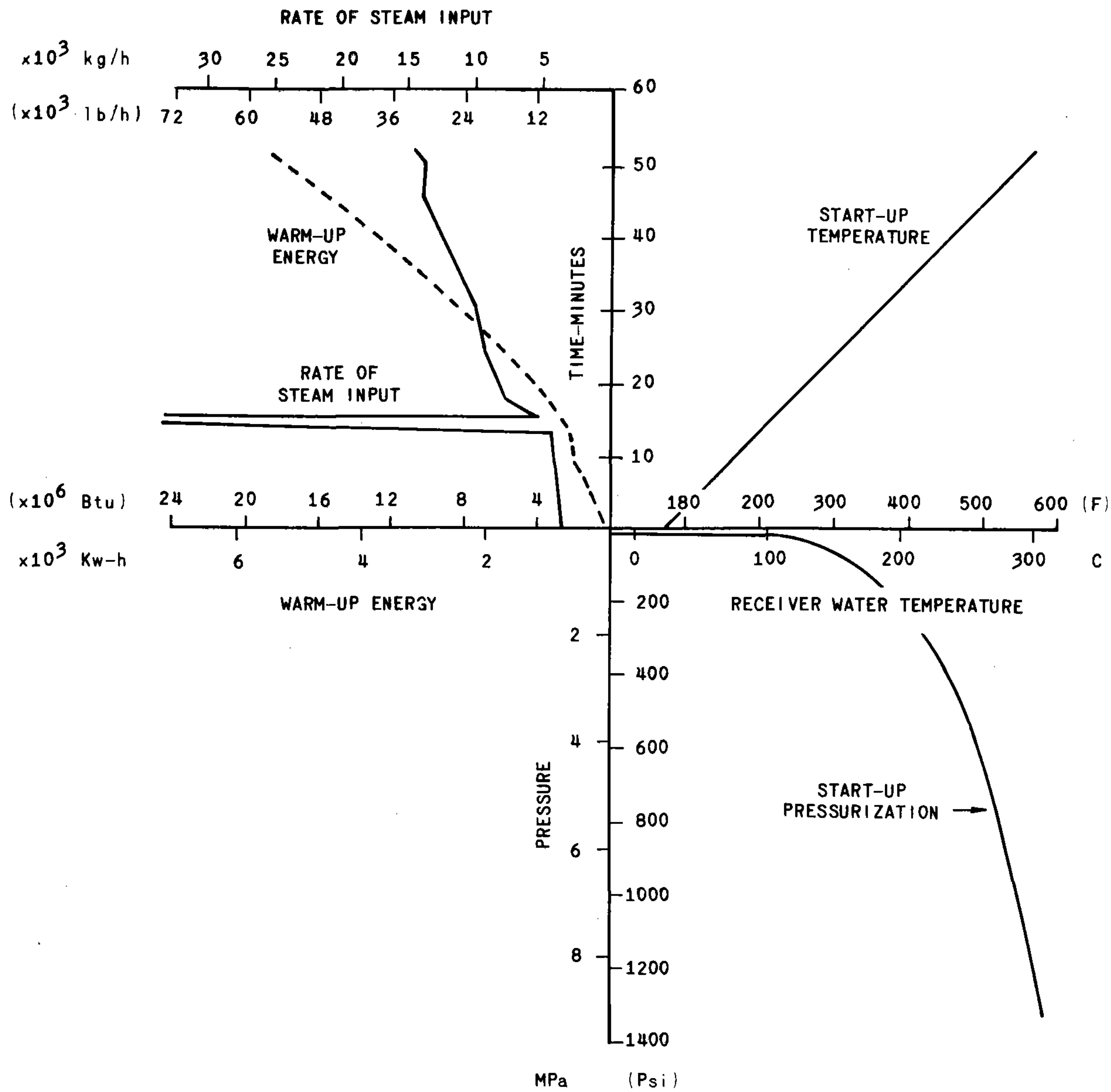

**RECEIVER THERMAL LOSSES VERSUS POWER OUTPUT**

**FIGURE 5.1-17**



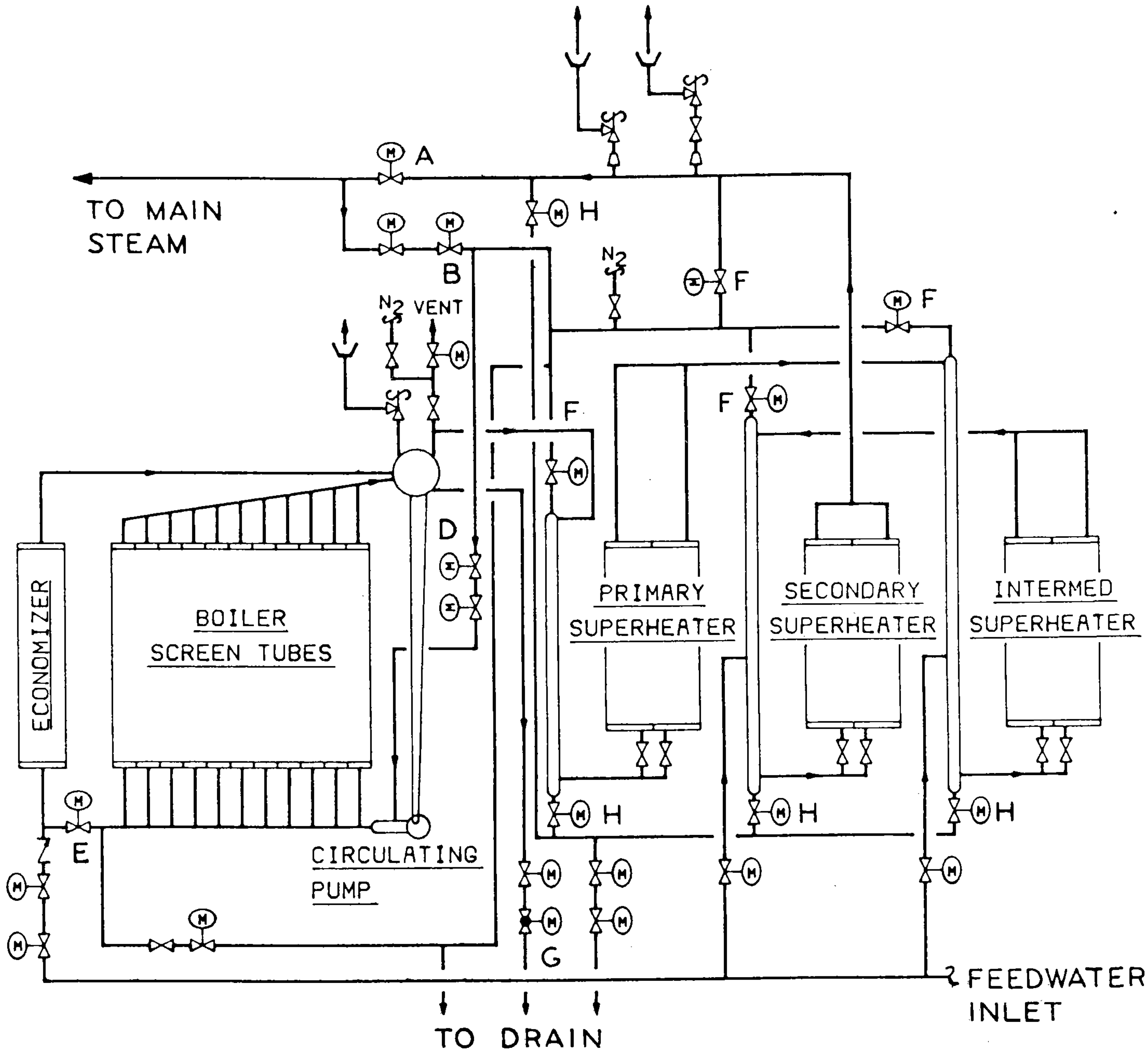

THERMAL EFFICIENCY AND LOSSES AT VARIOUS WIND SPEEDS AND AMBIENT TEMPERATURES

FIGURE 5.1-18




RECEIVER WARM-UP DATA DURING START-UP

FIGURE 5.1-19




SCHEMATIC LOCATION OF KEY RECEIVER VALVES

FIGURE 5.1-20

- -- Close nitrogen blanketing valves, open turbine end main steam stop valve, open warm-up valve B, and control prewarm-up of economizer and screen at prescribed rate. Note: This valve controls pressure and, thus, saturation temperature rate of change 3.3-5.6 C/min (6-10 F/min).
- -- Steam sparger inductor valve D is used to warm up the drum, screen tubes, economizer panels, and all associated connection piping. Open valve F when the drum water reaches saturation temperature 100 C (212 F). Steam is admitted through valve F into the SH, and condensation is returned through traps at H. If SH vent to atmosphere is open, close at 0.172 MPa (25 psia).
- -- As volume of water in drum swells on warm-up, excess is dumped through G to maintain level slightly higher than normal set point (single-element controller). Note: Time to warm-up to 9.6 MPa (1,390 psia), 327 C (620 F) is about 53 minutes after start of step 4, depending on ambient conditions. etc.
- -- At sunrise, open closure doors and focus heliostats on receiver.
- -- Steam evaporation beings at first insolation at a rate corresponding to net power input to screen tubes and economizer. Open main steam stop valve A. Close steam sparger inductor valve D. Close superheater vent valves F. Superheat spray attemperators must be available for use.
- -- Drum level dump valve G should be closed (automatically) as steam flow occurs. The feedwater flow is started when drum level drops below

normal. Economizer circulation valve E is closed as this occurs. Drum level control is automatic.

- -- The warm-up valve B and superheater drains H are closed.

- Diurnal Start-up (receiver warm)--See Figure 5.1-19 and data below.
  - -- Establish circulation with boiler circulating pump. Make sure economizer circulation valve E, superheater drains, and trap system H are open.
  - -- Open superheater vent valve F. Open warm-up valve B and sparger inductor valve D. Pressurization and saturation temperature are controlled at a prescribed rate of change.

    As volume of water in drum swells on warm-up, excess is dumped through G to maintain level slightly higher than normal set point (single-element controller).
  - -- The closure doors are operated just prior to sunrise, when the receiver attains steam line pressure and is ready to accept solar energy.
  - -- At sunrise, open the main steam stop valve A, close steam sparger inductor valve D. Close superheater vent valve F. Superheat spray attemperators must be available for use.
  - -- Drum level dump valve G should be closed (automatically) as steam flow occurs. The feedwater flow is started when the drum level drops below normal. Economizer circulation valve E is closed as this occurs. Drum level control is switches to the three-element control for normal operation.
  - -- The warm-up valve B and superheater drain H are closed.

- Mid-day Start-up--For start-up after sunrise, selective heliostat focusing is required to duplicate the morning solar power input to the receiver. Other procedures are the same as either the cold or warm morning start-up procedures.

(1) Shutdown procedure--The receiver is shut down by reducing the solar insolation due to either sunset or selected defocusing of heliostats. As steam generation and pressure are reduced, the load on the turbine will drop but the fossil boiler will maintain operation at constant fuel (gas) consumption and reduced pressure corresponding to the turbine load.

At the point of minimum solar energy input, the main steam stop valve A can be shut and the closure doors shut. As the receiver cools and the drum water level shrinks, feedwater is required to maintain desired level.

The receiver is usually either banked to conserve energy or cooled and drained to prevent freezing. When the receiver pressure drops below 0.14 MPa (20 psia) or when the unit is to be put in storage, wet or dry, a nitrogen blanket is admitted to the superheater and drum trough vent lines to protect those surfaces from corrosion. Normal idle boiler lay-up techniques are followed.

5.1.4 Receiver Piping System Data

(1) Equipment Design Characteristics.

| Equipment | Description |
|---|---|
| Receiver feedwater booster pump | One full capacity, two stage, centrifugal, motor driven direct vertical in line pump. The pump is rated at 54,000 kg/h (119,000 lb/h) with a head of 320 m (1,050 ft). The motor is approximately 112 kW (150 horsepower). |
| Receiver blowdown tank | One tank to serve the receiver drains. The tank is located near the receiver. The tank is of carbon steel construction, with an internal stainless steel wear plate at the inlet connection. The tank is 1.2 m (48 in) in diameter and 1.8 m (71 in) tall. |

| Equipment | Description |
|---|---|
| Receiver blowdown pump | One motor driven, direct drive, centrifugal pump. It is designed to pump saturated liquid at 100 C (212 F). The pump is sized at 95 liters per minute (25 gpm) with a head of 9.1 m (30 ft). The motor is approximately 0.56 kW (3/4 horsepower). |
| Chemical feed equipment | Equipment for the addition of chemicals to the receiver feedwater makeup to control receiver water chemistry. The equipment includes a chemical solution tank suitable for batch mixing, a chemical solution tank mixer, and a chemical feed pump. The chemical feed pump is a diaphragm type pump rated to deliver approximately 3.8 liters per hour (1 gph) at 14.9 MPa (2,175 psia) from the solution tank to the feedwater piping. |

(2) Piping Design Characteristics. The design characteristics for the system piping and associated valves will be as indicated on Table 5.1-9. Nomenclature and abbreviations included in the Pipeline Listing are defined as follows.

| Nomenclature | Description |
|---|---|
| ASTM A335 Grade P22 | Seamless 2-1/4 chrome, 1 per cent moly alloy piping. |
| ASTM A106 Grade B | Seamless carbon steel piping. |
| Sch | Schedule member for piping in compliance with ANSI B36.10, Welded and Seamless Pipe requirements for outside diameter and wall thickness. |
| CL | Valve classification in accordance with the requirements of ANSI B16.34, Steel Butt-welding End Valves. |
| 1-1/4 CR | Valve body materials to be alloy chrome in accordance with requirements of ASTM A216 Grade WC6. |
| 2-1/4 CR | Valve body materials to be alloy chrome in accordance with requirements of ASTM A217 Grade WC9. |
| CS | Valve body materials to be carbon steel in accordance with requirements of ASTM A216 Grade WEB. |

TABLE 5.1-9. PIPELINE LISTING

| Pipeline Listing | Pressures and Temperatures Operating | Pressures and Temperatures Design | Test Pressure MPa | Pipe | Valves 50 mm and Smaller | Valves 65 mm and Larger | Insulation Thickness | Special Features |
|---|---|---|---|---|---|---|---|---|
| Receiver Piping System | | | | | | | | |
| Main Steam Piping | 11.07 MPa<br>520 C | 11.24 MPa<br>529 C | 16.9 | ASTM A335<br>Grade P22<br>Sch 160 | CL 2500<br>2-1/4 CR,<br>SW | CL 2500<br>2-1/4 CR,<br>BW | .15 m | Fully radiograph |
| | | | | | | | | Shot blast cleaning |
| Feedwater Piping | 13.9 MPa<br>218 C | 14.89 MPa<br>246 C | 22.3 | ASTM A106<br>Grade B<br>Sch 160 | CL 1500<br>1-1/4 CR | CL 1500<br>CS, BW | .08 m | Shot blast cleaning |
| Condensate Piping | | 1.48 MPa<br>199 C | | ASTM A106<br>Grade B<br>Sch 80 | CL 600 | | .06 m | |

| Nomenclature | Description |
|---|---|
| SW | Socket-weld type valve end connections. |
| BW | Butt-weld type valve and connections. |

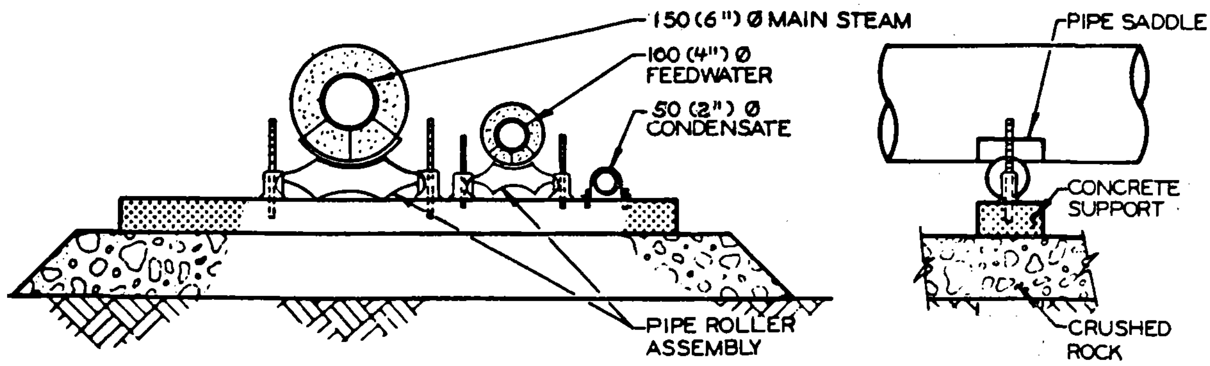
The piping lengths indicated below include piping within the receiver support tower and the expansion loops required to allow for thermal growth of the piping between ambient and operating temperatures.

| Piping System | Length |
|---|---|
| Main steam | 481 m (1,580 ft) |
| Feedwater | 443 m (1,455 ft) |
| Condensate | 437 m (1,435 ft) |

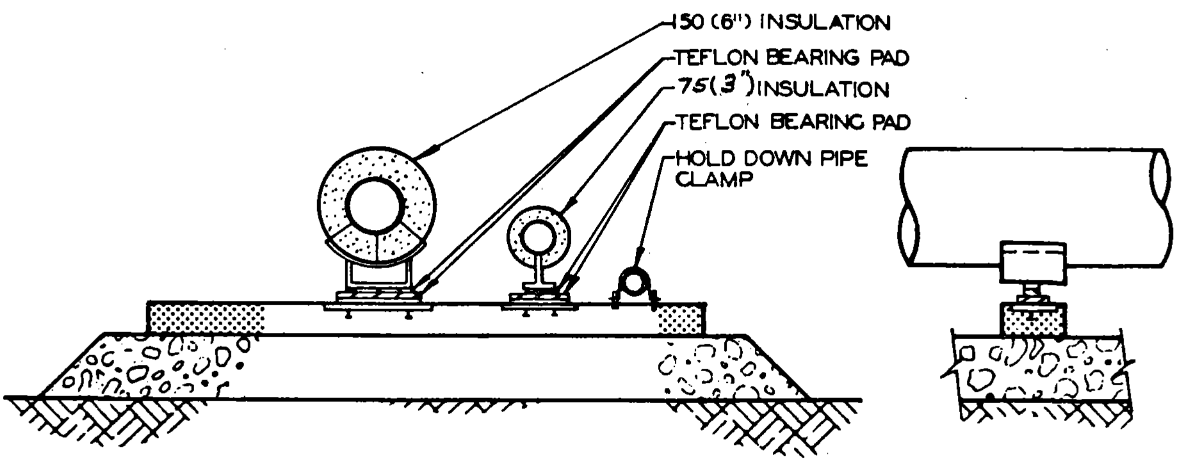
The piping support method is illustrated on Figure 5.1-21.

(3) Operating Characteristics. The Receiver Piping System normal operating characteristics are as follows.

| Main Steam Piping | Operating Conditions |
|---|---|
| Inlet pressure | 11.07 MPa (1,605 psia) |
| Outlet pressure | 9.72 MPa (1,410 psia) |
| Pressure Drop | 1.35 MPa (195 psi) |
| Inlet temperature | 520 C (968 F) |
| Outlet temperature | 510 C (950 F) |
| Flow rate | 54,331 kg/h (119,800 lb/h) |
| Piping thermal loss at normal operating temperature | 103.2 $kW_t$ (352,340 Btu/h) |
| **Feedwater Piping** | |
| Inlet pressure at EPGS interface | 11.13 MPa (1,615 psia) |
| Pressure at receiver feedwater booster pump discharge | 13.9 MPa (2,016 psia) |
| Outlet pressure at receiver interface | 12.79 MPa (1,855 psia) |
| Pressure drop | 1.35 MPa (195 psi) |
| Water temperature | 218 C (425 F) |
| Flow rate at normal operation | 54,331 kg/h (119,800 lb/h) |
| Piping thermal loss at normal operation | 43.1 $kW_t$ (146,955 Btu/h) |




AXIAL EXPANSION




AXIAL-TRANSVERSE EXPANSION

PIPE SUPPORTS

FIGURE 5.1-21

The normal shutdown of the solar facility will result in a reduction of the main steam pipe temperature. The expected rate in temperature decline from the normal operating temperature of 510 C (950 F) is indicated in Figure 5.1-22 as a function of the shutdown time.

5.1.5 Electric Power Generating System Data

(1) Design Characteristics. The Electric Power Generating System does not require any modifications to be compatible with the solar cogeneration systems. Interface design characteristics are consistent with the Receiver Piping System characteristics presented in Section 5.1.4.

(2) Operating Characteristics. A summary of the design point operating characteristics for operation with and without the solar addition is shown on Table 5.1-10. This summary includes the unit generation, process heat load, turbine heat input, plant heat input, and the system heat rates.

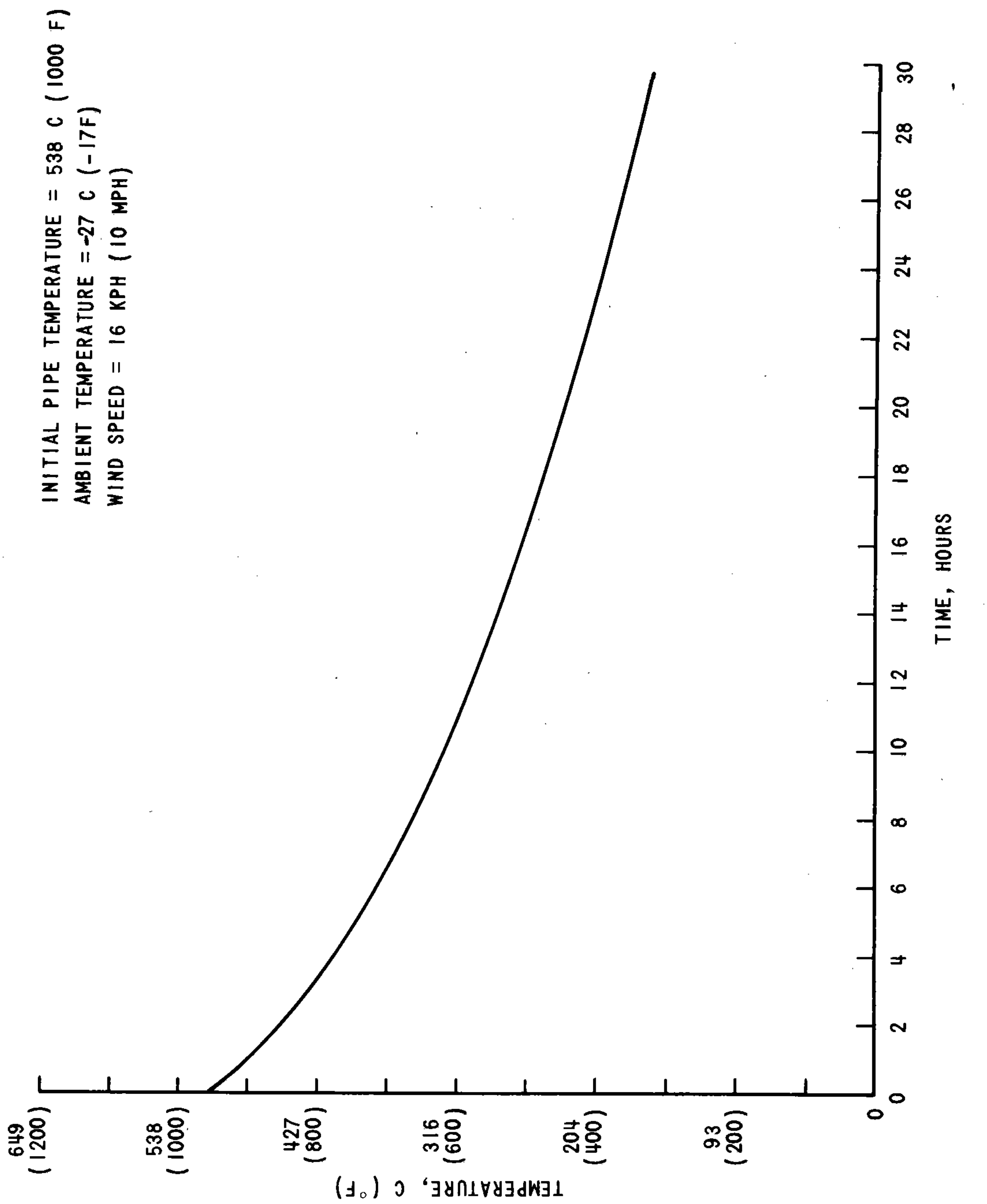
The turbine cycle will be operated with solar in accordance with the variable pressure curve shown in Figure 5.1-23. Figure 5.1-24 provides boiler efficiency as a function of steam flow. Figures 5.1-25 and 5.1-26 provide the gross turbine cycle heat rate for Unit 1 and Units 1 and 2 combined cycle operation.

5.1.6 Solar Master Control System Data

The Solar Master Control System (SMCS) consists of a control computer, a data acquisition computer, computer peripheral equipment control and display consoles, interface equipment to the other process systems, and all software required for a fully operational system.

The SMCS is comprised of the following major hardware components.

(1) Control Panel--A 3 m (10 ft) wide, 2.1 m (7 ft) high, 1.2 m (4 ft) deep standup bench front panel which contains all operator displays and controls. The panel includes a 0.9 m by 1.5 m (3 ft by 5 ft) graphic display subpanel which indicates, at a glance, the operational status of each heliostat.



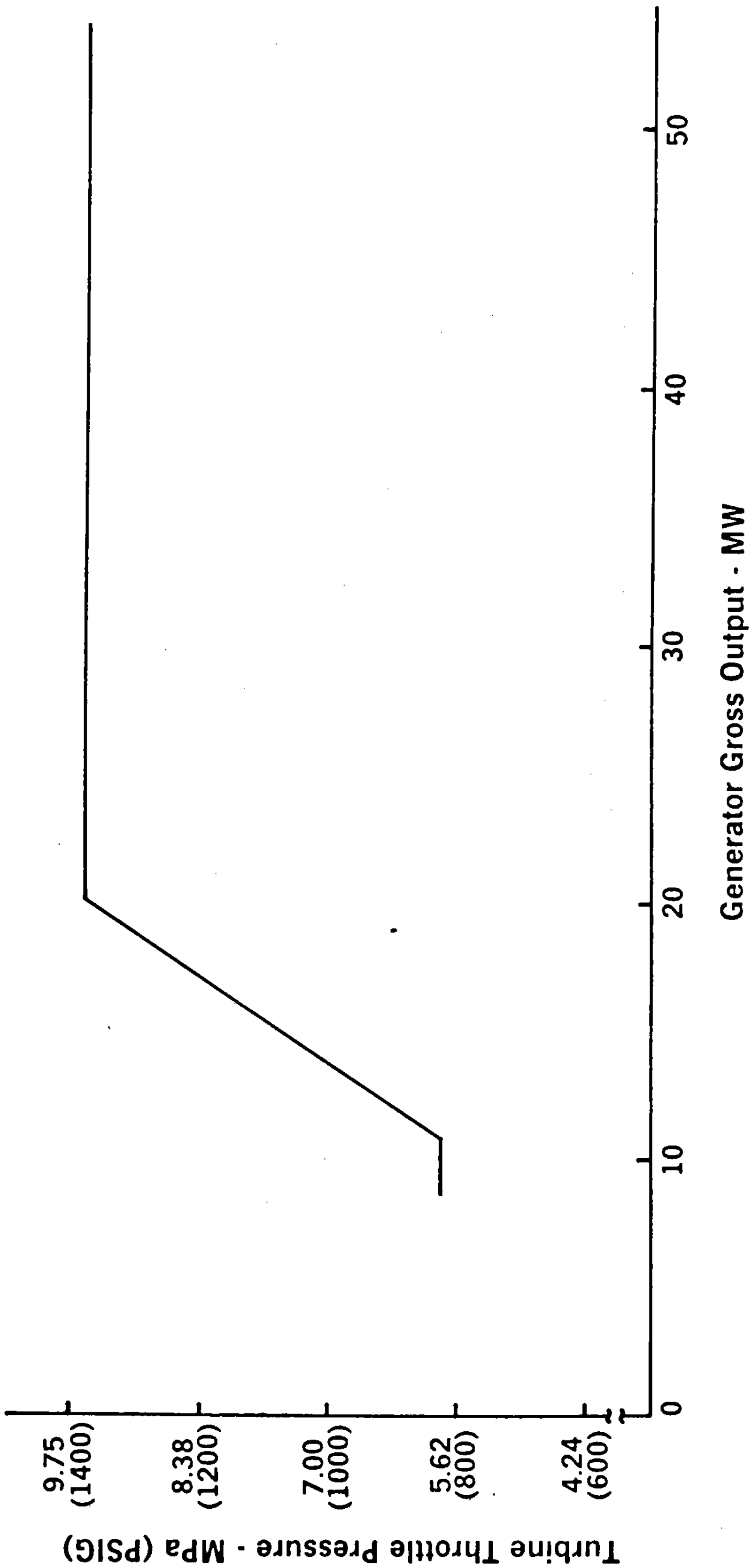

MAIN STEAM PIPE COOLDOWN TIME

FIGURE 5.1-22

TABLE 5.1-10. DESIGN POINT PERFORMANCE CHARACTERISTICS

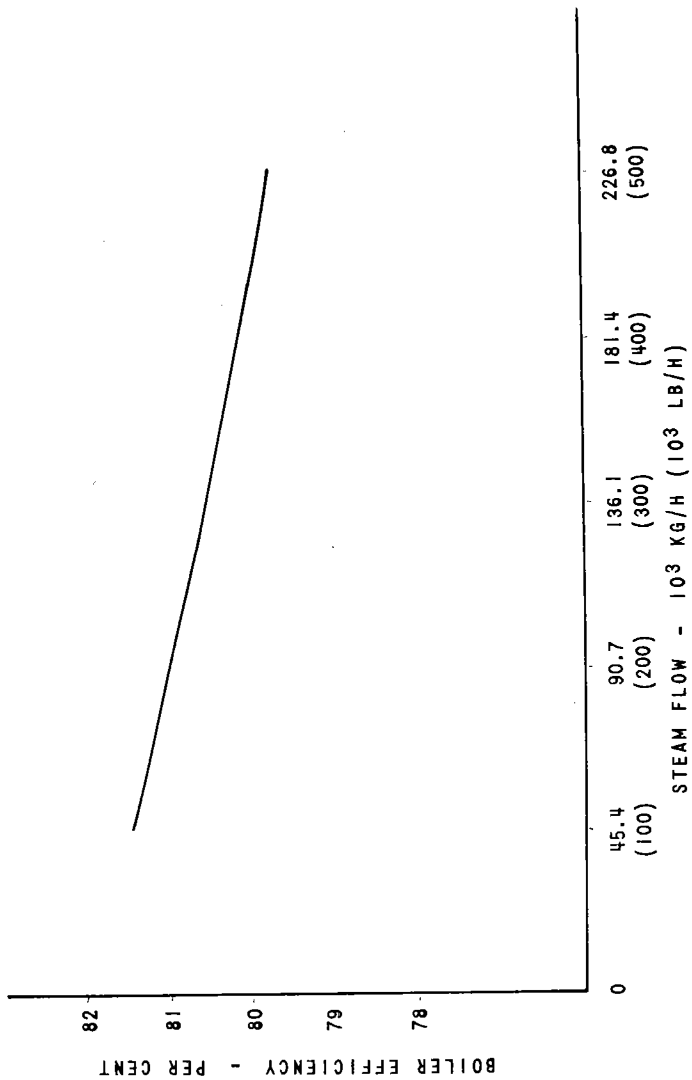
| | Fossil Only Operation | Fossil and Solar Operation |
|---|---|---|
| Unit 1 Generation* | | |
| Gross turbine output, kWe | 64,400 | 64,400 |
| Auxiliary power, kWe | 3,400 | 3,500 |
| Net plant output, kWe | 61,000 | 60,900 |
| Process heat load, kWt | 15,100 | 15,100 |
| Turbine Heat Input | | |
| Fossil, kWt | 150,000 | 112,900 |
| Solar, kWt | 0 | 37,100 |
| Total, kWt | 150,000 | 150,000 |
| Plant Heat Input | | |
| Fossil, kWt | 188,100 | 141,500 |
| Solar, kWt | 0 | 53,000 |
| Total, kWt | 188,100 | 194,500 |
| System Heat Rates | | |
| Gross turbine heat rate, Btu/kWh | 7,950 | 7,950 |
| Equivalent fossil gross turbine heat rate, Btu/kWh | 7,950 | 5,978 |
| Equivalent fossil net plant heat rate, Btu/kWh | 10,525 | 7,931 |

*Unit 1 and Unit 2 are operating in a combined cycle mode with Unit 2 at 12.5 MWe.



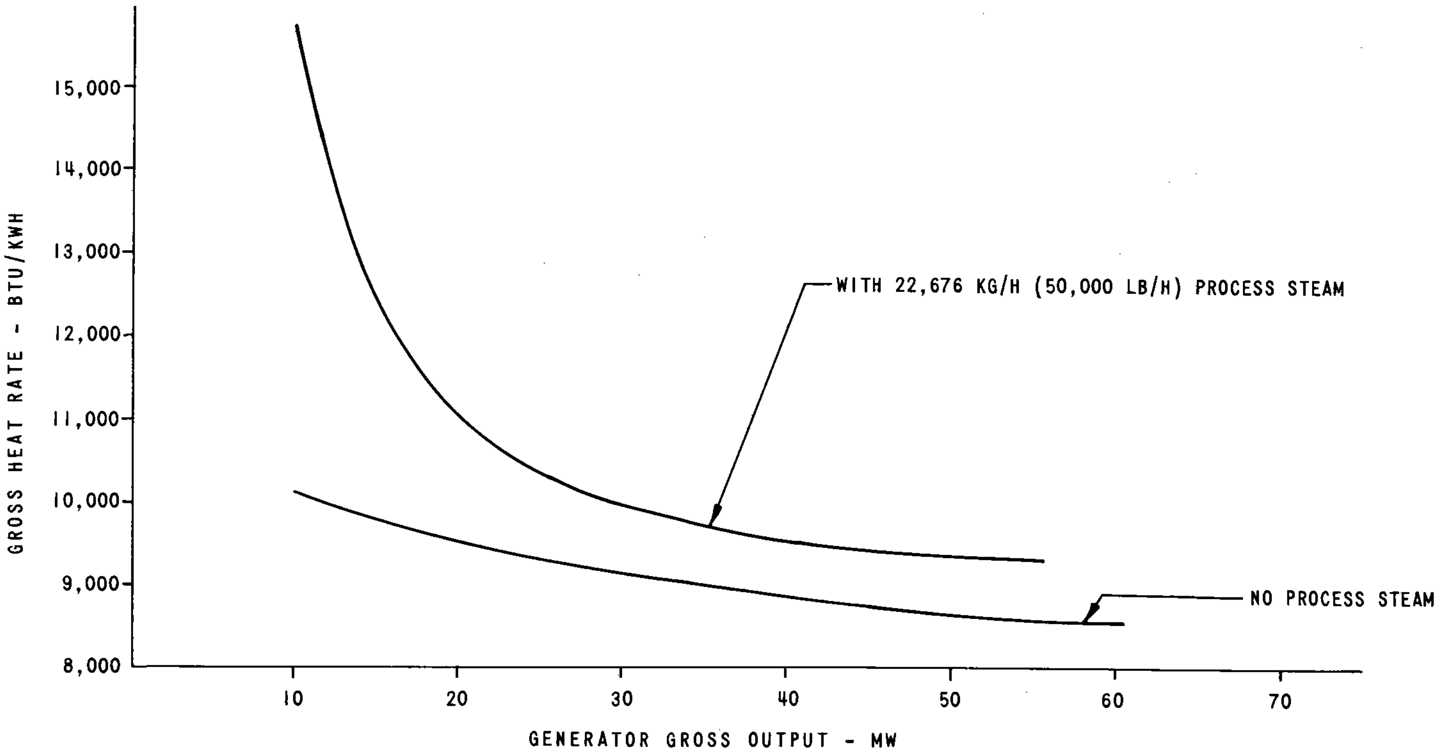

VARIABLE PRESSURE OPERATING CURVE

FIGURE 5.1-23




BOILER EFFICIENCY VERSUS STEAM FLOW

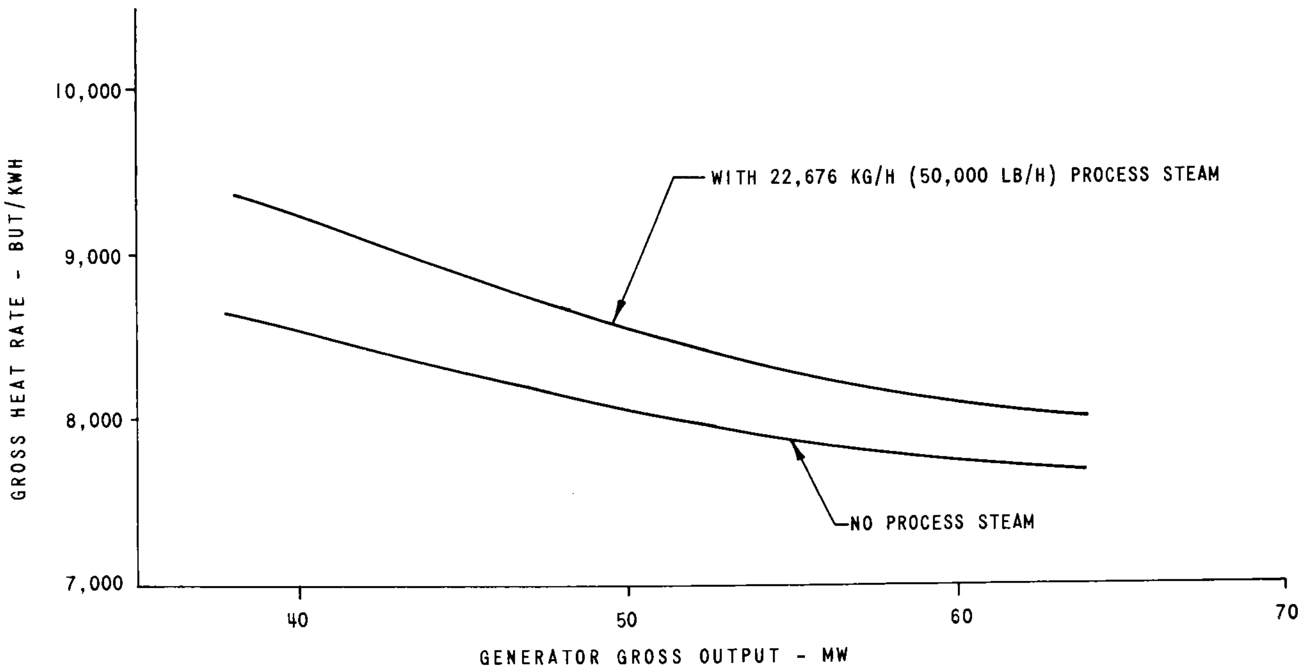
FIGURE 5.1-24




**GROSS HEAT RATE VERSUS GENERATOR OUTPUT UNIT I OPERATION**
**38 MM (1.5 IN.) HG CONDENSER PRESSURE**
**SLIDING PRESSURE OPERATION FROM**
**9.58 $MP_a$ (1390 PSIA) AT SECOND VALVE POINT**

FIGURE 5.1-25

SYSTEM SPECIFICATION
FACILITY DESIGN DATA
FILE NO. 9470.41.0200
SCF CRS 080781




GROSS HEAT RATE VERSUS GENERATOR OUTPUT
UNIT 1 AND UNIT 2 COMBINED
CYCLE OPERATION
38 MM (1.5 IN.) HG CONDENSER PRESSURE
9.58 $MP_a$ (1390 PSIA) THROTTLE PRESSURE

FIGURE 5.1-26

SYSTEM SPECIFICATION
FACILITY DESIGN DATA
FILE NO. 9470.41.0200
SCF CRS 080781

(2) Control Computer--A microprogrammed 16-bit microprocessor with 64 K words of high speed random access working memory. This computer is programmed by using a high level process control language.

(3) Data Acquisition Computer--A microprocessor with 24-bit word capacity. It has a main capacity of 64 K words and an auxiliary memory capacity of up to 13.8 million words of large core memory and moving head disc storage.

(4) Emergency Shutdown System--A hardwired relay cabinet with power supplies.

(5) Computer Input/Output System--A remote multiplexing station in the receiver tower and a high speed (1 million bits per second) digital data highway for communication between the master computers and the receiver and receiver piping systems. Asynchronous serial binary (EIA RS-232-C) ports are provided with the master computers for communications to the collector system.

(6) Programming Terminals--Consoles with cathode ray tube and keyboard for interrogating and modifying the computer software.

(7) Magnetic Tape Unit--An IBM compatible nine-track tape unit for program entry and long term data storage for offsite analysis.

(8) Interactive Cathode Ray Tubes and Keyboard--Color intelligent CRT terminals with alphanumeric characters and microprogrammed graphic characters. Each CRT uses an EIA RS-232-C compatible interface at serial rates up to 9,600 BAUD. Each CRT is accompanied by an alphanumeric keyboard and function push buttons for interactive display selection and modification.

(9) Printers--120 characters per second printing speed, 136-column print, complete with pedestal and enclosure.

### 5.1.7 Solar Auxiliary Electric System Data

The Solar Auxiliary Electric System has the following design and operating characteristics.

(1) Normal Auxiliary AC Power Supply Equipment.

(a) Switchgear.

- Quantity--1.
- Type--Metal enclosed assembly of two incoming modules, three feeder modules, one bus sectionalizing module, and one auxiliary module.
- Rating--4,160 volt, 60 BIL, three-phase, 60 hertz, 1,200 ampere, rated for 37,500 ampere rms symmetrical short circuit interrupting current.

(b) Emergency diesel generator.

- Quantity--1.
- Rating--450 kW, 0.8 power factor, 4,160 volt, three-phase, 60 hertz.
- Features--Fast start, radiator, 38 liter (10 US gallon) fuel tank, exhaust silencer, automatic start, storage battery, and battery charger.

(c) Heliostat field transformers.

- Quantity--5.
- Type--Low profile, pad-mounted.
- Rating--4,160 volt delta connected primary windings, 120/208 wye connected secondary windings, 150 kVA.

(2) Uninterruptible Auxiliary Power Supply Equipment.

(a) Static inverters.

- Quantity--2.
- Rating--37.5 kVA, 125 volt dc input, 120 volt, 60 hertz, single-phase ac output.
- Features--Automatic regulation of output voltage to ±2 per cent, solid state oscillator, protection against overloads, short circuits, and transients, output meters, alarms.

(b) Battery.

- Quantity--1.
- Type--Lead-acid.

- Rating--Nominal 125 volt, dc output, 60 cells each with 360 ampere-hour capacity or an 8-hour discharge basis, sized to provide uninterruptible power for a minimum of 1 hour after loss of charging power.

(c) Battery chargers.

- Quantity--2.
- Type--Self-regulating solid state silicon-controlled fullwave rectifier type.
- Rating--400 ampere 125 volt dc output, 480 volt three-phase ac input.

(3) Auxiliary Power Requirements. Auxiliary power requirements for the solar portion of the solar cogeneration facility are identified on Table 5.1-11.

## 5.2 EXISTING FACILITY DESCRIPTION

The existing cogeneration facility is described in the following sections.

### 5.2.1 Plant Site Description

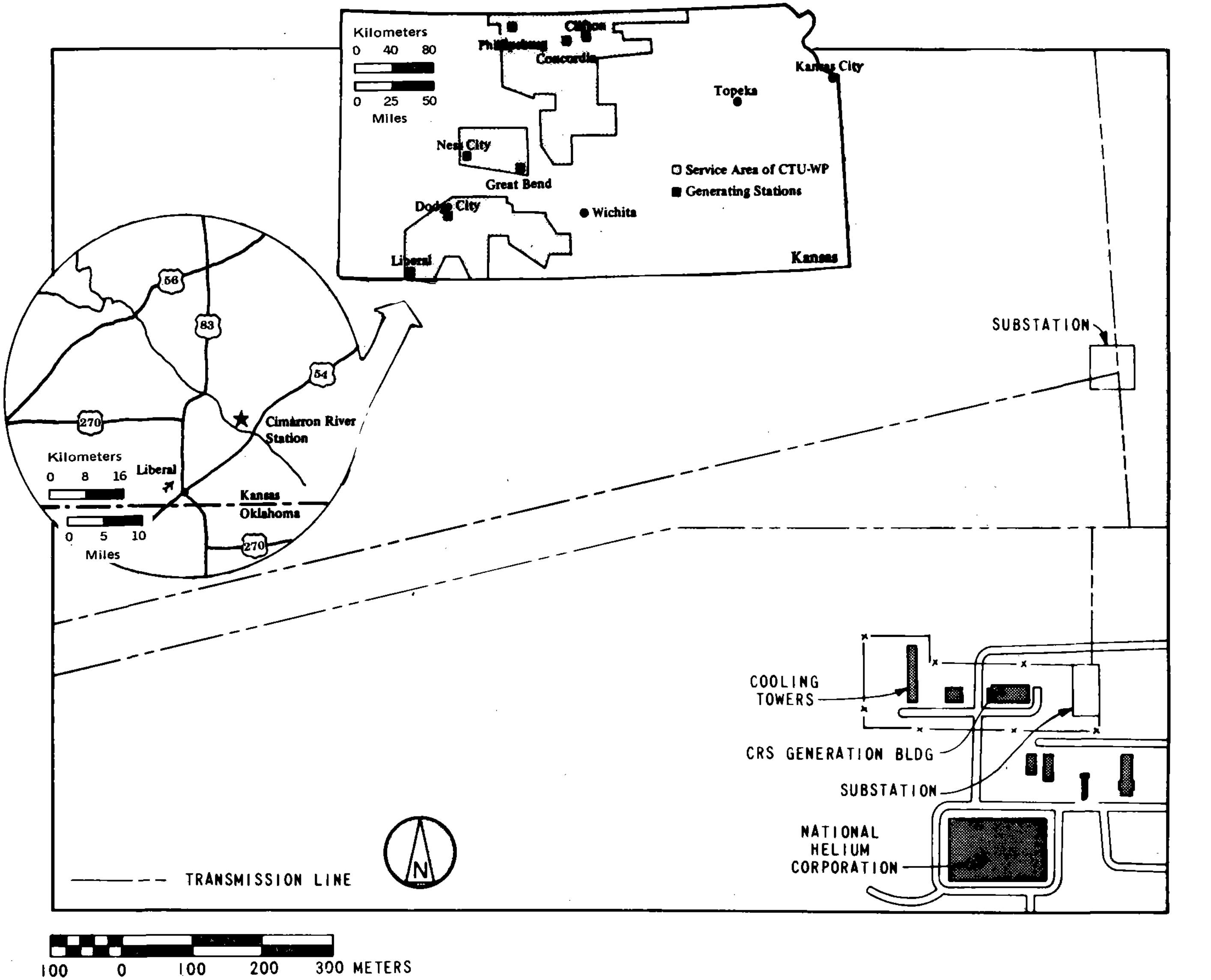
The plant site is located about 18 kilometers (11 miles) northeast of Liberal, Kansas near the intersection of US Highway 54 and the Cimarron River. The CTU-WP plant is at the south end of a 16.2 hectare (40 acre) site contiguous to the National Helium Corporation natural gas processing plant. NHC owns the land to the north, west, and south of the CTU-WP property. The plant location and site plan are shown on Figure 5.2-1. Additional key site characteristics are provided below.

| | |
|---|---|
| Surface Soil | Sandy Loam. |
| Structures | Gas wells, transmission lines, electrical substations, power plant (CRS), natural gas processing plant (NHC), pipelines, pipeline pumping station (Panhandle Eastern Pipeline Company). |
| Land Use | Grazing cattle--No high production or special crops. |
| Transportation | Air service, Liberal Kansas. Rail and highways. |

TABLE 5.1-11. SOLAR FACILITY AUXILIARY POWER REQUIREMENTS

| Solar Plant System | Design Point kW | Start-up kW | Shutdown kW |
| --- | --- | --- | --- |
| Collector System | 542.4* | 542.4* | 542.4* |
| Receiver System | 28.3 | 34.8 | 28.3 |
| Receiver Piping System | 111.9 | 83.8 | 83.8 |
| Solar Master Control System | 28.8 | 28.8 | 28.8 |
| Miscellaneous (Lighting, Heating) | 18.0 | 18.0 | 36.0 |
| Total | 729.4 | 712.8 | 719.3 |

*Peak power for total heliostat field. Average power requirement will be about 33.5 kW.




PLANT LOCATION AND SITE ARRANGEMENT--CIMARRON RIVER STATION, NATIONAL HELIUM CORPORATION

FIGURE 5.2-1

5.2.2 Plant Description

The Cimarron River Station cogeneration facility contains three major elements: a natural gas fueled conventional steam power plant (Unit 1), a combustion gas turbine (Unit 2), and a natural gas fueled process steam generator. Unit 1 utilizes a 44 MWe General Electric tandem compound, double flow, non-reheat turbine generator with design steam inlet conditions of 8.72 MPa (1,265 psia) and 510 C (950 F) and overpressure operating conditions of 9.58 MPa (1,390 psia). The turbine is normally operated at the overpressure condition for improved cycle efficiency and has a maximum capability of 60 MWe. The Unit 1 steam generator was built by Babcock & Wilcox and is a two drum Stirling, natural circulation, pressurized furnace, with a design rating of 192,740 Kg/h (425,000 lb/h), 9.06 MPa (1,315 psia), 513 C (955 F) superheated steam. The maximum extended capability is 226,760 Kg/h (500,000 lb/h), 9.99 MPa (1,450 psia), 513 C (955 F). The Unit 1 cycle configuration includes five stages of feedwater heating. The steam cycle also employs a horizontal, two pass, surface type condenser and mechanical draft wet cooling towers. The plant control systems were supplied by the Foxboro Company.

The combustion turbine (Unit 2) is rated at 14 MWe. It is provided with an exhaust heat recovery heat exchanger. When both units are operating in a combined cycle mode, the Unit 1 high pressure feedwater heaters are taken out of service and feedwater heating is provided by the exhaust heat recovery heat exchanger. The combustion turbine is normally only operated during the summer peaking season in a combined cycle mode with Unit 1.

The process steam generator, built by Babcock & Wilcox, has a design pressure of 1.83 MPa (265 psia) and has a capability of 27,200 Kg (60,000 pounds) of steam per hour. This steam generator is utilized to provide process steam to National Helium Corporation (NHC) when Unit 1 is shut down.

Service water and makeup water for the circulating water system is provided from five wells located onsite. Cooling tower blowdown is directed to an onsite evaporation pond.

The cogeneration facility provides process steam and electrical energy to the adjacent NHC plant. Process steam is taken from the first two extraction ports of the steam turbine through pressure regulating valves to maintain 0.65 MPa (95 psia) steam for delivery to NHC. This steam is desuperheated to 204 C (400 F). The electric energy supplied to NHC may be provided from either the CRS or the Western Power grid. The NHC plant processes the raw natural gas entering the Panhandle Eastern Pipeline for transportation to the Detroit, Michigan area. A refrigeration process is utilized to remove the propane, butane, and gasoline (pentane and greater fractions) products. At the same time, water and carbon dioxide are removed from the gas stream. The refrigeration process used requires both electric and thermal energy in the ratio of approximately 3:1, thermal equivalent. The addition of the solar facility requires no modifications to the NHC plant.

5.2.3 Equipment Specifications

(1) Unit 1 Steam Generator Characteristics--The technical data for the Unit 1 steam generator and related equipment, extracted from the original manufacturer's equipment data lists, are as follows.

(a) Main Steam Generators.

| | |
|---|---|
| Manufacturer | Babcock and Wilcox |
| Type of unit | Two drum Stirling, natural circulation, pressurized furnace |
| Continuous rating | 425,000 lb/h |
| Design pressure | 1,650 psig |
| Steam outlet conditions | |
| Pressure | 1,300 psig |
| Temperature | 955 F |
| Water capacity (normal level) | 148,400 lb |
| Water capacity (flooded) | 183,150 lb |

Performance data (design) for the steam generator as extracted from the original manufacturer's equipment lists are as follows.

| | Steam Flow at Superheater Outlet (1,000 lb/h) | | |
|---|---|---|---|
| Pressures (psig) | 212 | 425 | 500 |
| Superheater outlet | 1,265 | 1,300 | 1,435 |
| Drum pressure | 1,283 | 1,373 | 1,535 |
| Economizer inlet | 1,285 | 1,380 | 1,545 |
| Burner gas pressure | -- | -- | 7.5 |
| Temperatures (F) | | | |
| Feedwater to economizer | 335 | 420 | 310 |
| Feedwater from economizer | 413 | 490 | 420 |
| Superheater outlet steam | 955 | 955 | 955 |
| Air to FD fans at 60 per cent relative humidity | 80 | 80 | 80 |
| Air to regenerative air heaters | 80 | 80 | 80 |
| Air from regenerative air heaters | 440 | 526 | 524 |
| Average air in-gas out (corrected) regenerative air heaters | 140 | 168 | 175 |
| Air to burners | 440 | 526 | 524 |
| Gas leaving furnace (HVT) | 1,860 | 2,180 | 2,350 |
| Gas leaving boiler (HVT) | 710 | 830 | 920 |
| Gas leaving regenerative air heater (uncorrected) | 210 | 265 | 280 |
| Gas leaving regenerative air heater (corrected) | 201 | 255 | 270 |
| Air Friction Losses (in. $H_2O$) | | | |
| Burner and wind box | 0.8 | 3.1 | 5.0 |
| Air heaters, regenerative | 0.5 | 1.4 | 2.2 |
| Dampers, venturi and air ducts | 0.2 | 0.7 | 1.2 |
| Total air friction loss | 1.5 | 5.2 | 8.4 |

| Gas Friction Losses (in. $H_2O$) | Steam Flow at Superheater Outlet (1,000 lb/h) 212 | 425 | 500 |
|---|---|---|---|
| Furnace boiler, superheater, reheater and economizer | 0.8 | 2.6 | 4.7 |
| Air heaters, regenerative | 0.8 | 2.2 | 3.3 |
| Dampers and gas ducts | 0.2 | 0.7 | 1.2 |
| Total gas friction losses | 1.8 | 5.5 | 9.2 |
| Total Gas and Air Friction Loss (in. $H_2O$) | 3.3 | 10.7 | 17.6 |

(b) Boiler Drum.

| | |
|---|---|
| Drum inside diameter | 66 inches |
| Drum overall length | 29 feet |

(c) Low Temperature Superheater.

| | |
|---|---|
| Type | Continuous |
| Number of passes | One |
| Tube OD | 2-1/4 inch |

(d) High Temperature Superheater.

| | |
|---|---|
| Type | Continuous |
| Number of passes | One |
| Tube OD | 2-1/4 inch |

(e) Combustion Control

| | |
|---|---|
| Manufacturer | The Foxboro Company |
| Type of control | Electronic-pneumatic full floating, metering and proportioning. Control system to automatically hold a constant steam pressure by regulation of fuel and combustion air supply to the furnace. Safety circuits insure that fuel follows air on increasing load and air follows fuel on decreasing load. These circuits automatically cut back fuel on partial or complete loss of air. |

(f) Feedwater Control

| | |
|---|---|
| Manufacturer | The Foxboro Company |
| Type of control | Electronic-pneumatic operated. Three element type to maintain a constant boiler drum level by balancing feedwater flow against steam flow with drum level compensation. Feedwater flow is controlled by means of variable speed hydraulic coupling on the main boiler feed pump. |

(g) Steam Temperature Control

| | |
|---|---|
| Manufacturer | The Foxboro Company |
| Type of Control | Electronic-pneumatic operated system to maintain steam temperature at the superheater outlet at 950 F plus or minus 10 F by control of water attemperation. |

(h) Air Heater.

| | |
|---|---|
| Manufacturer | Air Preheater |
| Number | One |
| Type | Regenerative |

(i) FD Fan.

| | |
|---|---|
| Manufacturer | Sturdevant |
| Type | 750 Airfoil |
| Speed (operating) | 1,160 |
| Wheel diameter | 76-7/8 inches |
| Design temperature | 115 F |
| Test block shaft power | 776 hp fan 809 hp drive |
| Test block flow rate | 190,000 cmf @ 2,850 ft |
| Test block, static pressure | 22.0 inches $H_2O$ |
| Blades | |
| Number | 10 |
| Material | Low alloy |
| Thickness | 12 gauge |
| Shape | Airfoil |
| Motor rating | 700 hp, 4,000 volt, 3 phase, 60 Hz, 1,200 rpm, 1.15 service factor |

(j) FD Fan Variable Speed Drive.

| | |
|---|---|
| Manufacturer | Electric Machinery |
| Model | M-5537G |
| Type | Magnetic coupling |
| Minimum full load slip | 2 per cent |

(2) Unit 1 Electric Power Generating System (EPGS) Data--The technical data for major components of the CRS Unit 1 EPGS as extracted from the original manufacturer's equipment lists are as follows.

(a) Turbine Generator.

| | |
|---|---|
| Manufacturer | General Electric |
| Number of units | One |
| Type | Impulse, tandem compound, double flow, nonreheat |
| Maximum capability | 60,000 kW |
| Speed | 3,600 rpm |
| Number of extractions | Five |
| Generator | 58,824 kVA, 0.85 power factor, 13,800 v, 3 phase, 60 Hz, hydrogen cooled, static exciter and regulator |

| | Generator Output (kW) | | |
|---|---|---|---|
| | 25,000 | 44,000 | 61,450 |
| Performance data (design) | | | |
| Power factor | .85 | .85 | .85 |
| Throttle steam pressure (psig) | 1,250 | 1,250 | 1,375 |
| Throttle steam temperature (F) | 950 | 950 | 950 |
| Exhaust steam pressure (in. Hg abs) | 1.5 | 1.5 | 2.5 |
| Exhaust flow (lb/h) | 128,375 | 233,423 | 406,758 |
| Throttle steam flow (lb/h) | 235,210 | 399,261 | 491,340 |
| Turbine - cycle heat rate (Btu/kWh) | 10,854 | 9,786 | 9,533 |
| Process steam flow (lb/h) | 55,000 | 55,000 | 0 |

(b) Condenser.

| | |
|---|---|
| Manufacturer | Ingersoll-Rand |
| Type | Horizontal, two pass, surface type with divided water boxes, integral air cooler and deaerating hotwell |
| Condensing surface | 30,000 $ft^2$ |
| Tube sheet material | Carbon steel |
| Tube material | Stainless steel |
| Length of tubes | 24 ft |
| Design water flow | 42,000 gpm |
| Water velocity | 7.3 ft/s |
| Air ejector | 1 steam jet, twin element, two stage ejector |

(c) Condensate Pumps.

| | |
|---|---|
| Manufacturer | Ingersoll-Rand |
| Quantity | Two |
| Type | Vertical pit type, six stage |
| Capacity | 600 gpm |
| Total developed head | 325 ft |
| Speed | 1,750 rpm |
| Motor | General Electric, 75 hp, 1,800 rpm, 440 v, 3 phase, drip proof |

(d) Boiler Feed Pump.

| | |
|---|---|
| Quantity | One |
| Pump | |
| Manufacturer | Pacific Pumps |
| Type | 6 CSX-BF1-11 |
| Capacity | 1,000 gpm |
| Total developed head | 4,500 feet |
| Hydraulic coupling | |
| Manufacturer | American Standard |
| Type | VS Class 6 |
| Size | 171A |
| Motor rating | 1,250 hp, 4,000 volt, 3 phase, 60 Hz, 3,600 rpm, 1.15 service factor |

(e) Heat Exchangers.

| | |
|---|---|
| **Feedwater heater 1A** | |
| Manufacturer | Baldwin-Lima-Hamilton |
| Type | 28-132 "SSU" vertical, four pass |
| Tube material | Carbon steel |
| Tube design pressure | 150 psig |
| Tube design temperature | 366 F |
| Shell design pressure | 150 psig and vacuum |
| Shell design temperature | 400 F |
| **Feedwater heater 1B** | |
| Manufacturer | Baldwin-Lima-Hamilton |
| Type | 25-132 "SSU" vertical, four pass |
| Tube material | Carbon steel |
| Tube design pressure | 150 psig |
| Tube design temperature | 366 F |
| Shell design pressure | 150 psig |
| Shell design temperature | 400 F |
| **Feedwater heater 1C** | |
| Manufacturer | Baldwin-Lima-Hamilton |
| Type | 27-198 LSU, vertical, two pass |
| Tube material | Carbon steel |
| Tube design pressure | 1,945 psig |
| Tube design temperature | 366 F |
| Shell design pressure | 150 psig |
| Shell design temperature | 650 F |

| | |
|---|---|
| Feedwater heater 1D | |
| Manufacturer | Baldwin-Lima-Hamilton |
| Type | 27-200 LSU, vertical, two pass |
| Tube material | Carbon steel |
| Tube design pressure | 1,945 psig |
| Tube design temperature | 407 F |
| Shell design pressure | 250 psig |
| Shell design temperature | 650 F |
| Feedwater heater 1E | |
| Manufacturer | Baldwin-Lima-Hamilton |
| Type | 29-194 LSU, vertical, 4 pass |
| Tube material | Carbon steel |
| Tube design pressure | 1,945 psig |
| Tube design temperature | 454 F |
| Shell design pressure | 425 psig |
| Shell design temperature | 650 F metal/705 F water |
| Deaerating heater | |
| Manufacturer | Allis-Chalmers |
| Model | 9-T-1 |
| Design conditions | |
| Condensate flow | 86,000 lb/h |
| Condensate temperature | 190 F to 210 F |
| Steam supply | |
| Pressure | 3 psig |
| Enthalpy | 1,225 Btu/lb |
| Makeup flow | 20,000 lb/h |
| Makeup temperature | 55 F |
| Shell design pressure | 15 psig |

(f) Cooling Towers.

| | |
|---|---|
| Manufacturer | Marley |
| Number | Five |
| Type | Wet, mechanical draft |
| Fan motor rating | 75 hp, 440 volt, 3 phase, 60 Hz, 1,800 rpm, 1.0 service factor |

(g) Circulating Water Pumps

| | |
|---|---|
| Manufacturer | Ingersoll-Rand |
| Quantity | Two |
| Type | Horizontal split case |
| Speed | 695 rpm |
| Capacity | 21,000 gpm |
| TDH | 80 ft |
| Motor rating | 500 hp, 4,000 volt, 3 phase, 60 Hz, 720 rpm, 1.15 service factor |

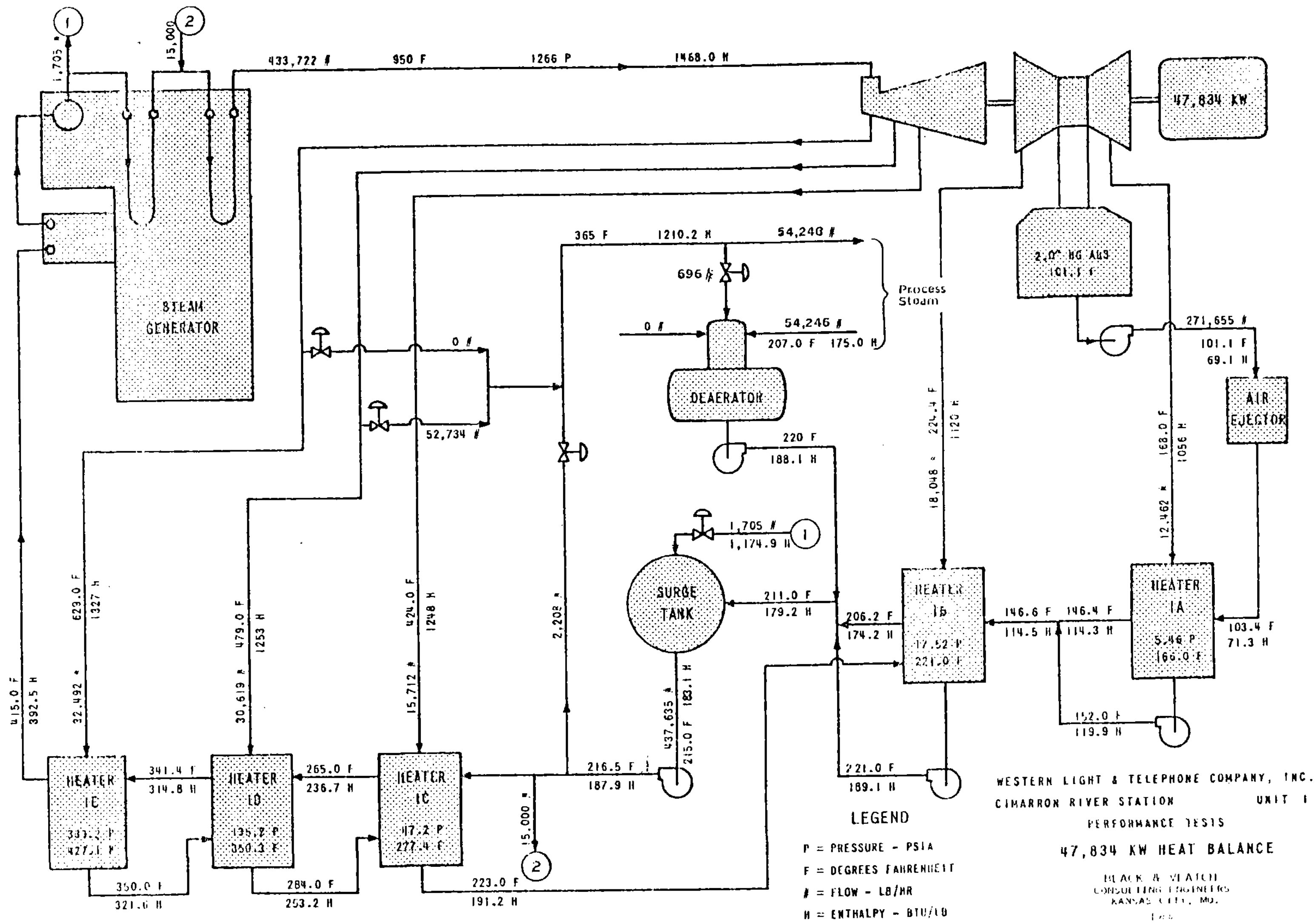
The operation of the existing facility is illustrated on the typical heat balance of Figure 5.2-2.

(3) Unit 2 Combustion Gas Turbine Data--The technical data for the combustion gas turbine as extracted from the original manufacturer's equipment lists are as follows.

Combustion Gas Turbine

| | |
|---|---|
| Manufacturer | General Electric |
| Number of units | One |
| Maximum capability | 14,000 kW |
| Speed | 3,600 rpm |
| Generator | 17,647 kVA, 0.85 power factor, 13,800 v, 60 Hz, air cooled |

(4) Process Heat System Data--Process steam at .65 MPa (95 psia), 204 C (400 F) is provided to NHC at a rate of approximately 22,700 Kg/h (50,000 lb/h) continuously. Turbine extraction pressure is a function of load on the turbine-generator. During high load operation, process steam is provided from the second extraction stage of the Unit 1 turbine. During moderate load operation, process steam is provided either partially or completely from the first extraction port, depending upon available pressure. At low turbine-generator loads, process steam is provided from the main steam system. During times when CRS Unit 1 is out of service, CTU-WP operates the auxiliary gas-fired package boiler at CRS to supply process steam to NHC. Specifications for the auxiliary boiler are as follows.




LEGEND

P = PRESSURE - PSIA
F = DEGREES FAHRENHEIT
# = FLOW - LB/HR
H = ENTHALPY - BTU/LB

WESTERN LIGHT & TELEPHONE COMPANY, INC.
CIMARRON RIVER STATION UNIT 1
PERFORMANCE TESTS
47,834 KW HEAT BALANCE
BLACK & VEATCH
CONSULTING ENGINEERS
KANSAS CITY, MO.

TYPICAL HEAT BALANCE

FIGURE 5.2-2

(a) Auxiliary Boiler.

| | |
|---|---|
| Manufacturer | Babcock & Wilcox |
| Number of units | One |
| Continuous rating | 60,000 lb/h |
| Design pressure | 250 psig |

Performance data (at rated conditions) for the auxiliary boiler as extracted from the original manufacturer's equipment lists are as follows.

| | |
|---|---|
| Steam flow | 60,000 lb/h |
| Pressures | |
| Superheater outlet | 125 psig |
| Drum pressure | 180 psig |
| Temperatures | |
| Feedwater to boiler | 220 F |
| Superheater outlet | 410 F |
| Air friction loss | 4.7 in. $H_2O$ |
| Efficiency | 77.4 per cent |

5.3 FACILITY COST DATA

Presented herein is the project cost estimate for the Solar Cogeneration at the Cimarron River Station. Documentation for the assumptions made by Black & Veatch in developing the estimate is included. The total project cost estimate is summarized on Table 5.3-1 and includes estimated owner costs, construction costs, and operations and maintenance costs.

5.3.1 Owner's Cost Estimate

The owner's cost estimate is summarized on Table 5.3-2.

5.3.1.1 Basis of Estimate. The following costs were considered owner's costs for the estimate.

(1) Land and Land rights at $1,483 hectare ($600/acre).

(2) Consulting services for site studies including topographic surveying, geotechnical investigations, and construction control testing.

(3) Onwer's managerial, engineering, financing, and accounting, procurement, labor relations, general services, estimating, planning and scheduling, coordination, construction management, and other home office services directly associated with the project. Also includes insurance, consumable supplies and start

TABLE 5.3-1. PROJECT COST ESTIMATE SUMMARY (July 1, 1980 Dollars)

| | |
|---|---|
| Owner's Cost Estimate | $ 5,609,645 |
| Construction Cost Estimate | $28,226,753 |
| Annual Operations and Maintenance Cost Estimate | $135,610 |

TABLE 5.3-2. OWNER'S COST ESTIMATE SUMMARY

| Item | Total Cost $ |
|---|---|
| Land and Land Rights | 48,000 |
| Topographic Survey | 18,000 |
| Geotechnical Investigation | 10,250 |
| Construction Control Testing | 40,000 |
| Western Power Indirect Costs | 479,885* |
| Design Engineering | ** |
| Property Tax | 486,735 |
| Sales Tax | 17,035 |
| AFDC | 4,509,740 |
| Total (7-1-80 $) | 5,609,645 |

*Includes consumable supplies and start-up costs, licenses and permits, and insurance.

**Included in construction cost estimate.

up costs as well as costs of obtaining all necessary licenses and permits including preparation of environmental information document.

(4) Plant consumable supplies and start-up costs (included as part of the onwers indirect costs).

(5) Ad valorem property tax and sales tax.

(6) Cost of money, AFUDC (Allowance for Funds Used During Construction) based upon a rate of 13 per cent compounded semi-annually.

5.3.2 Construction Cost Estimate

The construction cost estimate is summarized by cost code on Table 5.3-3 and by cost account on Table 5.3-4. The detailed breakdown of the construction cost estimate showing material and labor costs is presented in Appendix B.

5.3.2.1 Basis of Estimate. The construction cost estimate is based upon the following.

(1) Estimate uses Construction Cost Code format with alphabetical cost account breakdown.

(2) Costs are for a facility to be located at the Central Telephone and Utilities-Western Power Cimarron River Station near Liberal, Kansas.

(3) General owner's costs not included in the construction cost estimate are land, licenses and permits, taxes, and cost of money.

(4) A minimal account of spare parts is included as required; those included are considered necessary for normal operation of the facility.

(5) Costs are summarized in July 1, 1980 dollars. Costs are given in the supporting base sheets in Appendix B are also July 1, 1980 dollars and indicate material and labor cost breakdowns.

(6) Each line item is based on current design information. Some items are based on vendor quotations that have been checked against costs for similar items from recent B&V projects; other items are based on recently contracted costs. The price basis varies throughout the estimate.

TABLE 5.3-3. CONSTRUCTION COST SUMMARY BY COST CODE

| Cost Code | Element Description | Construction Cost* Level 2 | Level 1 | Level 0 |
|---|---|---|---|---|
| 5000 | Total Facility** | | | 28,227 |
| 5100 | Site Improvement | | 6,019 | |
| 5110 | Site Preparation | 1,657 | | |
| 5120 | Site Facilities and Improvements | 362 | | |
| 5200 | Site Building (excluding receiver tower) | | 21 | |
| 5300 | Collector System | | 13,192 | |
| 5400 | Receiver System | | 8,179 | |
| 5410 | Receiver | 7,350 | | |
| 5420 | Receiver Tower | 829 | | |
| 5500 | Master Control System | | 2,676 | |
| 5700 | Solar Auxiliary Electrical System | | 709 | |
| 5800 | Electric Power Generating System Modifications | | 67 | |
| 5900 | Receiver Piping System | | 1,366 | |
| 5910 | Main Steam Piping | 769 | | |
| 5920 | Feedwater Piping | 421 | | |
| 5930 | Condensate Piping | 176 | | |

*Cost expressed in thousands of July, 1980 dollars.

**Total facility cost excludes owner's costs and operations and maintenance costs.

TABLE 5.3-4. CONSTRUCTION COST SUMMARY BY COST ACCOUNT

**CONSTRUCTION COST ESTIMATE**

CLIENT Central Tel & Util; Western Pwr DESCRIPTION Total Construction Cost

LOCATION Cimarron River Station

PROJECT Solar Cogeneration Fac.

CONT. NO. 81SF11439

MADE BY R. Dedrick

APPROVED J E Harder

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
|---|---|---|---|---|---|---|
| A | Excavation & Civil | 48919 | 498,243 | 4800 | 151,039 | 654082 |
| B | Concrete | 1,361 | 12,234 | 43,200 | 44,130 | 99,564 |
| C | Structural Steel | 9,242 | 197,170 | | 610,149 | 807,319 |
| D | Buildings | 138 | 1,560 | | 9,900 | 11,460 |
| E | Machinery & Equipment | 323 | 3,706 | 104,470 | 12,067,490 | 12,175,666 |
| F | Piping | 26,078 | 634,555 | | 2,745,953 | 3,380,508 |
| G | Electrical | 28,782 | 339,254 | | 1,909,205 | 2,241,457 |
| H | Instruments | 1,909 | 63,852 | | 607,120 | 670972 |
| J | Painting | | | | 85,000 | 85,000 |
| K | Insulation | 13,692 | 426,026 | | 224,228 | 650,254 |
| | DIRECT FIELD COSTS | 130,544 | 2,175,600 | 152,470 | 18,454,214 | 20,782,284 |
| L | Temporary Construction Facilities | | | | | 202,135 |
| M | Construction Services, Supplies & Expense | | | | | 283,025 |
| N | Field Staff, Subsistence & Expense | | | | | 716,705 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 539,649 |
| Q | Equipment Rental | | | | | 678,590 |
| | INDIRECT FIELD COSTS | | | | | 2,420,104 |
| | TOTAL FIELD COSTS | | | | | 23,202,388 |
| R | Engineering | | | | | 2,170,875 |
| | Design & Engineering B&V | | | | | 1,147,875 |
| | Home Office Costs | | | | | |
| | R & D B&V | | | | | 1,023,875 |
| S | Major Equipment Procurement | | | | | 43,045 |
| T | Construction Management | | | | | 244,375 |
| | TOTAL OFFICE COSTS | | | | | 2,458,295 |
| | TOTAL FIELD & OFFICE COSTS | | | | | 25,660,683 |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 2,566,070 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 28,226,753 |

DATE 21 MAY 81 REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

(7) Labor costs in lines A-K are based on recently experienced man-hours to complete similar tasks on other B&V projects, multiplied by the appropriate base wage rate without employee benefits. Labor costs in lines L-Q include overhead and profit and line P includes fringe benefits for crafts. The wage rates used for the estimate are based on a wage rate survey of the Liberal, Kansas area. The labor costs for heliostat installation (Account 5300 Collector System) are not shown separately, but are included in the $215/m^2 total heliostat costs.

(8) Direct accounts in most cases include only direct labor and material costs. Distributable items are included in field cost categories. Exceptions to the above statements are as follows.

(a) Account 5310 Collector System (total installed heliostat costs figures at $215/m^2).

(b) Account 5410 - Codes C, F, H, K - Babcock & Wilcox receiver contract is all-inclusive.

(9) A contingency allowance of 10 per cent is included. A diligent effort has been exercised to include a cost for all items of facility design, to price each item according to the best available design information, and to obtain a realistic price for all items. No other adjustment factors or hidden contingency costs are included in the estimate.

5.3.2.2 Methodology. The methodology used to prepare the estimate is outlined by the following.

(1) Current design data for all items to be estimated is obtained.

(2) Quantity takeoffs are prepared from the design data, as required, to estimate costs. A punch list of items requiring pricing is also prepared.

(3) All quantity takeoffs are priced; the method of pricing varies with the item considered. Some prices are based on recent B&V contract prices for similar tasks or items. Vendor quotations were requested for items that differ significantly from those recently purchased for clients by B&V.

Common items of defined design are priced from vendor price books. Published estimating books are used to estimate some items.

(4) All takeoffs, unit prices, price projection, and mathematical manipulations are carefully checked.

5.3.3 Operations and Maintenance Cost Estimate

The operations and maintenance cost estimate for the life of the facility is summarized on Table 5.3-5. A detailed description of the operations and maintenance cost is shown on Table 5.3-6.

5.4 ECONOMIC DATA

The economic evaluation involves determining the economic value of the solar addition to Western Power in the context of the Western Power system.

Section 5.5.3 discusses in detail the method used to perform the evaluation, but a brief description is needed to understand the assumption required.

The evaluation consisted of the following.

(1) System expansion plans and schedules were developed for Western Power system generation additions during the period after 1985 for the system with and without the solar addition and with and without the NHC process steam and electric loads.

(2) Black & Veatch's economic dispatch, system simulation program was used to model the expansion plans and determine the annual production costs based on Western Power projected fuel, O&M and purchased power costs.

(3) Annual production costs are combined with projected capital costs of the expansion plans and, using Western Power financial factors, comparative costs were calculated.

(4) Examination of comparative costs for the different expansions plans allows the calculation of the value to the Western Power system of the solar addition.

TABLE 5.3-5. OPERATIONS AND MAINTENANCE COST SUMMARY (1980 Dollars)

| | |
|---|---|
| OM100 Operations | $ 25,600 |
| OM200 Maintenance Materials | $ 41,940 |
| OM300 Maintenance Labor | $ 68,070 |
| Annual Total Operations and Maintenance Cost Estimate | $135,610 |

TABLE 5.3-6. ANNUAL OPERATIONS AND MAINTENANCE COSTS[a]

| | Cost (1980 Dollars) $/yr |
|---|---|
| OM100 Operations | |
| OM110 Personnel | |
| Master Control Technician (1 man) | 21,000 |
| Total | 21,000 |
| OM120 Operating Comsumables | |
| Nitrogen [694 scm/yr (24,500 scf/yr)][b] | 2,440 |
| Makeup Water [907,000 kg/yr (2,000,000 lb/yr)][c] | 380 |
| Water Treatment Chemicals (Acid, Phosphates, Hydrazine, Chlorine) | 1,780 |
| Total | 4,600 |
| OM130 Fixed Charge Rate | |
| OM100 Total | 25,600 |
| OM200 Maintenance Materials | |
| OM210 Spare Parts | |
| OM211 Site | |
| None | |
| OM212 Site Buildings | |
| No change from existing facilities | |
| OM213 Collector System[d] | |
| Mirror Modules | 2,920 |
| Rack Structures | 1,270 |
| Drive Units | 3,700 |
| Motors | 1,190 |
| Electrical Components | 3,470 |
| Wiring and Instrumentation | 240 |
| Total | 12,790 |
| OM214 Receiver System[e] | |
| Superheater Tubes | 3,300 |
| Boiler Tubes | 2,330 |
| Controls and Sensors | 2,880 |

TABLE 5.3-6 (Continued). ANNUAL OPERATIONS AND MAINTENANCE COSTS[a]

| | Cost (1980 Dollars) $/yr |
|---|---|
| Insulation and Lagging | 2,490 |
| Solar Doors | 1,500 |
| Aircraft Warning Lights | 100 |
| Total | 12,600 |
| OM215 Master Control System | |
| Computer Main Frame | 2,200 |
| Moving Head Disc | 450 |
| Printer | 650 |
| Total | 3,300 |
| OM216 Fossil Energy Delivery System (Modifications) | |
| Minimal | |
| OM217 Solar Auxiliary Electric System (Includes fuses, contactors, control transformers, circuit cards, etc.) | 3,000 |
| OM218 Electric Power Generating System (Modifications) | |
| Minimal | |
| OM219 Receiver Piping System[f] (Includes insulation, lagging, controls, instrumentation, etc.) | 100 |
| OM220 Materials for Repairs (Materials presently in use at plant, e.g. welding rods, paint, lubricants, oxygen, acetylene, etc.) | 5,000 |
| OM230 Other | |
| Heliostat Washing Solution [148,000 liters/yr (39,000 gal/yr)][g] | 1,090 |
| Heliostat Rinsing Solution [337,000 liters/yr (89,000 gal/yr)][g] | 140 |
| Pyromark Receiver Paint [26 liters/yr (7 gal/yr)] | 450 |
| Heliostat Maintenance Vehicle Spare Parts | 450 |
| Heliostat Maintenance Vehicle Fuel [1,420 liters/yr (375 gal/yr)] | 570 |

TABLE 5.3-6 (Continued). ANNUAL OPERATIONS AND MAINTENANCE COSTS[a]

| | Cost (1980 Dollars) $/yr |
|---|---|
| Heliostat Washing Equipment Spare Parts | 550 |
| Heliostat Washing Equipment Fuel (1,265 gal/yr) | 1,900 |
| Total | 5,150 |
| OM200 Total | 41,940 |
| OM300 Maintenance Labor | |
| OM310 Scheduled Maintenance Labor | |
| OM311 Site | |
| Mowing of Heliostat Field Area[h] | 1,620 |
| OM312 Site Buildings | |
| Normal Facility Upkeep (Painting, oiling gravel roads, seal coating asphalt, etc.) | 5,000 |
| OM313 Collector System | |
| Inspection (1,057 man-hours/yr)[i] | 10,600 |
| Cleaning (2,114 man-hours/yr)[j] | 21,000 |
| Total | 31,800 |
| OM314 Receiver System | |
| Annual Inspection of Drums, Tubes, etc. (160 man-hours/yr) | 1,750 |
| Valve Packing (120 man-hours/yr) | 1,320 |
| Pump Maintenance (48 man-hours/yr) | 530 |
| Absorptive Surface Painting (120 man-hours/yr) | 1,200 |
| Controls Recalibration (48 man-hours/yr) | 530 |
| Elevator Maintenance | 2,000 |
| Tower Repainting (120 man-hours/yr) | 1,200 |
| Solar Door Maintenance (32 man-hours/yr) | 350 |
| Total | 8,880 |
| OM315 Master Control System | |
| Labor Cost included in OM110 | |
| OM316 Fossil Energy Delivery System (Modifications) | |
| Minimal | |

TABLE 5.3-6 (Continued). ANNUAL OPERATIONS AND MAINTENANCE COSTS[a]

| | Cost (1980 Dollars) $/yr |
|---|---|
| OM317 Solar Auxiliary Electrical System | |
| Inspect Switchgear and Inverters (120 man-hours/yr) | 1,320 |
| Routine Battery Maintenance (32 man-hours/yr) | 350 |
| Emergency Diesel Maintenance and Startup Testing (42 man-hours/yr) | 460 |
| Total | 2,130 |
| OM318 Electric Power Generating System (Modifications) | |
| Minimal | |
| OM319 Receiver Piping System | |
| Inspection (32 man-hours/yr) | 350 |
| Valve Packing (42 man-hours/yr) | 460 |
| Pump Maintenance (16 man-hours/yr) | 180 |
| Controls and Recalibration (16 man-hours/yr | 180 |
| Total | 1,170 |
| OM320 Corrective Maintenance Labor | |
| OM321 Site | |
| Minimal | |
| OM322 Site Buildings | |
| Minimal | |
| OM323 Collector System | |
| Repairs (1,090 man-hours/yr) | 11,950 |
| OM324 Receiver System | |
| Repairs (400 man-hours/yr) | 4,380 |
| OM325 Master Control System | |
| Included in OM110 | |
| OM326 Fossil Energy Delivery System (Modifications) | |
| Minimal | |
| OM327 Solar Auxiliary Electric System | |
| Repairs (40 man-hours/yr) | 440 |

TABLE 5.3-6 (Continued). ANNUAL OPERATIONS AND MAINTENANCE COSTS[a]

| | Cost (1980 Dollars) $/yr |
|---|---|
| OM328 Electric Power Generating System (Modifications) | |
| Minimal | |
| OM329 Receiver Piping System | |
| Repairs (64 man-hours/yr) | 700 |
| OM300 Total | 68,070 |
| OM Total (per year) | 135,610 |

[a]Materials and supplies excluded G&A and Overhead. Labor costs include payroll burden, fringe benefits, etc.

[b]Nitrogen blanket applied when receiver pressure drops below .14 MPa (20 psia) following shutdown, as in the case of extremely cold winter temperatures or extended cloud coverage. Volume of nitrogen per application is 12.7 scm (450 scf); 50 applications per year are assumed.

[c]Assumes makeup is 1 per cent of total receiver steam flow.

[d]Estimates based upon failure rates and cost breakdown for Northrup heliostat components (DOE-SF/10736-1/3).

[e]Costs of spare motor for recirculating water pump, spare drives for motorized valves, spare parts for elevator have been included in capital cost estimate.

[f]Costs of spare drives for motorized valves have been included in capital cost estimate.

[g]Based on 12 washings per year, 11 liters (3 gallons) of washing solution and 26 liters (7 gallons) of rinsing solution (demineralized water) per heliostat.

[h]Three mowings per year.

[i]Two inspections per year, two men, 15 minutes per heliostat.

[j]Twelve washes per year, two men, 5 minutes per wash, per heliostat.

Table 5.4-1 shows the financial factors and the values of fuel and capital cost used by Western Power for their projections. Operating and maintenance costs (O&M) (as shown in Section 5.3.3) for the solar addition were developed jointly by Black & Veatch and Western Power; O&M costs for other Western Power units were provided by Western Power.

## 5.5 SIMULATION MODELS

### 5.5.1 Insolation Models

The insolation model used in the solar plant performance calculations was published in the ASHRAE Handbook of Fundamentals.[1]

The direct normal insolation at the surface of the earth on a clear day is represented by the equation

$$I = \frac{A}{e^{B/\sin E}} \quad \text{Btu/h - sq ft} \quad (x) \ \frac{1}{317.46} = \frac{KW}{m^2}$$

Where A is the apparent solar irradiation at air mass = 0; B is an atmospheric extinction coefficient, and E is the solar elevation.

The values of A and B vary during the year because of seasonal changes in the dust and water vapor content of the atmosphere, and also because of the changing earth-sun distance. The values listed on Table 5.5-1, which take account of these effects, were derived from the results of research at the University of Minnesota,[2] and represent the conditions of average cloudless days.

To implement the equations and data in a computer algorithm, the values of A and B have been approximated by the functional relationships

$$A = 368.5 + 24 \sin [0.0172 (DAY - 265)]$$

$$B = 0.172 - 0.033 \sin [0.0172 (DAY - 282)]$$

Where DAY is the day of year (beginning with January 1st as DAY = 1).

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[1] ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 345 East 47th Street, New York, New York 10017, 1972, p. 386.

[2] J. L. Threlkeld and R. C. Jordan: Direct solar radiation available on clear days (ASHRAE Transactions, Vol. 64, 1958, p .45).

TABLE 5.4-1. ECONOMIC EVALUATION PARAMETERS (CTU-WP Values)

| Financial Factors | Per Cent |
|---|---|
| Discount rate | 13.45 |
| Investment tax credit | 11.0 |
| AFUDC rate | 13.0 |
| Property tax rate | 1.45 |
| Insurance rate | 0.22 |
| General inflation rate | |
| 1981 | 10.2 |
| 1982 | 8.7 |
| 1983-1990 | 8.0 |
| 1991-2000 | 7.0 |
| Combined state and federal income tax rate | 49.645 |
| Fixed charge rate | |
| Solar | 17.50 |
| Combustion turbine | 16.27 |
| Pulverized coal | 15.43 |

Fuel Cost Projections

| Fuel | 1980 Cost $/MBtu | Escalation Rate per cent |
|---|---|---|
| Natural gas | 1.86 | -- |
| 1981 | -- | 14.5 |
| 1982 | -- | 13.4 |
| 1983-1990 | -- | 12.0 |
| 1991-2000 | -- | 11.0 |
| Coal | 1.10 | -- |
| 1981 | -- | 12.2 |
| 1982 | -- | 10.7 |
| 1983 | -- | 10.1 |
| 1984-1985 | -- | 10.0 |
| 1986-1990 | -- | 9.0 |

TABLE 5.4-1 (Continued). ECONOMIC EVALUATION PARAMETERS (CTU-WP Values)

| | | |
|---|---|---|
| 1991-1995 | -- | 8.0 |
| 1996-2000 | -- | 7.0 |

Unit Capital Cost Projections

| Unit Type | 1980 Capital Cost* $/kW | Escalation Rate |
|---|---|---|
| Coal | 750 | Use general inflation rate above |

O&M Cost Projections

| Unit Type | 1980 O&M Cost mills/kWhe | Escalation Rate |
|---|---|---|
| CRS | 12 month operation: 2.31<br>3 month operation: 4.00 | Use general inflation rate above |
| Coal | 2.55 | Use general inflation rate above |

Other Factors

| | |
|---|---|
| Heliostat cost | $215/m^2$ ($21.37/ft$^2$) |
| Land Cost | $1,483/hectare ($600/acre) |
| Minimum boiler load | 45,400 kg/h (100,000 lb/h) |
| Annual average process steam to NHC | 22,700 kg/h (50,000 lb/h) |
| Annual average electric power to NHC | 18.9 MWe |
| Coal unit capacity factor | 65 per cent for 1985-2000 |

WP grid load growth projections

| Annual Energy | Peak Power |
|---|---|
| 3.9 per cent to 1990 | 3.5 per cent to 1990 |
| 3.6 per cent after 1990 | 3.2 per cent after 1990 |

*Based on 1982 commercial operation.

TABLE 5.5-1. INSOLATION MODEL PARAMETERS

| Date | A<br>Btu/h/sq ft | B<br>Air Mass$^{-1}$ |
|---|---|---|
| January 21 | 390 | 0.142 |
| February 21 | 385 | 0.144 |
| March 21 | 376 | 0.156 |
| April 21 | 360 | 0.180 |
| May 21 | 350 | 0.196 |
| June 21 | 345 | 0.205 |
| July 21 | 344 | 0.207 |
| August 21 | 351 | 0.201 |
| September 21 | 365 | 0.177 |
| October 21 | 378 | 0.160 |
| November 21 | 387 | 0.149 |
| December 21 | 391 | 0.142 |

5.5.2 Facility Performance Model

Predictions of annual system performance were made using the Black & Veatch computer code, Solar Thermal Electric Plant Performance Evaluator (STEPPE). Runs of STEPPE were utilized to estimate daily, monthly, and annual electrical and process steam production by the facility. These performance estimates were utilized as inputs in subsequent economic analyses.

STEPPE predicts performance by integrating time point power traces computed at discrete time intervals (15-minute intervals in this case) throughout representative days of the year. Annual performance was extrapolated from runs for the 15th day of each month. System characterization included the following.

(1) Heliostat field efficiency as a function of sun azimuth and elevation, as computed by the Black & Veatch optical codes.

(2) Receiver efficiency loss data as provided by B&W, as a function of input power, windspeed, and dry bulb temperature.

(3) Receiver start-up assuming fossil steam preheating, with heat capacities, losses, and temperature ramp rates modeled.

(4) Solar main steam piping losses and heat-up requirements.

(5) Conventional system characterizations (e.g., turbine heat rate vs. electrical and process steam load, and wet bulb temperature; fossil boiler efficiency, etc.).

(6) Existing plant auxiliary power requirements were modified to include solar auxiliary power.

Solar insolation was modeled using the ASHRAE Clear Air Model described in Section 5.5.1. Results were modified to include the effects of cloudy days using per cent sunshine data[1] for Dodge City, Kansas. Dry bulb temperature, wet bulb temperature, and windspeed were modeled artificially

[1]Normals based on the 1941-1970 period, "Local Climatological Data, 1978, Dodge City, Kansas," National Climatic Center, Ashville, NC.

using normal monthly data for daily low, high, and average values for the respective variables.[1, 2]

5.5.3 Economic Models

The economic evaluation of the solar cogeneration facility was performed by explicitly comparing the revenue requirements of the Western Power system with and without the solar addition.

The economic comparison was performed in several steps.

(1) Two Western Power system expansion plans were developed for the system with and without the solar repowering.

(2) Black & Veatch's economic dispatch system simulation program was used to develop the annual system production costs for the alternate expansion plans.

(3) The production costs were combined with the annual fixed charges for new capital investments and purchased power costs of the two expansion plans to develop comparative revenue requirements. This method allows the explicit inclusion of capacity credits in the economic evaluation.

(4) Comparison of the cumulative discounted comparative revenue requirements for the two expansion plans resulted in the determination of the value of the repowered facility.

(5) Annual production costs, capital costs, and comparative costs were calculated based on values provided by Western Power.

5.5.3.1 System Expansion Plans. Without the solar addition, Western Power's Cimarron River Station Unit 1 would be retired in January, 1994. The CRS economic lifetime, with the solar addition, will extend through 2000. The additional life of this unit impacts the future capacity addition schedule.

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[1] Normals based on the 1941-1970 period, "Local Climatological Data, 1978, Dodge City, Kansas," National Climatic Center, Ashville, NC.

[2] "Uniform Summary of Surface Weather Observations, Part E--Psychrometric Summary, Dodge City, Kansas, January 1949-December 1958," Data Processing Division, Climatic Center, USAF, Asheville, NC.

5.5.3.2 Annual Production Costs. Power production costs were estimated through the use of a computerized mathematical model, specially constrained to simulate Western Power system operation. The production costs include fuel costs, operating and maintenance (O&M) costs, and purchase power costs. Black & Veatch's economic dispatch system simulation program is the basic tool used by Black & Veatch for planning studies and fuel forecasting.

The production cost computer program utilizes as its basis the principle of economic dispatch. A detailed description of this principle is beyond the scope of this document; however, the subject is discussed in a number of references.* The essence is that the optimum allocation of load among a number of generating units is achieved by dispatching each unit so that all units operate at the point of equal incremental costs. This principle is routinely applied in actual power system operating practice as well as in planning investigations.

The economic dispatch incremental cost principle is expressed in mathematical terms in a computer code algorithm. Constraints are applied to this optimization algorithm in order to reflect the fact that, in normal utility system operation, the opportunities for mathematically true least cost dispatch are modified because of planned and unscheduled unit outages, reliability considerations, unit start-up limitations, system stability requirements, and similar factors. As run, the Black & Veatch program can thus be characterized as a constrained (optimum) economic dispatch.

(1) Program Inputs. The program requires three principal inputs in order to perform the optimization. These are as follows.

(a) Load Models. A load model is specified for each month for a year. The load models were developed from historical system load data.

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*See, for example, Leon K. Kirchmayer, Economic Operation of Power Systems, John Wiley & Sons, Inc., 1958.

(b) Generating Unit Operating and Cost Parameters. For each unit which is available during the planning period, unit heat rate data, minimum and maximum loadings, fuel and O&M base year costs, and annual escalation rates are required. Maintenance and forced outage rates are also input for each unit.

(c) Specified Load and Energy Data. For each month, the projected peak load and load factor are computed. The total peak load generation required includes loads to satisfy system losses and any external sales requirements.

The determination of Western Power system production costs with solar incorporates the same methods and computer code as used for more typical investigations. However, accounting for the unique technical and economic characteristics of the solar addition requires special modeling so that the heat rate and output power of the repowered unit are properly adjusted to reflect the solar input.

In normal production costing simulations involving fossil and nuclear units, the load model is used to represent the variations in system load and the units are dispatched at varying levels of output to meet the loads. However, when a solar unit is to be simulated, the load model must reflect both the time variation in system load and also the time variation in the output of the solar unit.

To represent this time-varying capacity in the computer code, the projected realtime load models for each month were adjusted hourly to account for the output of CRS credited to the solar facility. The resulting realtime load model was then used as input to the economic dispatch program.

Following the load model adjustment to ensure that the amount of solar capacity available in each load period is accurately represented, the only remaining task in modeling the solar facility was to modify the fuel burn or input-output curve to reflect the solar thermal input to the facility. The input-output curve is used in the code to perform the economic dispatch since the slope of the input-output curve is the incremental heat rate.

5.5.3.3 Comparative Costs. Combination of the annual production costs with the capital costs for the two generation expansion plans was performed by a Black & Veatch comparative cost analysis program. The program calculates comparative annual revenue requirements--fixed costs of capital plus production costs. The cumulative present worth sum of these annual costs is calculated using the Western Power specified discount rate.

5.6 OTHER DATA

No other data has been identified.

# APPENDIX B

# DETAILED FACILITY COST ESTIMATE DATA

# APPENDIX B
## DETAILED FACILITY COST ESTIMATE DATA

A detailed breakdown of the Solar Cogeneration Facility construction cost estimate is provided in the following.

# CONSTRUCTION COST ESTIMATE

CLIENT Central Tel & Util; Western Pwr  DESCRIPTION Total Construction Cost

LOCATION Cimarron River Station

PROJECT Solar Cogeneration Fac.

CONT. NO. 81SF11439
MADE BY R. Dedrick
APPROVED J E Harder

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST | | | |
|---|---|---|---|---|---|---|
| | | | LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
| A | Excavation & Civil | 48919 | 498,243 | 4800 | 151,039 | 654082 |
| B | Concrete | 1,361 | 12,234 | 43,200 | 44,130 | 99,564 |
| C | Structural Steel | 9,242 | 197,170 | | 610,149 | 807,319 |
| D | Buildings | 138 | 1,560 | | 9900 | 11,460 |
| E | Machinery & Equipment | 323 | 3,706 | 104,470 | 12,067,490 | 12,175,666 |
| F | Piping | 26,078 | 634555 | | 2,745,953 | 3,380,508 |
| G | Electrical | 28,782 | 338,254 | | 1,909,205 | 2,241,459 |
| H | Instruments | 1,909 | 63,852 | | 607120 | 670972 |
| J | Painting | | | | 85,000 | 85,000 |
| K | Insulation | 13,692 | 426,026 | | 224,228 | 650,254 |
| | | | | | | |
| | | | | | | |
| | DIRECT FIELD COSTS | 130,544 | 2,175,600 | 152,470 | 18,454,214 | 20,782,284 |
| | | | | | | |
| | | | | | | |
| L | Temporary Construction Facilities | | | | | 202,135 |
| M | Construction Services, Supplies & Expense | | | | | 283,025 |
| N | Field Staff, Subsistence & Expense | | | | | 716,705 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 539,649 |
| Q | Equipment Rental | | | | | 678,590 |
| | INDIRECT FIELD COSTS | | | | | 2,420,104 |
| | | | | | | |
| | TOTAL FIELD COSTS | | | | | 23,202,388 |
| | | | | | | |
| | | | | | | |
| R | Engineering | | | | | 2,170,875 |
| | Design & Engineering B&V | | | | | 1,147,875 |
| | Home Office Costs | | | | | |
| | R & D B&V | | | | | 1,023,875 |
| | | | | | | |
| S | Major Equipment Procurement | | | | | 43,045 |
| | | | | | | |
| T | Construction Management | | | | | 244,375 |
| | TOTAL OFFICE COSTS | | | | | 2,458,295 |
| | | | | | | |
| | TOTAL FIELD & OFFICE COSTS | | | | | 25,660,683 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| U | Labor Productivity | | | | | |
| | | | | | | |
| V | Contingency | | | | | 2,566,070 |
| | | | | | | |
| W | Fee | | | | | |
| | | | | | | |
| | | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 28,226,753 |

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## CONSTRUCTION COST ESTIMATE

CLIENT Central Tel. & Util.; Western Pwr DESCRIPTION Site Prep - 5110

LOCATION Cimarron River Station CONT. NO. 815F11439

PROJECT Solar Cogeneration Fac. MADE BY J.L. Dedrick

APPROVED J.C. Harder

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
|---|---|---|---|---|---|---|
| A | Excavation & Civil | 43,610 | 454,855 | 4800 | | 459,655 |
| B | Concrete | | | | | |
| C | Structural Steel | | | | | |
| D | Buildings | | | | | |
| E | Machinery & Equipment | | | | | |
| F | Piping | 1199 | 14,185 | | 8,125 | 22,310 |
| G | Electrical | 6056 | 72,965 | | 5,900 | 78,865 |
| H | Instruments | | | | | |
| J | Painting | | | | | |
| K | Insulation | | | | | |
| | DIRECT FIELD COSTS | 50,865 | 542,005 | 4,800 | 14,025 | 560,830 |
| L | Temporary Construction Facilities | | | | | 28,040 |
| M | Construction Services, Supplies & Expense | | | | | 39,260 |
| N | Field Staff, Subsistence & Expense | | | | | 61,690 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 144,170 |
| Q | Equipment Rental | | | | | 501,500 |
| | INDIRECT FIELD COSTS | | | | | 774,660 |
| | TOTAL FIELD COSTS | | | | | 1,335,490 |
| R | Engineering | | | | | 136,755 |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| S | Major Equipment Procurement | | | | | 5,130 |
| T | Construction Management | | | | | 29,115 |
| | TOTAL OFFICE COSTS | | | | | 171,000 |
| | TOTAL FIELD & OFFICE COSTS | | | | | 1,506,490 |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 150,650 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 1,657,140 |

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CLIENT CENTRAL TEL. & UTIL.; WESTERN PWR.

# CONSTRUCTION COSTS

LOCATION CIMARRON RIVER STATION

PROJECT SOLAR COGENERATION FAC.

BY TLD CHKD. JCB APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5110 | SITE PREPERATION | | | | | | | | | | | | |
| F1 | 6" CAST IRON PIPE - 3'-0" COVER | 825 | LF | 1.39 | 1145 | 11.83 | 16.42 | | 9.85 | 13,545 | | 8,125 - | 21,670 - |
| F2 | EXCAVATION & CONNECTION OF CAST IRON PIPE TO TRANSITE PIPE | 1 | EA | 54 | 54 | 11.83 | 639 - | | | 640 - | | | 640 - |
| A1 | CLEARING | 60 | AC | 72 | 4320 | 10.43 | 750 | | | 45,060 - | | | 45,060 - |
| A2 | GRADING & COMPACTION | 200,000 | CY | .19 | 38340 | 10.43 | 2.00 | | | 399,885 - | | | 399,885 - |
| A5 | DRAINAGE DITCH INCL. CULVERTS | 5,000 | CY | .19 | 950 | 10.43 | 2.00 | | | 9910 - | | | 9910 - |
| | RELOCATE TRANSMISSION LINES: | | | | | | | | | | | | |
| | REMOVE EXISTING WIRES | | | | | | | | | | | | |
| G1 | 3 ϕ WIRES | 5000 | LF | .07 | 350 | 11.38 | .80 | | | 3,985 - | | | 3,985 - |
| G2 | 2 S WIRES | 5000 | LF | .03 | 150 | 11.38 | .34 | | | 1,707 | | | 1,707 - |
| | REINSTALL WIRES | | | | | | | | | | | | |
| G3 | 3 ϕ WIRES | 5000 | LF | .07 | 350 | 11.38 | .80 | | | 3,783 - | | | 3,783 - |
| G4 | 2 S WIRES | 5000 | LF | .03 | 150 | 11.38 | .34 | | | 1,707 - | | | 1,707 - |
| | INSTALL NEW WIRES | | | | | | | | | | | | |
| G5 | 3 ϕ WIRES | 2000 | LF | .09 | 180 | 11.38 | 1.55 | | 2.30 | 2,050.00 | | 4,600.00 | 6,650 - |
| G6 | 2 S WIRES | 2000 | LF | .03 | 60 | 11.38 | .43 | | .65 | 683.00 | | 1,300.00 | 1,983 - |
| G7 | REMOVE TANGENT H-FRAME | 8 | EA | 60 | 480 | 12.22 | 733 - | | | 5,865.00 | | | 5,865 - |
| G8 | REINSTALL TANGENT H-FRAME | 8 | EA | 60 | 480 | 12.22 | 733 - | | | 5,865 - | | | 5,865 - |
| G9 | INSTALL DEADEND STRUCT. | 8 | EA | 482 | 3856 | 12.22 | 5890. - | | | 47,120 - | | | 47,120.00 |
| A3 | SOW WHEAT APRIL 1984 - | 60 | AC | | | | | 20 - | | | 1,200 - | | 1,200 - |
| A4 | SOW GRASS APRIL 1985 - | 60 | AC | | | | | 60 - | | | 3,600 - | | 3,600 - |

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CLIENT CENTRAL TEL. & UTIL.; WESTERN PWR.

# CONSTRUCTION COSTS

LOCATION CIMARRON RIVER STATION

PROJECT SOLAR COGENERATION FACILITY

BY TLD CHKD. JCB APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS ( ) LABOR | COSTS ( ) SUB CONTRACT | COSTS ( ) MATERIAL | COSTS ( ) TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5120 | SITE FACILITIES & IMPROVEMENTS | | | | | | | | | | | | |
| A1 | 12' GRAVEL SHOT ROAD | 5000 | LF | .35 | 1750 | 9.03 | 3.17 | | 13.80 | 15 800 – | | 69 000 – | 84 800 – |
| A2 | 20' ASPHALT ROAD W/ SHOULDERS | 1000 | LF | .73 | 730 | 9.03 | 6.59 | | 30.00 | 6 590 – | | 30 000 | 36 590 – |
| A3 | ASPHALT PARKING AREA | 4000 | SF | .03 | 120 | 9.03 | .25 | | 1.00 | 1 085 – | | 4 000 – | 5 085 – |
| | SECURITY FENCE: | | | | | | | | | | | | |
| A4 | 8' W/ 3 BARB STRANDS | 6000 | LF | .40 | 2400 | 7.01 | 2.80 | | 17,180 | 16 825 – | | 36 000 – | 52 825 – |
| A5 | 12' WIDE GATES | 2 | EA | 7 | 14 | 7.01 | 50 – | | 382.50 | 100 – | | 765 – | 865 – |
| E1 | NITROGEN SYSTEM | 1 | LS | 75 | 75 | 11.49 | 860 | | 2,960 | 860 – | | 2 960 – | 3 820 – |
| E2 | FIRE EXTINGUISHERS | 3 | EA | 1 | 3 | 9.26 | 10.00 | | 90 | 30 – | | 270 – | 300 – |

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## CONSTRUCTION COST ESTIMATE

CLIENT: CENTRAL TEL. & UTIL.; WESTERN P.&R.
DESCRIPTION: SITE FACILITIES & IMPROVEMENTS -5120
LOCATION: CIMARRON RIVER STATION
PROJECT: SOLAR COGENERATION FAC.
CONT. NO. 515F11439
MADE BY: T.L. DEDRICK
APPROVED: J.E. HARDER

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST | | | |
|---|---|---|---|---|---|---|
| | | | LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
| A | Excavation & Civil | 5014 | 40,400 | | 139,765 | 180,165 |
| B | Concrete | | | | | |
| C | Structural Steel | | | | | |
| D | Buildings | | | | | |
| E | Machinery & Equipment | 78 | 890 | | 3,230 | 4,120 |
| F | Piping | | | | | |
| G | Electrical | | | | | |
| H | Instruments | | | | | |
| J | Painting | | | | | |
| K | Insulation | | | | | |
| | DIRECT FIELD COSTS | 5092 | 41,290 | | 142,995 | 184,285 |
| L | Temporary Construction Facilities | | | | | 9,215 |
| M | Construction Services, Supplies & Expense | | | | | 12,900 |
| N | Field Staff, Subsistence & Expense | | | | | 20,270 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 34,670 |
| Q | Equipment Rental | | | | | 30,300 |
| | INDIRECT FIELD COSTS | | | | | 107,355 |
| | TOTAL FIELD COSTS | | | | | 291,640 |
| R | Engineering | | | | | 29,865 |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| S | Major Equipment Procurement | | | | | 1,120 |
| T | Construction Management | | | | | 6,360 |
| | TOTAL OFFICE COSTS | | | | | 37,345 |
| | TOTAL FIELD & OFFICE COSTS | | | | | 328,985 |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 32,900 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 361,885 |

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## CONSTRUCTION COST ESTIMATE

CLIENT CENTRAL TEL & UTIL; WESTERN PWR. DESCRIPTION SITE BUILDINGS (EXCLUDING RECIEVER TOWER) - 5200

LOCATION CIMARRON RIVER STATION CONT. NO. 81SF11439

MADE BY T.L. DEDRICK

PROJECT SOLAR COGENERATION FACILITY APPROVED J.E. HARPER

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
|---|---|---|---|---|---|---|
| A | Excavation & Civil | | | | | |
| B | Concrete | 60 | 540 | | 1,650 | 2,190 |
| C | Structural Steel | | | | | |
| D | Buildings | 87 | 1055 | | 8,020 | 9,075 |
| E | Machinery & Equipment | | | | | |
| F | Piping | | | | | |
| G | Electrical | | | | | |
| H | Instruments | | | | | |
| J | Painting | | | | | |
| K | Insulation | | | | | |
| | DIRECT FIELD COSTS | 147 | 1,595 | | 9,670 | 11,265 |
| L | Temporary Construction Facilities | | | | | 565 |
| M | Construction Services, Supplies & Expense | | | | | 790 |
| N | Field Staff, Subsistence & Expense | | | | | 1240 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 1,690 |
| Q | Equipment Rental | | | | | 1,400 |
| | INDIRECT FIELD COSTS | | | | | 5,685 |
| | TOTAL FIELD COSTS | | | | | 16,950 |
| R | Engineering | | | | | 1,735 |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| S | Major Equipment Procurement | | | | | 65 |
| T | Construction Management | | | | | 370 |
| | TOTAL OFFICE COSTS | | | | | 2,170 |
| | TOTAL FIELD & OFFICE COSTS | | | | | 19,120 |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 1,910 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 21,030 |

DATE 14 MAY 81 REVISION NO. ______ REVISION DATE ______ PAGE NO. ______

# CONSTRUCTION COSTS

CLIENT Central Tel. & Util.; Western Pwr.
LOCATION Cimarron River Station
PROJECT Solar Cogeneration Facility

BY TLD CHKD. JCB APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5200 | Site Bldgs (except reciever twr.) | | | | | | | | | | | | |
| 01 | Prefab metal bldg. 24'x24'x12' uninsulated w/ 8'x8' rolling steel door & skylites - | 1 | EA | 70 | 70 | 12.22 | | | | 855 - | | 6480 - | 7335 - |
| B1 | Foundation. | 1 | EA | 60 | 60 | 8.99 | | | | 540 - | | 1650 | 2190 - |
| 02 | Space heater | 1 | EA | 17 | 17 | 11.62 | 200 | | 1540 | 200 - | | 1540 - | 1740 - |

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## CONSTRUCTION COST ESTIMATE

CLIENT CENTRAL TEL. & UTIL.; WESTERN PWR. DESCRIPTION COLLECTOR SYSTEM-5300

LOCATION CIMARRON RIVER STATION

PROJECT SOLAR COGENERATION FAC.

CONT. NO. 81SF11439

MADE BY L. DEDRICK

APPROVED J.E. HARPER

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
|---|---|---|---|---|---|---|
| A | Excavation & Civil | | | | | |
| B | Concrete | | | | | |
| C | Structural Steel | | | | | |
| D | Buildings | | | | | |
| E | Machinery & Equipment | | | | 11,992,700 | 11,992,700 |
| F | Piping | | | | | |
| G | Electrical | | | | | |
| H | Instruments | | | | | |
| J | Painting | | | | | |
| K | Insulation | | | | | |
| | DIRECT FIELD COSTS | | | | | 11,992,700 |
| L | Temporary Construction Facilities | | | | | — |
| M | Construction Services, Supplies & Expense | | | | | — |
| N | Field Staff, Subsistence & Expense | | | | | — |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | — |
| Q | Equipment Rental | | | | | — |
| | INDIRECT FIELD COSTS | | | | | — |
| | TOTAL FIELD COSTS | | | | | — |
| R | Engineering | | | | | — |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| S | Major Equipment Procurement | | | | | — |
| T | Construction Management | | | | | — |
| | TOTAL OFFICE COSTS | | | | | — |
| | TOTAL FIELD & OFFICE COSTS | | | | | 11,992,700 |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 1,199,270 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 13,191,970 |

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# CONSTRUCTION COSTS

CLIENT CENTRAL TEL & UTIL; WESTERN PWR.
LOCATION CIMARRON RIVER STATION
PROJECT SOLAR COGENERATION FAC

BY TLD CHKD. JCB APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS ( ) LABOR | COSTS ( ) SUB CONTRACT | COSTS ( ) MATERIAL | COSTS ( ) TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5300 | COLLECTOR SYSTEM | 1057 | EA | | | | | 11,346.55 | | | 11,992,700.00 | | 11,992,700 - |

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## CONSTRUCTION COST ESTIMATE

CLIENT CENTRAL TEL. & UTIL.; WESTERN PWR. DESCRIPTION 5410 - RECIEVER

LOCATION CIMARRON RIVER STATION

PROJECT SOLAR COGENERATION FAC.

CONT. NO. 81SF11439
MADE BY T.L. DEDRICK
APPROVED J.E. HARDER

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST | | | |
|---|---|---|---|---|---|---|
| | | | LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
| | | | | | | |
| A | Excavation & Civil | | | | | |
| B | Concrete | | | | | |
| C | Structural Steel | 5,180 | 146,500 | | 443,000 | 589,500 |
| D | Buildings | | | | | |
| E | Machinery & Equipment | | | | | |
| F | Piping | 14,090 | 489,500 | | 2,355,200 | 2,844,700 |
| G | Electrical | | | | | |
| H | Instruments | 1,940 | 63,000 | | 603,000 | 666,000 |
| J | Painting | | | | 85,000 | 85,000 |
| K | Insulation | 10,960 | 394,000 | | 166,000 | 559,000 |
| | | | | | | |
| | DIRECT FIELD COSTS | 32,060 | 1,093,000 | | 3,651,200 | 4,744,200 |
| | | | | | | |
| L | Temporary Construction Facilities | | | | | |
| M | Construction Services, Supplies & Expense | | | | | |
| N | Field Staff, Subsistence & Expense | | 167,000 | | 105,000 | 272,000 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | |
| Q | Equipment Rental | | | | | |
| | INDIRECT FIELD COSTS | | | | | 272,000 |
| | | | | | | |
| | TOTAL FIELD COSTS | | | | | 5,016,200 |
| | | | | | | |
| R | Engineering | | | | | 513,660 |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | 1,023,000 |
| | | | | | | |
| S | Major Equipment Procurement | | | | | 19,260 |
| | | | | | | |
| T | Construction Management | | | | | 109,355 |
| | TOTAL OFFICE COSTS | | | | | 1,665,275 |
| | | | | | | |
| | TOTAL FIELD & OFFICE COSTS | | | | | 6,681,475 |
| | | | | | | |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 668,150 |
| W | Fee | | | | | |
| | | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 7,349,625 |

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# CONSTRUCTION COSTS

CLIENT Central Tel & Util; Western Pwr.
LOCATION Cimarron River Station
PROJECT Solar Cogeneration Facility

BY TLD CHKD. JCB APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS LABOR* | COSTS SUB CONTRACT | COSTS MATERIAL** | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 540 | B&W Related Costs - Reciever | | | | | | | | | | | | |
| F1 | Economizer | | | | 460 | | | | | 10,500 - | | 42,000 - | 52,500 - |
| F2 | Evaporator Sys | | | | 7400 | | | | | 260,000 - | | 458,000 - | 718,000 - |
| F3 | Circulating Pump Sys | | | | 1010 | | | | | 35,000 - | | 247,000 - | 282,000 - |
| F4 | Superheater | | | | 5220 | | | | | 184,000 - | | 1,445,000 - | 1,629,000 - |
| H1 | Instrumentation & Controls | | | | 1840 | | | | | 63,000 - | | 603,000 - | 666,000 - |
| K1 | Insulation & Lagging (Mat'l) | | | | 10950 | | | | | 394,000 - | | 165,000 - | 559,000 - |
| C1 | Solar Doors | | | | 2490 | | | | | 53,500 - | | 309,000 - | 362,500 - |
| C2 | Support Structure & Grating | | | | 2690 | | | | | 93,000 - | | 134,000 - | 227,000 - |
| J1 | Painting, Loading & Shipping | | | | | | | | | | | 85,000 - | 85,000 - |
| N1 | Service & Supervision | | | | | | | | | 167,000 - | | 105,000 - | 272,000 - |
| R1 | Engineering | | | | | | | | | 1,023,000 - | | | 1,023,000 - |
| | * Includes costs other than direct labor | | | | | | | | | | | | |
| | ** Includes material & shop fabrication | | | | | | | | | | | | |
| F5 | Spare motor for C.W. pump | | | | | | | | | | | | 160,000 - |
| F6 | Spare drives for 4", 2½", & 1" valves | | | | | | | | | | | | 3,200 - |

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## CONSTRUCTION COST ESTIMATE

CLIENT Central Tel. & Util.; Western Pwr  DESCRIPTION Reciever Tower – 5420

LOCATION Cimarron River Station

PROJECT Solar Cogeneration Fac.

CONT. NO. 815F11439
MADE BY TL Dedrick
APPROVED JE Harder

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST | | | |
|---|---|---|---|---|---|---|
| | | | LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
| | | | | | | |
| A | Excavation & Civil | 83 | 885 | | — | 885 |
| B | Concrete | 740 | 6,650 | 43,200 | 38,480 | 88,330 |
| C | Structural Steel | 3587 | 43,570 | | 149,440 | 193,010 |
| D | Buildings | 51 | 505 | | 1,880 | 2,385 |
| E | Machinery & Equipment | | | 104,470 | | 104,470 |
| F | Piping | | | | | |
| G | Electrical | 355 | 4625 | | 5475 | 10,100 |
| H | Instruments | | | | | |
| J | Painting | | | | | |
| K | Insulation | | | | | |
| | | | | | | |
| | | | | | | |
| | DIRECT FIELD COSTS | 4810 | 56,235 | 147,670 | 195,275 | 399,180 |
| | | | | | | |
| | | | | | | |
| L | Temporary Construction Facilities | | | | | 19,960 |
| M | Construction Services, Supplies & Expense | | | | | 27,945 |
| N | Field Staff, Subsistence & Expense | | | | | 43,910 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 80,595 |
| Q | Equipment Rental | | | | | 96,400 |
| | INDIRECT FIELD COSTS | | | | | 268,810 |
| | | | | | | |
| | TOTAL FIELD COSTS | | | | | 667,990 |
| | | | | | | |
| | | | | | | |
| R | Engineering | | | | | 68,400 |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| | | | | | | |
| S | Major Equipment Procurement | | | | | 2,565 |
| | | | | | | |
| T | Construction Management | | | | | 14,560 |
| | TOTAL OFFICE COSTS | | | | | 85,525 |
| | | | | | | |
| | TOTAL FIELD & OFFICE COSTS | | | | | 753,515 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| U | Labor Productivity | | | | | |
| | | | | | | |
| V | Contingency | | | | | 75,350 |
| | | | | | | |
| W | Fee | | | | | |
| | | | | | | |
| | | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 828,865 |

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# CONSTRUCTION COSTS

CLIENT Central Tel. & Util.; Western Pwr.
LOCATION Cimarron River Station
PROJECT Solar Cogeneration Facility

BY T.L.D. CHKD. JCB APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5420 | RECIEVER TOWER | | | | | | | | | | | | |
| C1 | A-36 STRUCT STL. 10-20#/LF | 20 | TN | 40 | 800 | 12.22 | 488.80 | | 1600- | 9775- | | 3200- | 41775- |
| C2 | A-36 STRUCT STL. 20-50#/LF | 40 | TN | 24 | 960 | 12.22 | 293.28 | | 900- | 11730- | | 36000- | 47730- |
| C3 | A572 STRUCT. STL. 50-200#/LF | 65 | TN | 24 | 1560 | 12.22 | 293.28 | | 1100- | 19065- | | 71500- | 90565- |
| C4 | CAGED LADDER W/ REST PLATFORMS | 250 | LF | .09 | 22.5 | 12.22 | 1.10 | | 13- | 275- | | 3250- | 3525- |
| G1 | FLASHING BEACONS | 4 | EA | 40 | 160 | 11.24 | 450- | | 1020- | 1800- | | 4080- | 5880- |
| G2 | OBSTRUCTION LIGHTING | 4 | EA | 40 | 160 | 11.24 | 450- | | 55- | 1800- | | 220- | 2020- |
| G3 | MISC. CONNECTIONS | 1 | LS | 35 | 35 | 11.24 | 395- | | 905- | 395- | | 905- | 1300- |
| G4 | LIGTINING PROTECTION | 1 | LS | 56 | 56 | 11.24 | 630- | | 270- | 630- | | 270- | 900- |
| | EQUIPMENT ROOM | | | | | | | | | | | | |
| C5 | PREFABRICATED FLOOR | 200 | SF | .31 | 62 | 12.22 | 3.79 | | 8.70 | 760- | | 1740- | 2500- |
| D1 | WINDOW AC | 1 | LS | 9.0 | 9.0 | 11.62 | 105 | | 500 | 105 | | 500- | 605.00 |
| D2 | SPACE HEATER | 1 | LS | 9.9 | 9.9 | 11.62 | 115 | | 880 | 116- | | 880- | 995.00 |
| C6 | INSUL. METAL WALL PANEL | 800 | SF | .15 | 120 | 12.22 | 1.83 | | 5.60 | 1465- | | 4480- | 5945- |
| C7 | STL. PL HATCH 2'x2' | 1 | EA | 8 | 8 | 8.88 | 70 | | 70 | 70- | | 70- | 140- |
| C8 | STL. PL HATCH 3'x4' | 2 | EA | 24 | 48 | 8.88 | 430 | | 200 | 430- | | 400- | 830- |
| D3 | INTERIOR DOOR | 1 | EA | 15 | 15 | 8.88 | 135 | | 200 | 135- | | 200- | 335- |
| D4 | EXTERIOR DOOR | 1 | EA | 17 | 17 | 8.88 | 150 | | 300 | 150- | | 300- | 450- |
| | TOWER FDN. | | | | | | | | | | | | |
| B1 | REINF. CONC. | 296 | CY | 2.5 | 740 | 8.99 | 22.48 | | 130- | 6650- | | 38480- | 45130- |
| B2 | 14" AUGER CAST PILES ≈ 27' DP. | 64 | EA | | | | | 25/LF | | | | | 43200- |
| A1 | EXCAVATION & BACKFILL | 296 | CY | .28 | 83 | 10.66 | 3.00 | | | 885- | | | 885- |
| | ELEVATOR: | | | | | | | | | | | | |
| E1 | MAST | 250 | LF | | | | | 125/LF | | | | | 31250- |
| E2 | CAGE | 1 | LS | | | | | | | | | | 32290- |
| E3 | BRAKES | 1 | LS | | | | | | | | | | 6310- |
| E4 | 3 LANDING ENCL. | 1 | LS | | | | | | | | | | 3900- |
| E5 | 3 LANDING FRONT | 1 | LS | | | | | | | | | | 920- |
| E6 | INSTALLATION | 17 | DAYS | | | | | 1400 | | | | | 23800- |
| E7 | SPARE PARTS | | | | | | | | | | | | 6000- |

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# CONSTRUCTION COST ESTIMATE

CLIENT: CENTRAL TELEPHONE & UTILITY - WESTERN POWER
DESCRIPTION: #5500 MASTER CONTROL SYS. (SOLAR COGENERATION FACILITY)
LOCATION: CIMARRON RIVER STATION
PROJECT: #9470.005
CONT. NO. 815F11439
MADE BY: J.M. STURDIVAN
APPROVED: J.E. HARDER

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
|---|---|---|---|---|---|---|
| A | Excavation & Civil | | — | | — | — |
| B | Concrete | | — | | — | — |
| C | Structural Steel | | — | | — | — |
| D | Buildings | | — | | — | — |
| E | Machinery & Equipment | | — | | — | — |
| F | Piping | | — | | — | — |
| G | Electrical | 13,767 | 162,587 | N/A | 1,556,181 | 1,718,768 |
| H | Instruments | | — | | — | — |
| J | Painting | | — | | — | — |
| K | Insulation | | — | | — | — |
| | | | | | | |
| | | | | | | |
| | DIRECT FIELD COSTS | 13,767 | 162,587 | — | 1,556,181 | 1,718,768 |
| | | | | | | |
| L | Temporary Construction Facilities | | | | | 85,900 |
| M | Construction Services, Supplies & Expense | | | | | 120,300 |
| N | Field Staff, Subsistence & Expense | | | | | 189,000 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 40,850 |
| Q | Equipment Rental | | | | | 1,500 |
| | INDIRECT FIELD COSTS | | | | | 437,550 |
| | | | | | | |
| | TOTAL FIELD COSTS | | | | | 2,156,318 |
| | | | | | | |
| R | Engineering | | | | | 220,805 |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| | | | | | | |
| S | Major Equipment Procurement | | | | | 8,280 |
| | | | | | | |
| T | Construction Management | | | | | 47,005 |
| | TOTAL OFFICE COSTS | | | | | 276,090 |
| | | | | | | |
| | TOTAL FIELD & OFFICE COSTS | | | | | 2,432,408 |
| | | | | | | |
| U | Labor Productivity | | | | | |
| | | | | | | |
| V | Contingency | | | | | 243,240 |
| | | | | | | |
| W | Fee | | | | | |
| | | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 2,675,648 |

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# CONSTRUCTION COSTS

CLIENT Western Power - Central Telephone & Utility

LOCATION Cimarron River Station

PROJECT Solar Cogeneration Facility

BY JMS CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS 7/80 RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT 7/80 $ MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5500 | Control Panel & Computer | | | | | | | | | | | | |
| G1 | Equipment & Emergency Shutdown Equipment | 1 | LS | — | 6,600 | 12.35 | | | 1,500,000 | 81,510 - | | * 1,500,000 - | 1,581,510 - |
| G2 | Cable, 10 Conductor | 2,900 | LF | .063 | 183 | 11.40 | | | 1.24 | 2,086 - | | 3,596 - | 5,682 - |
| G3 | Cable, 2 Conductor | 93,100 | LF | .023 | 2,141 | 11.40 | | | 0.35 | 24,407 - | | 32,585 - | 56,992 - |
| G4 | Conduit; RGS - 2" | 10,000 | LF | .481 | 4,810 | 11.30 | | | 2.00 | 54,353 - | | 20,000 - | 74,353 - |
| | Core Drilling; 12" ϕ | | | | | | | | | | | | |
| G5 | Thru 8" Conc. Slab | 6 | EA | 5.5 | 33 | 7.00 | | | — | 231 - | | — | 231 - |

* Includes $29,800 for Start-up Engineering by Controls Subcontractor

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# CONSTRUCTION COST ESTIMATE

CLIENT CENTRAL TEL & UTILITY; WESTERN PWR
DESCRIPTION SOLAR AUX ELEC SYS. #5700

LOCATION CIMARRON RIVER STATION

PROJECT SOLAR COGENERATION FAC.

CONT. NO. 81SF11439
MADE BY TL DEDRICK
APPROVED JE HARDER

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
|---|---|---|---|---|---|---|
| A | Excavation & Civil | | | | | |
| B | Concrete | | | | | |
| C | Structural Steel | | | | | |
| D | Buildings | | | | | |
| E | Machinery & Equipment | | | | | |
| F | Piping | | | | | |
| G | Electrical | 8,435 | 96,133 | | 306,049 | 402,182 |
| H | Instruments | | | | | |
| J | Painting | | | | | |
| K | Insulation | | | | | |
| | DIRECT FIELD COSTS | 8,435 | 96,133 | | 306,049 | 402,182 |
| L | Temporary Construction Facilities | | | | | 20,110 |
| M | Construction Services, Supplies & Expense | | | | | 28,150 |
| N | Field Staff, Subsistence & Expense | | | | | 44,240 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 76,585 |
| Q | Equipment Rental | | | | | — |
| | INDIRECT FIELD COSTS | | | | | 169,085 |
| | TOTAL FIELD COSTS | | | | | 571,267 |
| R | Engineering | | | | | 58,500 |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| S | Major Equipment Procurement | | | | | 2,195 |
| T | Construction Management | | | | | 12,455 |
| | TOTAL OFFICE COSTS | | | | | 73,150 |
| | TOTAL FIELD & OFFICE COSTS | | | | | 644,417 |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 64,440 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 708,857 |

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# CONSTRUCTION COSTS

CLIENT: CENTRAL TELEPHONE & UTILITY – WESTERN POWER
LOCATION: CIMARRON RIVER STATION
PROJECT: SOLAR COGENERATION FACILITY

BY: TJ Nance  CHKD. TLD  APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS 7/80 RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT 7/80 $ MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5700 | SOLAR AUX. ELECTRICAL SYSTEM | | | | | | | | | | | | |
| | ELECTRICAL SERVICE TO COLLECTOR SYS. | | | | | | | | | | | | |
| 61 | 150 KVA 4160 - 120/208V 3ϕ LOW PROFILE PAD MOUNTED TRANSFORMER | 5 | EA | 47 | 235 | 11.50 | | | 3,500 | 2,700 - | | 17,500 - | 20,200 - |
| 62 | 5KV DIRECT BURIAL CABLE 3/C #2 AWG COPPER EPR/PVC | 3800 | LF | .137 | 521 | 11.40 | | | 5.45 | 5,939 - | | 20,710 - | 26,649 - |
| 63 | 5KV CABLE TERMINATIONS | 36 | EA | 4.5 | 162 | 11.40 | | | 20.00 | 1,847 - | | 720 - | 2,567 - |
| 64 | GROUNDING | LS | | | 226 | 11.05 | | | | 2,500 - | | 1,500 - | 4,000 - |

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REVISION NO. ______  REVISION DATE ______

CLIENT: CENTRAL TELEPHONE & UTILITY - WESTERN POWER

# CONSTRUCTION COSTS

LOCATION: CIMARRON RIVER STATION

PROJECT: SOLAR COGENERATION FACILITY

BY: TJ NANCE CHKD. ILD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS 1/80 RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT 1/80 $ MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5700 | SOLAR AUX ELECTRICAL SYSTEM | | | | | | | | | | | | |
| | ELECTRICAL SERVICE TO RECIEVER SYS. | | | | | | | | | | | | |
| G1 | 480V MOTOR CONTROL CENTER | 1 | EA | 261 | 261 | 11.50 | | | 8,000 | 3,000 - | N/A | 8,000 - | 11,000 - |
| G2 | 480-120/208V TRANSFORMER DRY TYPE 37.5KVA | 1 | EA | 23 | 23 | 11.50 | | | 850 | 265 - | | 850 - | 1,115 - |
| G3 | WALL MOUNTED LIGHTING & POWER PANEL, 42 POLES | 2 | EA | 17 | 34 | 11.50 | | | 1,100 | 391 - | | 1,100 - | 1,491 - |
| G4 | LIGHTING FIXTURES & ASSOC. EQUIP & COMMUNICATION | 1 | LS | - | 51 | 11.25 | | | 950 | 575 - | | 950 - | 1,525 - |
| G6 | LIGHTNING PROTECTION | 1 | LS | - | 96 | 11.50 | | | 1,000 | 1,100 - | | 1,000 - | 2,100 - |
| G7 | 600V CABLE EPR/CSP | | | | | | | | | | | | |
| | 1/C 500 MCM | 200 | LF | .060 | 12 | 11.40 | | | 2.85 | 137 - | | 570 - | 707 - |
| | 1/C 250 MCM | 750 | LF | .049 | 37 | | | | 1.60 | 422 - | | 1,200 - | 1,622 - |
| | 1/C 2/0 AWG | 1000 | LF | .038 | 38 | | | | 0.83 | 433 - | | 850 - | 1,283 - |
| G8 | 600V CABLE XLP/CSP | | | | | | | | | | | | |
| | 3/C #2 AWG | 1000 | LF | .049 | 49 | | | | 2.45 | 559 - | | 2,450 - | 3,009 - |
| | 3/C #8 AWG | 250 | LF | .032 | 8 | | | | 0.95 | 91 - | | 238 - | 329 - |
| | 3/C #12 AWG | 7200 | LF | .023 | 166 | | | | 0.45 | 1,892 - | | 3,240 - | 5,132 - |
| G9 | LIGHTING CABLE 1/C #12 AWG | 5000 | LF | .010 | 50 | | | | 0.15 | 570 - | | 750 - | 1,320 - |
| G10 | RIGID STEEL CONDUIT | | | | | | | | | | | | |
| | 3" ID | 1000 | LF | .802 | 802 | | | | 4.30 | 9,143 - | | 4,300 - | 13,443 - |
| | 1 1/2" ID | 1000 | LF | .440 | 440 | | | | 1.45 | 5,016 - | | 1,450 - | 6,466 - |
| | 1" ID | 2000 | LF | .306 | 612 | | | | 1.00 | 6,977 - | | 2,000 - | 8,977 - |
| | 3/4" ID | 1000 | LF | .256 | 256 | | | | 0.75 | 2,918 - | | 750 - | 3,668 - |
| G11 | 3" RIGID STEEL CONDUIT ENCASED IN CONCRETE | 100 | LF | .802 | 80 | | | | 4.30 | 912 - | | 430 - | 1,342 - |
| G12 | GROUNDING | LS | | - | 172 | 11.05 | | | 1,100 | 1,900 - | | 1,100 - | 3,000 - |

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1 CENTRAL TELEPHONE & UTILITY-

CLIENT WESTERN POWER

# CONSTRUCTION COSTS

LOCATION CIMARRON RIVER STATION

PROJECT SOLAR COGENERATION FACILITY

BY TJ NANCE CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS 7/80 RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT 7/80 # MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5700 | SOLAR AUX. ELEC. SYSTEM | | | | | | | | | | | | |
| | ELECTRICAL SERVICE TO MASTER CONTROL SYS | | | | | | | | | | | | |
| 61 | 125V BATTERY & FUSES | 1 | EA | 100 | 100 | 11.50 | | | 30,000 | 1,150 - | | 30,000 - | 31,150 - |
| 62 | 125V DC PANEL | 1 | EA | 13 | 13 | 11.50 | | | 300 | 150 - | | 300 - | 450 - |
| 63 | 37.5KVA REGULATING TRANS. | 1 | EA | 20 | 20 | 11.50 | | | 700 | 230 - | | 700 - | 930 - |
| 64 | 125V DC BATTERY CHARGER | 2 | EA | 35 | 70 | 11.50 | | | 7,500 | 805 - | | 15,000 - | 15,805 - |
| 65 | 120V 36KVA UPS, INCLUDING | | | | | | | | | | | | |
| | 2 INVERTERS, 2 STATIC SWITCHES | | | | | | | | | | | | |
| | 2 DISTRIBUTION PANELS | 1 | EA | 1,304 | 1,304 | 11.50 | | | 50,000 | 15,000 - | | 50,000 - | 65,000 - |
| 66 | 600V CABLE XLP/CSP | | | | | | | | | | | | |
| | 2/C #10 AWG | 150 | LF | .017 | 2.5 | 11.40 | | | 0.37 | 29 - | | 55 - | 84 - |
| 67 | 600V CABLE EPR/CSP | | | | | | | | | | | | |
| | 1/C 4/0 AWG | 900 | LF | .044 | 40 | 11.40 | | | 1.45 | 456 - | | 1,305 - | 1,761 - |
| | 1/C 350MCM | 200 | LF | .055 | 11 | 11.40 | | | 2.50 | 125 - | | 500 - | 625 - |
| 68 | RIGID STEEL CONDUIT | | | | | | | | | | | | |
| | 4" ID | 100 | LF | 1.258 | 126 | 11.30 | | | 6.30 | 1,424 - | | 630 - | 2,054 - |
| | 3" ID | 150 | LF | .802 | 120 | 11.30 | | | 4.30 | 1,356 - | | 645 - | 2,001 - |
| | 1" ID | 150 | LF | .306 | 46 | 11.30 | | | 1.00 | 520 - | | 150 - | 670 - |
| 69 | GROUNDING | LS | | | 54 | 11.05 | | | 350.00 | 600 - | | 350 - | 950 - |

DATE 5-5-81 REVISION NO. ______ REVISION DATE ______ PAGE NO. ______ OF ______

REVISION NO. ______ REVISION DATE ______

- CENTRAL TELEPHONE & UTILITY -

# CONSTRUCTION COSTS

CLIENT: WESTERN POWER

LOCATION: CIMARRON RIVER STATION

PROJECT: SOLAR COGENERATION FACILITY

BY: TJ NANCE CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS 7/80 RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT 7/80$ MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5700 | SOLAR AUX ELECTRICAL SYSTEM | | | | | | | | | | | | |
| 61 | 450 KVA 4160 V DIESEL GENERATOR & ASSOC. EQUIP | 1 | EA | 290 | 290 | 11.50 | | | 80,000 | 3,335 - | | 80,000 | 83,335 - |
| 62 | 4160 V SWITCHGEAR | 1 | EA | 304 | 304 | 11.50 | | | 30,000 | 3,500 - | | 30,000 - | 33,500 - |
| 63 | 480 V MOTOR CONTROL CENTER | 1 | EA | 261 | 261 | 11.50 | | | 8,000 | 3,000 - | | 8,000 - | 11,000 - |
| 64 | 300 KVA 4160-480/277V 3Ø PAD MOUNTED TRANSFORMER INCL. CONC. PAD | 1 | EA | 69 | 69 | 11.50 | | | 4,700 | 795 - | | 4,700 - | 5,495 - |
| 65 | 5KV CABLE EPR/PVC | | | | | | | | | | | | |
| | 1/C 4/0 AWG | 2800 | LF | .050 | 140 | 11.40 | | | 1.65 | 1,596 - | | 4,620 - | 6,216 - |
| | 1/C #2 AWG | 750 | LF | .032 | 24 | 11.40 | | | 1.00 | 274 - | | 750 - | 1,024 - |
| 66 | 600V CABLE EPR/CSP | | | | | | | | | | | | |
| | 1/C 500 MCM | 200 | LF | .080 | 16 | 11.40 | | | 3.50 | 182 - | | 700 - | 882 - |
| 67 | 3" RIGID STEEL CONDUIT | 1000 | LF | .802 | 802 | 11.30 | | | 4.30 | 9,063 - | | 4,300 - | 13,363 - |
| 68 | 4" RIGID STEEL CONDUIT | 20 | LF | 1.258 | 25 | 11.30 | | | 6.30 | 283 - | | 126 - | 409 - |
| 69 | 5KV CABLE TERMINATIONS | 18 | EA | 4.5 | 81 | 11.40 | | | 20.00 | 923 - | | 360 - | 1,283 - |
| 610 | GROUNDING | LS | | | 185.5 | 11.05 | | | 1,200 | 2,050 - | | 1,200 - | 3,250 - |

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# CONSTRUCTION COST ESTIMATE

CLIENT: CENTRAL TELEPHONE & UTILITY – WESTERN POWER

DESCRIPTION: #5800 ELECTRIC POWER GENERATING SYSTEM MODIFICATIONS. (SOLAR COGENERATION FACILITY)

LOCATION: CIMARRON RIVER STATION

PROJECT: #9470.005

CONT. NO. 81SF11439

MADE BY: J.M. SULLIVAN

APPROVED: J E HARDER

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST | | | |
|---|---|---|---|---|---|---|
| | | | LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
| | | | | | | |
| A | Excavation & Civil | | — | | — | — |
| B | Concrete | | — | | — | — |
| C | Structural Steel | | — | | — | — |
| D | Buildings | | — | | — | — |
| E | Machinery & Equipment | | — | | — | — |
| F | Piping | 35 | 425 | | 410 | 835 |
| G | Electrical | 169 | 1,944 | N/A | 35,600 | 37,544 |
| H | Instruments | | | | — | — |
| J | Painting | | — | | — | — |
| K | Insulation | | — | | — | — |
| | | | | | | |
| | DIRECT FIELD COSTS | 204 | 2,369 | — | 36,010 | 38,379 |
| | | | | | | |
| L | Temporary Construction Facilities | | | | | 1,920 |
| M | Construction Services, Supplies & Expense | | | | | 2,685 |
| N | Field Staff, Subsistence & Expense | | | | | 4,220 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 6,445 |
| Q | Equipment Rental | | | | | — |
| | INDIRECT FIELD COSTS | | | | | 15,270 |
| | TOTAL FIELD COSTS | | | | | 53,649 |
| | | | | | | |
| R | Engineering | | | | | 5,495 |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| S | Major Equipment Procurement | | | | | 205 |
| T | Construction Management | | | | | 1170 |
| | TOTAL OFFICE COSTS | | | | | 6,870 |
| | TOTAL FIELD & OFFICE COSTS | | | | | 60,519 |
| | | | | | | |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 6,050 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 66,569 |

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CLIENT WESTERN POWER - CENTRAL TELEPHONE & UTILITY

# CONSTRUCTION COSTS

LOCATION CIMARRON RIVER STATION

PROJECT SOLAR COGENERATION FACILITY

BY JMS CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS 7/80 RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT 7/80 $ MAT'L. | COSTS LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5800 | ELECTRIC POWER GENERATING SYSTEM (MODIFICATIONS) | | | | | | | | | | | | |
| G1 | MODIFY EXISTING LCUS | 1 | EA | 8 | 8 | 11.50 | | | 500 | 92 - | | 500 - | 592 - |
| G2 | MODIFY EXISTING 4.16 KV SWITCHGEAR | 1 | EA | 1 | 1 | 11.50 | | | 100 | 12 - | | 100 - | 112 - |
| F1 | 1½" 600# C.S. GLOBE VALVE W/ QUICK DISCONNECT | 1 | EA | INCL. IN PIPE | | | | | 100 | | | | 100 - |
| F2 | 1½" C.S. PIPE | 50 | LF | .7 | 35 | 12.13 | 8.49 | | 2.90 | 425 - | | 145 - | 570 - |
| F3 | HOSE | 150 | LF | | | | | | 1.10 | | | 165 - | 165 - |

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CLIENT Western Power - Central Telephone & Utility

# CONSTRUCTION COSTS

LOCATION Cimarron River Station

PROJECT Solar Cogeneration Facility

BY JMS CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS | | | COST/UNIT | | | COSTS ( ) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PER UNIT | TOTAL | 7/80 RATE | LABOR | SUB CONTR. | 7/80 $ MAT'L. | LABOR | SUB CONTRACT | MATERIAL | TOTAL |
| 5800 | Modifications to Boiler & Turbine Control Systems. | 1 | LS | | 160 | 11.50 | | | 35,000 | 1,840 - | | 35,000 - | 36,840 - |

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# CONSTRUCTION COST ESTIMATE

CLIENT Central Tel & Util; Western Power
DESCRIPTION Main Steam (5910)
Receiver Piping System (5900)

LOCATION Cimarron River Station

PROJECT Solar Cogeneration Facility

CONT. NO. 815F11439
MADE BY RLW
APPROVED JCHARDER

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
|---|---|---|---|---|---|---|
| 5910 | | | | | | |
| A | Excavation & Civil | 65 | 645 | | 3,451 | 4,096 |
| B | Concrete | 303 | 2,724 | | 1,864 | 4,588 |
| C | Structural Steel | 445 | 5,438 | | 17,010 | 22,448 |
| D | Buildings | | | | | |
| E | Machinery & Equipment | | | | | |
| F | Piping | 4,815 | 58,404 | | 269,735 | 328,139 |
| G | Electrical | | | | | |
| H | Instruments | 12 | 148 | | 1,100 | 1,248 |
| J | Painting | | | | | |
| K | Insulation | 1,580 | 18,454 | | 36,340 | 54,794 |
| | | | | | | |
| | DIRECT FIELD COSTS | 7,220 | 85,813 | | 329,500 | 415,313 |
| | | | | | | |
| L | Temporary Construction Facilities | | | | | 20,665 |
| M | Construction Services, Supplies & Expense | | | | | 28,930 |
| N | Field Staff, Subsistence & Expense | | | | | 45,465 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 85,365 |
| Q | Equipment Rental | | | | | 23,730 |
| | INDIRECT FIELD COSTS | | | | | 204,155 |
| | TOTAL FIELD COSTS | | | | | 619,468 |
| R | Engineering | | | | | 63,435 |
| | Design & Engineering | | | | | |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| S | Major Equipment Procurement | | | | | 2,380 |
| T | Construction Management | | | | | 13,505 |
| | TOTAL OFFICE COSTS | | | | | 79,320 |
| | TOTAL FIELD & OFFICE COSTS | | | | | 698,788 |
| | | | | | | |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 69,880 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 768,668 |

DATE 5/12/81 REVISION NO. ____ REVISION DATE ____ PAGE NO. ____

# CONSTRUCTION COSTS

CLIENT Central Telephone & Utility - Western Power
LOCATION Cimarron River Station
PROJECT Solar Cogeneration Facility (9470)

BY RLW CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS 7/80 RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT 7/80 $ MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5900 | Receiver Piping System | | | | | | | | | | | | |
| 5910 | MAIN STEAM | | | | | | | | | | | | |
| A | EXCAVATION AND CIVIL | | | | | | | | | | | | |
| A1 | PIPE SUPPORTS | 390 | CY | .070 | 27 | 9.91 | | | — | 268 - | | — | 268 - |
| A2 | 1" ø GRAVEL | 390 | CY | .097 | 38 | 9.91 | | | 8.85 | 377 - | | 3 451 - | 3 828 - |
| | A. CIVIL TOTAL | | | | 65 | | | | | 645 - | | 3 451 - | 4 096 - |
| B | CONCRETE | | | | | | | | | | | | |
| B1 | PIPE SUPPORTS 12"x12"x6" | 60 | EA | 1.90 | 114 | 8.99 | | | 15.70 | 1 025 - | | 942 - | 1 967 - |
| B2 | TRUSS SUPPORTS | 32 | EA | 5.90 | 189 | 8.99 | | | 28.80 | 1 699 - | | 922 - | 2 621 - |
| | B. CONCRETE TOTAL | | | | 303 | | | | | 2 724 - | | 1 864 - | 4 588 - |
| C | STRUCTURAL STEEL | | | | | | | | | | | | |
| C1 | PIPE SUPPORT STEEL | 11 | TN | 35.00 | 385 | 12.22 | | | 1500.00 | 4 705 - | | 16 500 - | 21 205 - |
| C2 | PIPE ROLLERS (6") | 60 | EA | 1.00 | 60 | 12.22 | | | 8.50 | 733 - | | 510 - | 1 243 - |
| | C. STRUCT. ST. TOTAL | | | | 445 | | | | | 5 438 - | | 17 010 - | 22 448 - |
| F | PIPING | | | | | | | | | | | | |
| F1 | 6" ASTM A335 GR P22 SCH 160 - Average System | 1580 | LF | 3.0 | 4740 | 12.13 | | | 159.00 | 57 496 - | | 251 220 - | 308 416 - |
| F2 | 6" GATE VLV W/ MOTOR OPERATOR 2500# 2 1/4 CR | 1 | EA | — | | | | | 11,000.00 | — | | 11 000 - | 11 000 - |
| F3 | 6" FLOW NOZZLE ASTM A335 GR P22 SCH 160 | 1 | EA | 6.0 | 6 | 12.13 | | | 525.00 | 73 - | | 525 - | 598 - |
| F4 | 1" GLOBE VALVE 1500# 2 1/4 CR | 6 | EA | — | | | | | 250.00 | — | | 1500 | 1500 - |
| F5 | 2" M.O. GLOBE VALVE 1500# 2 1/4 CR. | 1 | EA | | | | | | 2750.00 | | | 2750.00 | 2750 - |
| F6 | 2" A335 P22 PIPE | 15 | LF | 4.6 | 69 | 12.13 | | | 56.00 | 835 - | | 840 - | 1675 - |
| H | INSTRUMENTATION | | | | | | | | | | | | |
| H1 | FLOW TRANSMITTER SERVICE 950°F 1500 PSI | 1 | EA | 12.0 | 12 | 12.36 | | | 1100.00 | 148 - | | 1100 - | 1 248 - |
| | H. INSTR. TOTAL | | | | 12 | | | | | 148 - | | 1100 | 1 248 - |
| F7 | 6" SPARE MO FOR 2500# 2 1/4% CR GATE VALVE | | | | | | | | 1900.00 | | | | 1900.00 |

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# CONSTRUCTION COSTS

CLIENT: Central Telephone & Utility - Western Power
LOCATION: Cimarron River Station
PROJECT: Solar Cogeneration Facility (9470)

BY: RLW  CHKD. TLD  APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS 7/80 RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT 7/80 MAT'L. | COSTS ( ) LABOR | COSTS ( ) SUB CONTRACT | COSTS ( ) MATERIAL | COSTS ( ) TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5910 | MAIN STEAM (CON'T) | | | | | | | | | | | | |
| K | INSULATION | | | | | | | | | | | | |
| K1 | 6" THICK PIPE INSULATION FOR 6" PIPE. WITH LASSING. | 1580 | FT | 1.0 | 1580 | 11.68 | | | 23.00 | 18 454 - | | 36 340 - | 54 794 - |
| | K. INSUL. TOTAL | | | | 1580 | | | | | 18 454 - | | 36 340 - | 54 794 - |

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# CONSTRUCTION COST ESTIMATE

CLIENT Central Tel & Util - Western Power

DESCRIPTION Feedwater (5920)
Receiver Piping System (5900)

LOCATION Cimarron River Station

PROJECT Solar Cogeneration Facility

CONT. NO. 816F11439
MADE BY RLW
APPROVED JE HARDER

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST | | | |
|---|---|---|---|---|---|---|
| | | | LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
| 5920 | | | | | | |
| A | Excavation & Civil | 63 | 625 | | 3,336 | 3961 |
| B | Concrete | 110 | 989 | | 911 | 1,900 |
| C | Structural Steel | 58 | 709 | | 348 | 1,057 |
| D | Buildings | | | | | |
| E | Machinery & Equipment | 165 | 1,896 | | 61,260 | 63,156 |
| F | Piping | 3,402 | 41,266 | | 90,177 | 131,443 |
| G | Electrical | | | | | |
| H | Instruments | 18 | 222 | | 1,680 | 1,902 |
| J | Painting | | | | | |
| K | Insulation | 746 | 8,713 | | 16,287 | 25,000 |
| | DIRECT FIELD COSTS | 4562 | 54420 | | 173,999 | 228,419 |
| L | Temporary Construction Facilities | | | | | 11,420 |
| M | Construction Services, Supplies & Expense | | | | | 15,990 |
| N | Field Staff, Subsistence & Expense | | | | | 25,125 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 47,923 |
| Q | Equipment Rental | | | | | 10,143 |
| | INDIRECT FIELD COSTS | | | | | 110,601 |
| | TOTAL FIELD COSTS | | | | | 339020 |
| R | Engineering | | | | | |
| | Design & Engineering | | | | | 34,715 |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| S | Major Equipment Procurement | | | | | 1,300 |
| T | Construction Management | | | | | 7,390 |
| | TOTAL OFFICE COSTS | | | | | 43,405 |
| | TOTAL FIELD & OFFICE COSTS | | | | | 382,425 |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 38,245 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 420,670 |

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# CONSTRUCTION COSTS

CLIENT: Central Telephone & Utility - Western Power
LOCATION: Cimarron River Station
PROJECT: Solar Cogeneration Facility (9470)

BY: [illegible] CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5920 | FEEDWATER | | | | | | | | | | | | |
| A | EXCAVATION AND CIVIL | | | | | | | | | | | | |
| A1 | PIPE SUPPORTS | 377 | CY | .070 | 26 | 9.91 | | | — | 258 - | | — | 258 - |
| A2 | 1" ϕ GRAVEL | 377 | CY | .097 | 37 | 9.91 | | | 8.85 | 367 - | | 3336 - | 3703 - |
| | A. CIVIL TOTAL | | | | 63 | | | | | 625 - | | 3336 - | 3961 - |
| B | CONCRETE | | | | | | | | | | | | |
| B1 | PIPE SUPPORTS | 58 | EA | 1.9 | 110 | 8.99 | | | 15.70 | 989 - | | 911 - | 1900 - |
| | B. CONCRETE TOTAL | | | | 110 | | | | | 989 - | | 911 - | 1900 - |
| C | STRUCTURAL STEEL | | | | | | | | | | | | |
| C1 | PIPE ROLLERS (4") | 58 | EA | 1.0 | 58 | 12.22 | | | 6.00 | 709 - | | 318 - | 1057 - |
| | C. STRUCT. ST. TOTAL | | | | 58 | | | | | 709 - | | 348 - | 1057 - |
| E. | EQUIPMENT | | | | | | | | | | | | |
| E1 | RECEIVER FEEDWATER BOOSTER PUMP. I-R 3x13VB 2 STG W/ MOTOR, VERT; 100 HP | 1 | EA | 100.00 | 100 | 11.49 | | | 60,000 | 1149 - | | 60000 - | 61149 - |
| E2 | CHEMICAL FEED EQUIPMENT | 1 | LS | 65. | 65 | 11.49 | | | 1260.00 | 747 - | | 1260 - | 2007 - |
| | E. EQUIP TOTAL | | | | 165 | | | | | 1896 | | 61260 | 63156 - |
| F | PIPING | | | | | | | | | | | | |
| F1 | 4" ASTM A106 GRB SCH 160 - AV. System | 1455 | LF | 1.8 | 2619 | 12.13 | | | 32.30 | 31768 - | | 46997 - | 78765 - |
| F2 | 2" ASTM A106 GRB SCH 160 | 365 | FT | 1.65 | 602 | 12.13 | | | 8.30 | 7302 - | | 3030 - | 10332 - |
| F3 | 4" GATE VALVE 1500# CS | 5 | EA | — | | | | | 3300.00 | — | | 16500 - | 16500 - |
| F4 | MOTOR OPERATOR FOR 4" VALVE | 1 | EA | — | | | | | 3,000.00 | — | | 3000 - | 3000 - |
| F5 | 2" GATE VALVE 1500# 1 1/4 CR | 4 | EA | — | | | | | 800.00 | — | | 3200 - | 3200 - |
| F6 | 1" GLOBE VALVE 1500# 1 1/4 CR | 12 | EA | — | | | | | 250.00 | — | | 3000 - | 3000 - |

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# CONSTRUCTION COSTS

CLIENT Central Telephone & Utility. Western Power
LOCATION Cimarron River Station
PROJECT Solar Cogeneration Facility (9470)

BY ww CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5920 | FEEDWATER (CONT) | | | | | | | | | | | | |
| F7 | 4" FISHER CONTROL VALVE | 1 | EA | 5.0 | 5 | 12.13 | | | 4500.00 | 61 - | | 4500 - | 4561 - |
| | 1500# CS (TYPE ET) | | | | | | | | | | | | |
| F8 | 1½" FISHER CONTROL VALVE | 1 | EA | 3.0 | 3 | 12.13 | | | 2000.00 | 36 - | | 2000 - | 2036 - |
| | 1500# CS (TYPE ET) | | | | | | | | | | | | |
| F9 | 2" PRESSURE BREAKDOWN | 1 | EA | 4.0 | 4 | 12.13 | | | 450.00 | 49 - | | 450 - | 499 - |
| | ORIFICE, CS BODY SS | | | | | | | | | | | | |
| | PLATES. SCH 160. | | | | | | | | | | | | |
| | ΔP = 1850 PSI | | | | | | | | | | | | |
| F10 | 2" CHECK VALVE 1500# CS | 1 | EA | — | | | | | 1200.00 | — | | 1200 - | 1200 - |
| F11 | 4" CHECK VALVE 1500# CS | 1 | EA | — | | | | | 2800.00 | — | | 2800 - | 2800 - |
| F12 | 4" FLOW NOZZLE ASTM | 1 | EA | 4.0 | 4 | 12.13 | | | 400.00 | 49 - | | 400 - | 449 - |
| | A106 GR B SCH 160 | | | | | | | | | | | | |
| F13 | 2" A106 GRB SCH 80 (FOR | 100 | FT | 1.65 | 165 | 12.13 | | | 4.80 | 2001 - | | 480 - | 2481 - |
| | PUMP COOLING WATER) | | | | | | | | | | | | |
| | 2" 600# C.S. GLOBE | 2 | EA | — | | | | | 560 | — | | 1120 - | 1120 - |
| F14 | SPARE 4" AIO FOR VALVE | 1 | EA | | | | | | 1500 | | | | 1500 - |
| H. | INSTRUMENTATION | | | | | | | | | | | | |
| H1 | FLOW TRANSMITTER | 1 | EA | 12.0 | 12 | 12.36 | | | 1500.00 | 148 - | | 1500 - | 1648 - |
| | SERVICE 500 F 1800 PSI | | | | | | | | | | | | |
| H2 | PRESSURE INDICATOR | 2 | EA | 3.0 | 6 | 12.36 | | | 90.00 | 74 - | | 180 - | 254 - |
| | RANGE 0-2000 PSI | | | | | | | | | | | | |
| | H. INSTR. TOTAL | | | | 18 | | | | | 222 - | | 1680 | 1902 - |
| K | INSULATION | | | | | | | | | | | | |
| K1 | CL B 4" PIPE WITH | 1455 | FT | .42 | 611 | 11.68 | | | 9.35 | 7136 - | | 13604 - | 20740 - |
| | LASSINS AND FREEZE | | | | | | | | | | | | |
| | PROTECTION | | | | | | | | | | | | |
| K2 | CL B 2" PIPE WITH | 365 | FT | .37 | 135 | 11.68 | | | 7.35 | 1577 - | | 2683 - | 4260 - |
| | LASSINS AND FREEZE | | | | | | | | | | | | |
| | PROTECTION | | | | | | | | | | | | |
| | K INSUL. TOTAL | | | | 746 | | | | | 8713 - | | 16287 - | 25000 - |

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# CONSTRUCTION COST ESTIMATE

CLIENT Central Tel & Util. - Western Power DESCRIPTION Condensate (5930) Receiver Piping System (5900)

LOCATION Cimarron River Station

PROJECT Solar Cogeneration Facility

CONT. NO. 815F11439
MADE BY [illegible]
APPROVED J. E. Harder

| A/C NO. | ITEM & DESCRIPTION | MAN HOURS | ESTIMATED COST LABOR | SUBCONTRACTS | MATERIALS | TOTALS |
|---|---|---|---|---|---|---|
| 5930 | | | | | | |
| A | Excavation & Civil | 84 | 833 | | 4,487 | 5,320 |
| B | Concrete | 148 | 1,331 | | 1,225 | 2,556 |
| C | Structural Steel | 78 | 953 | | 351 | 1,304 |
| D | Buildings | | | | | |
| E | Machinery & Equipment | 80 | 920 | | 10,300 | 11,220 |
| F | Piping | 2,537 | 30,775 | | 22,306 | 53,081 |
| G | Electrical | | | | | |
| H | Instruments | 39 | 482 | | 1,340 | 1,822 |
| J | Painting | | | | | |
| K | Insulation | 416 | 4,859 | | 6,601 | 11,460 |
| | DIRECT FIELD COSTS | 3,382 | 40,153 | | 46,610 | 86,763 |
| L | Temporary Construction Facilities | | | | | 4,340 |
| M | Construction Services, Supplies & Expense | | | | | 6,075 |
| N | Field Staff, Subsistence & Expense | | | | | 9,545 |
| P | Craft Benefits, Payroll Burdens & Insurances | | | | | 21,366 |
| Q | Equipment Rental | | | | | 13,617 |
| | INDIRECT FIELD COSTS | | | | | 54,933 |
| | TOTAL FIELD COSTS | | | | | 141,696 |
| R | Engineering | | | | | |
| | Design & Engineering | | | | | 14,510 |
| | Home Office Costs | | | | | |
| | R & D | | | | | |
| S | Major Equipment Procurement | | | | | 545 |
| T | Construction Management | | | | | 3,090 |
| | TOTAL OFFICE COSTS | | | | | 18,145 |
| | TOTAL FIELD & OFFICE COSTS | | | | | 159,841 |
| U | Labor Productivity | | | | | |
| V | Contingency | | | | | 15,985 |
| W | Fee | | | | | |
| | TOTAL CONSTRUCTION COST | | | | | 175,826 |

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CLIENT Central Telephone & Utility - Western Power **CONSTRUCTION COSTS**

LOCATION Cimarron River Station

PROJECT Solar Cogeneration Facility (9470)

BY [illegible] CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS ( ) LABOR | COSTS SUB CONTRACT | COSTS MATERIAL | COSTS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5930 | CONDENSATE | | | | | | | | | | | | |
| A | EXCAVATION AND CIVIL | | | | | | | | | | | | |
| A1 | PIPE SUPPORTS | 507 | CY | .070 | 35 | 9.91 | | | — | 347 - | | — | 347 - |
| A2 | 1" ϕ GRAVEL | 507 | CY | .097 | 49 | 9.91 | | | 8.85 | 486 - | | 4487 - | 4973 - |
| | A. CIVIL TOTAL | | | | 84 | | | | | 833 - | | 4487 | 5320 - |
| B | CONCRETE | | | | | | | | | | | | |
| B1 | PIPE SUPPORTS | 78 | ea | 1.90 | 148 | 8.99 | | | 15.70 | 1331 - | | 1225 - | 2556 - |
| | B. CONCRETE TOTAL | | | | 148 | | | | | 1331 - | | 1225 - | 2556 - |
| C | STRUCTURAL STEEL | | | | | | | | | | | | |
| C1 | PIPE ROLLERS (2") | 78 | EA | 1.0 | 78 | 12.22 | | | 4.50 | 953 - | | 351 - | 1304 - |
| | C. STRUCT. ST. TOTAL | | | | 78 | | | | | 953 - | | 351 - | 1304 - |
| E | EQUIPMENT | | | | | | | | | | | | |
| E1 | BLOWDOWN TANK-INSULATED 4' DIA × 6' HIGH, CS 25 PSI DESIGN P. | 1 | EA | 40.0 | 40 | 11.49 | | | 8,800.00 | 460 - | | 8800 - | 9260 - |
| E2 | RECEIVER BLOWDOWN PUMP 25 GPM @ 30 FT; 1 HP | 1 | EA | 40.0 | 40 | 11.49 | | | 1500.00 | 460 - | | 1500 - | 1960 - |
| | E. EQUIP. TOTAL | | | | 80 | | | | | 920 - | | 10300 | 11220 - |
| F | PIPING | | | | | | | | | | | | |
| F1 | 2" ASTM A106 GR B SCH 80 | 1435 | FT | 1.65 | 2368 | 12.13 | | | 4.80 | 28724 - | | 6888 - | 35612 - |
| F2 | 1" ASTM A106 GRB SCH 80 | 50 | FT | 1.65 | 83 | 12.13 | | | 3.65 | 1007 - | | 183 - | 1190 - |
| | 2" GLOBE VALVE 1500# 1 1/4 CR | 5 | EA | — | | | | | 800.00 | | | 4000 - | 4000 - |
| | 2" GATE VALVE 600# CS | 6 | EA | — | | | | | 450.00 | | | 2700 - | 2700 - |
| | 2" CHECK VALVE 600# CS | 1 | EA | — | | | | | 400.00 | | | 400 - | 400 - |
| | 2" TRAP w/ STRAINER 1500# CR | 1 | EA | 3.5 | 4 | 12.13 | | | 360.00 | 49 - | | 360 - | 409 - |

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# CONSTRUCTION COSTS

CLIENT Central Telephone & Utility - Western Power
LOCATION Cimarron River Station
PROJECT Solar Cogeneration Facility

BY [illegible] CHKD. TLD APVD. JEH

| A/C NO. | ITEM & DESCRIPTION | QUAN. | UNIT | MANHOURS PER UNIT | MANHOURS TOTAL | MANHOURS RATE | COST/UNIT LABOR | COST/UNIT SUB CONTR. | COST/UNIT MAT'L. | COSTS ( ) LABOR | COSTS ( ) SUB CONTRACT | COSTS ( ) MATERIAL | COSTS ( ) TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5930 | CONDENSATE (CONT) | | | | | | | | | | | | |
| F3 | 3" GATE VALVE 150# CS | 1 | EA | — | | | | | 425.00 | — | | 425 - | 425 - |
| F4 | 3" Y-STRAINER 150# CS | 1 | EA | 33 | 3 | 12.13 | | | 260.00 | 36 - | | 260 - | 296 - |
| F5 | 1" GLOBE VALVE 600# CS (INST ISOLATION) | 5 | EA | — | | | | | 320.00 | — | | 1600 - | 1600 — |
| F6 | MOTOR OPERATOR FOR 2" VALVE (1500# GLOBE) | 2 | EA | — | | | | | 1500.00 | — | | 3000 - | 3000 - |
| F7 | ORIFICE PLATE FOR 2" PIPE (INCLUDING FLANGES) | 1 | SET | 4.0 | 4 | 12.13 | | | 210.00 | 49 - | | 210 - | 259 - |
| F8 | 4" A106 GR B SCH 40 (BLOWDOWN TANK VENT) | 50 | FT | 1.5 | 75 | 12.13 | | | 15.60 | 910 - | | 780 - | 1690 - |
| F9 | SPARE M.O. FOR 2" VALVE | 1 | EA | | | | | | 1500 | | | | 1500 — |
| H | INSTRUMENTATION | | | | | | | | | | | | |
| H1 | LEVEL SWITCH; 1500 PSI 975 F | 2 | EA | 12.0 | 24 | 12.36 | | | 450.00 | 297 - | | 900 - | 1197 - |
| H2 | LEVEL SWITCH; ATMOSPHERE, 220 F | 1 | EA | 12.0 | 12 | 12.36 | | | 350.00 | 148 - | | 350 - | 498 - |
| H3 | PRESSURE GAGE; 0-20 PSI | 1 | EA | 3.0 | 3 | 12.36 | | | 90.00 | 37 - | | 90 - | 127 - |
| | H. INSTRUMENT. TOTAL | | | | 39 | | | | | 482 - | | 1340 - | 1822 - |
| K | INSULATION | | | | | | | | | | | | |
| | 2" CLASS D WITH FREEZE PROTECTION | 1435 | FT | .29 | 416 | 11.68 | | | 4.60 | 4859 - | | 6601 - | 11460 - |
| | K. INSULATION TOTAL | | | | | | | | | 4859 - | | 6601 | 11460 |

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