DOE/SF/10738-1/3

SOLAR REPOWERING FOR ELECTRIC GENERATION, NORTHEASTERN STATION UNIT 1, PUBLIC SERVICE COMPANY OF OKLAHOMA

Appendix

July 15, 1980

Work Performed Under Contract No. AC03-79SF10738

Black & Veatch Consulting Engineers
Kansas City, Missouri

U.S. Department of Energy

Solar Energy

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SOLAR REPOWERING FOR ELECTRIC GENERATION

NORTHEASTERN STATION UNIT 1

PUBLIC SERVICE COMPANY OF OKLAHOMA

APPENDIX

July 15, 1980

Black & Veatch, Consulting Engineers
Public Service Company of Oklahoma
Babcock & Wilcox Company

Department of Energy
Contract No. DE-AC 0379SF 10738

PREFACE

This report describes the conceptual design and evaluation of solar repowering an electric generation plant as part of the Department of Energy (DOE) Solar Repowering/Industrial Retrofit Program. The DOE San Francisco Operations Office issued Contract Number DE-AC03-79SF 10738 to Black & Veatch (B&V) for this effort, which was performed during the period September 24, 1979 to July 15, 1980 on B&V Project 8734. Significant contributions to the project were made by B&V's subcontractors, Public Service Company of Oklahoma, the utility and site owner, and the Babcock & Wilcox Company, designer of the solar receiver. B&V expresses appreciation for the guidance provided by Mr. Fred Corona, Contract Manager for the DOE San Francisco Operations Office, and Mr. Jim Gibson, Technical Manager for Sandia National Laboratories, Livermore, California.

The report is contained in three volumes: Executive Summary, Final Report, and Appendix. The Executive Summary provides a brief overview of the conceptual design, a synopsis of the performance and economic evaluation, and an assessment of the concept from the site owner's perspective. The Final Report contains a more comprehensive description of the work performed on the project; this volume presents the trade studies, conceptual design, system performance, economic analysis, and development plan as well as a description of a test program carried out on the project. The Appendix volume consists of the System Requirements Specification and insolation data obtained in the test program.

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SOLAR REPOWERING FOR ELECTRIC GENERATION
NORTHEASTERN STATION UNIT 1
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SYSTEM REQUIREMENTS SPECIFICATION

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SOLAR REPOWERING FOR ELECTRIC GENERATION
NORTHEASTERN STATION UNIT 1
PUBLIC SERVICE COMPANY OF OKLAHOMA

1.0 GENERAL

1.1 SCOPE

Northeastern Station Unit 1 is an existing 155 MWe gross gas and oil fired steam electric generating unit located approximately one mile south of Oologah, Oklahoma in Rogers County. The Solar Repowering for Electric Generation Project involves the development of a site specific conceptual design of a 30 MWe solar central receiver steam generation system for operation in conjunction with the existing 155 MWe Northeastern Station Unit 1. Principal elements of the solar repowered plant include the following.

(1) Site.
(2) Site Facilities.
(3) Collector System.
(4) Receiver System.
(5) Receiver Loop System.
(6) Master Control System.
(7) Fossil Energy System.
(8) Specialized Equipment.

This System Requirements Specification (SRS) defines the system characteristics, system environmental requirements, and plant conceptual design data requirements. This SRS also provides economic data and overall plant cost data.

1.2 SYSTEM DESCRIPTION

For the purpose of the repowered conceptual design project, the repowering system will be as described in the following paragraphs.

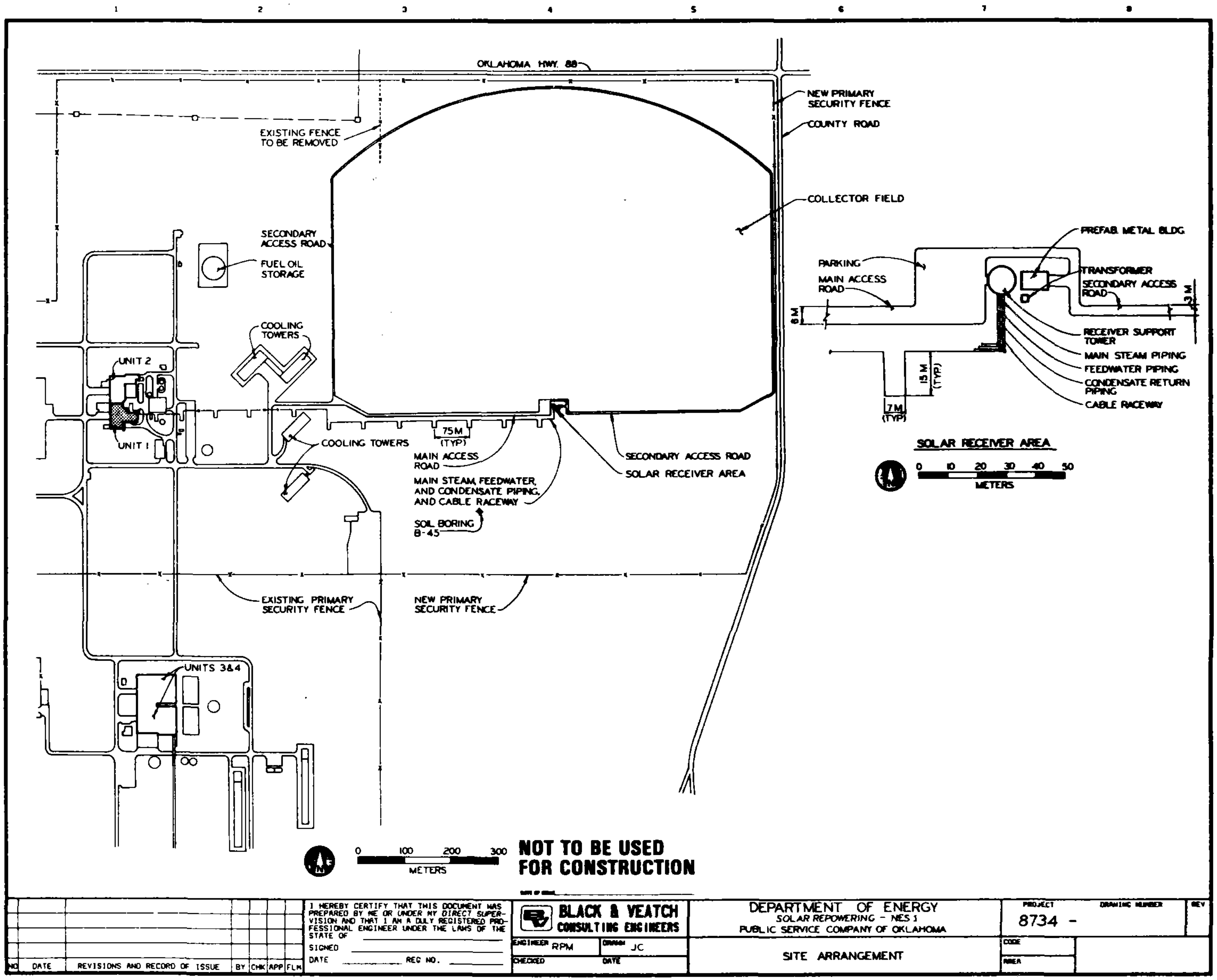
1.2.1 Site

The Northeastern Station of the Public Service Company of Oklahoma (PSO) is located on a 1,320 acre site adjacent to the Oologah Reservoir, approximately 30 miles northeast of Tulsa, Oklahoma. The heliostat field and receiver steam generator will be situated in the northeast quadrant of the property, east of Unit 1, on land presently owned by PSO. The overall site arrangement is shown on Figure 1.2-1. The maximum dimension of the heliostat field will be approximately 880 metres (2,887 feet).

The plant site is located entirely on the Oologah Formation, a geologic member of the Marmaton Group in the Desmoinesian series. This formation is represented by, in ascending order: the Pawnee Limestone; the Bandera Shale; and the Altamont Limestone. Pawnee Limestone is comprised of gray, massive crinoidal limestone which is overlain by black, fissile shale. The Bandera Shale is a very thin, gray to brown, sandy shale which grades vertically into sandstone and black shale. The Altamont Limestone is composed of gray shale and limestone, overlain by black fissile shale and gray cherty limestone. Test borings for Units 1 through 4 at Northeastern Station indicated that the top surface of the Oologah Formation is slightly weathered.

A thin soil mantle, generally 0.3 to 0.9 metres (1 to 3 feet thick), overlies the limestone bedrock. This soil is a silty clay which contains residual pieces of limestone. Specifically, the soil is classified as the Claremore Silt Loam, a soil formed under tall prairie grasses in material that weathered from limestone. It is easily worked, drains moderately well, but is susceptible to erosion. Due to its plastic nature, it is not good for borrow material.

The soil boring closest to the proposed heliostat field (B-45) shown on Figure 1.2-1 indicates a clay soil 0.8 metres (2.5 feet) thick overlays 0.6 metres (2.0 feet) of weathered limestone with some clay layers which in turn overlays the competent limestone.



SITE PLAN

FIGURE 1.2-1

The heliostat field area slopes gently toward the southwest from about El 210 metres (690 feet) mean sea level (MSL) to El 198 metres (650 feet) MSL. Natural drainage for the area is provided by two depressions, one of which includes a farm pond. The area is a pasture, with little brush and few trees.

1.2.2 Site Facilities

Facilities at the Northeastern Station currently include Unit 1, rated at 155,000 kW; Unit 2, rated at 441,800 kW; and Units 3 and 4, which have a gross generating capability of 441,000 kW each. Units 1 and 2 utilize natural gas as the primary fuel with fuel oil as the secondary or backup fuel. Units 3 and 4 are coal fired with natural gas and fuel oil as secondary fuels.

The arrangement of the basic existing facilities associated with Units 1 and 2 is shown on Figure 1.2-2.

Facilities available to all of the units include the following.

(1) Site facilities, such as roads, railroads, parking, area drainage, fencing, fire protection, etc.

(2) Plant water supply pump house and transport pipeline for makeup to cooling towers and for service water.

(3) Fuel gas supply system, fuel oil unloading, and storage.

(4) Service water treatment and storage.

(5) Wastewater treatment, plant drainage, and sewerage system.

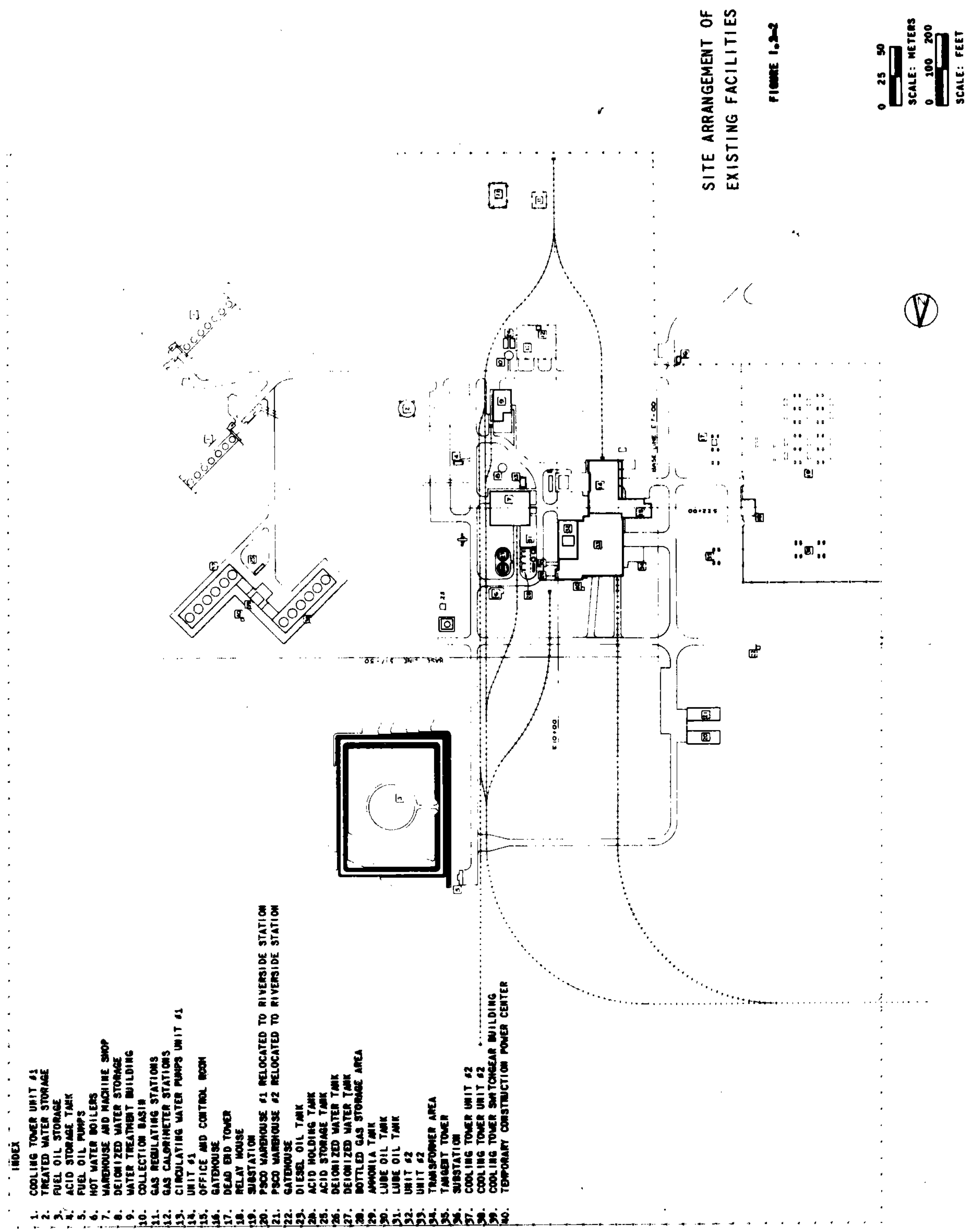
(6) Office, shop, and warehousing facilities.

(7) 138-345 kV substation, transmission line network.

(8) Station communications.

Because of the physical distance between Units 1 and 2 and Units 3 and 4, many of the plant systems cannot be utilized by all units. The facilities available to Unit 1 are described in the following paragraphs.

Unit 1 and 2 facilities include outdoor steam generators with enclosed turbine generators and feedwater heaters. Enclosures are also provided below the operating deck level for the steam generator and turbine generator auxiliaries of Unit 2. Separate structures are provided for warehousing, machine shop, and water treatment functions. The station offices and the



SITE ARRANGEMENT OF EXISTING FACILITIES

FIGURE 1.2-2

control room functions are housed in an attached building located to the west of the turbine room at the north end of Unit 1 facilities. A common turbine room enclosure, including gantry type traveling crane, serves the main turbine, boiler feed pumps and turbines, generators, and miscellaneous turbine and generator auxiliaries for both units.

The generator step-up, main auxiliary, and reserve auxiliary transformers are located to the west of the turbine generator building at grade level. The substation for both units is located west of the central complex structures. Facilities and structures housing auxiliary or support functions for Units 1 and 2 are located in a "rear yard" area to the east of the central complex structures. Cooling towers and fuel oil storage tanks are also located, at greater distances, to the east and northeast of the central complex structures.

1.2.3 Collector System

The Collector System consists of an array of computer-controlled, two-axis tracking heliostats; its functions are to intercept the incident direct solar insolation (energy) and to redirect and concentrate that energy onto the receiver. The collector system design will be specified in terms of the number and locations of heliostats required to produce a specified power level; these heliostat locations are determined to maximize annual efficiency. 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 lands upon the receiver and, further, that it provides the desired flux distribution on the receiver.

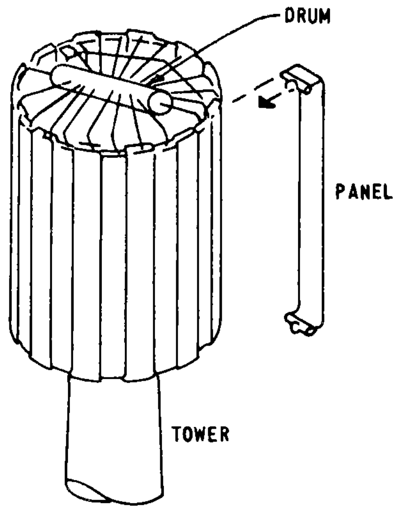
The Collector System also includes electromechanical and electrical controllers, including individual heliostat and heliostat field controllers, control system interface electronics, and power supplies. The heliostat itself consists of reflective surfaces, structural supports, drive units, control sensors,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

1.2.4 Receiver System

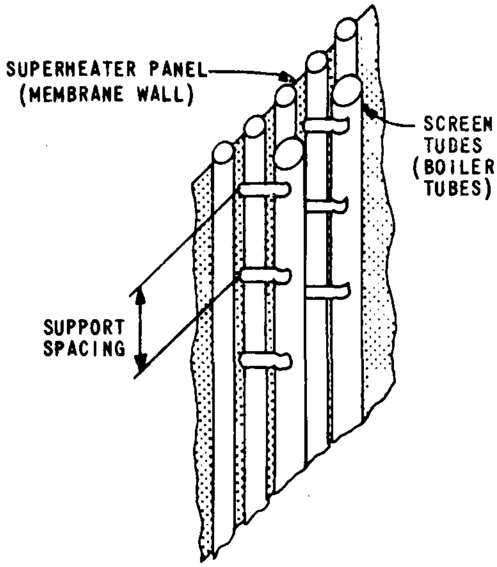
The Receiver System intercepts the solar energy redirected by the heliostats of the Collector System, converts this energy to thermal energy, and transfers this thermal energy to the receiver fluid changing the feedwater to superheated steam. The Receiver System includes the solar receiver with closure doors, associated pumps, valves, heat exchangers, traps, drains, and controls, the receiver support tower and the tower accessories. The feedwater and steam piping within the tower will be part of the Receiver Loop System.

1.2.4.1 Solar Receiver. The solar receiver will be structured with an external absorber surface as shown in Figure 1.2-3. 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 spaced, vertical tubes which form a screen in front of the welded membrane superheater tube panels; the economizer panels are located at the sides of the superheater panels. The screen tubes absorb part of the incident solar energy to maintain a relatively low heat flux required on the superheater tubes. The solar flux incident on the screen tubes is non-uniform around the receiver, however, the center-to-center spacing of the screen tubes 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.

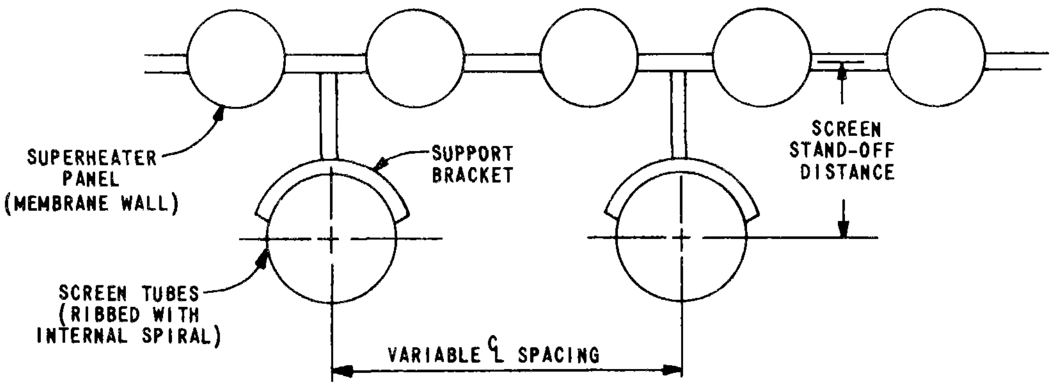
The flow sequence through the solar receiver will be as illustrated on Figure 1.2-4. Feedwater is introduced into the economizer tubes, where it is preheated; it is then injected into the drum, where it is mixed with saturated water. Slightly subcooled water flows from the drum, through a downcomer, and is pumped through supply pipes into headers which distribute the flow to the boiler screen tubes. The steam/water mixture (of average steam fraction less than 0.30) 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 screen tubes; this mixture flows through the downcomer to the pump and is recirculated. Moisture-free steam from the drum flows to the primary superheater, where initial superheating occurs. The steam leaving the primary superheater flows through a steam



SOLAR RECEIVER



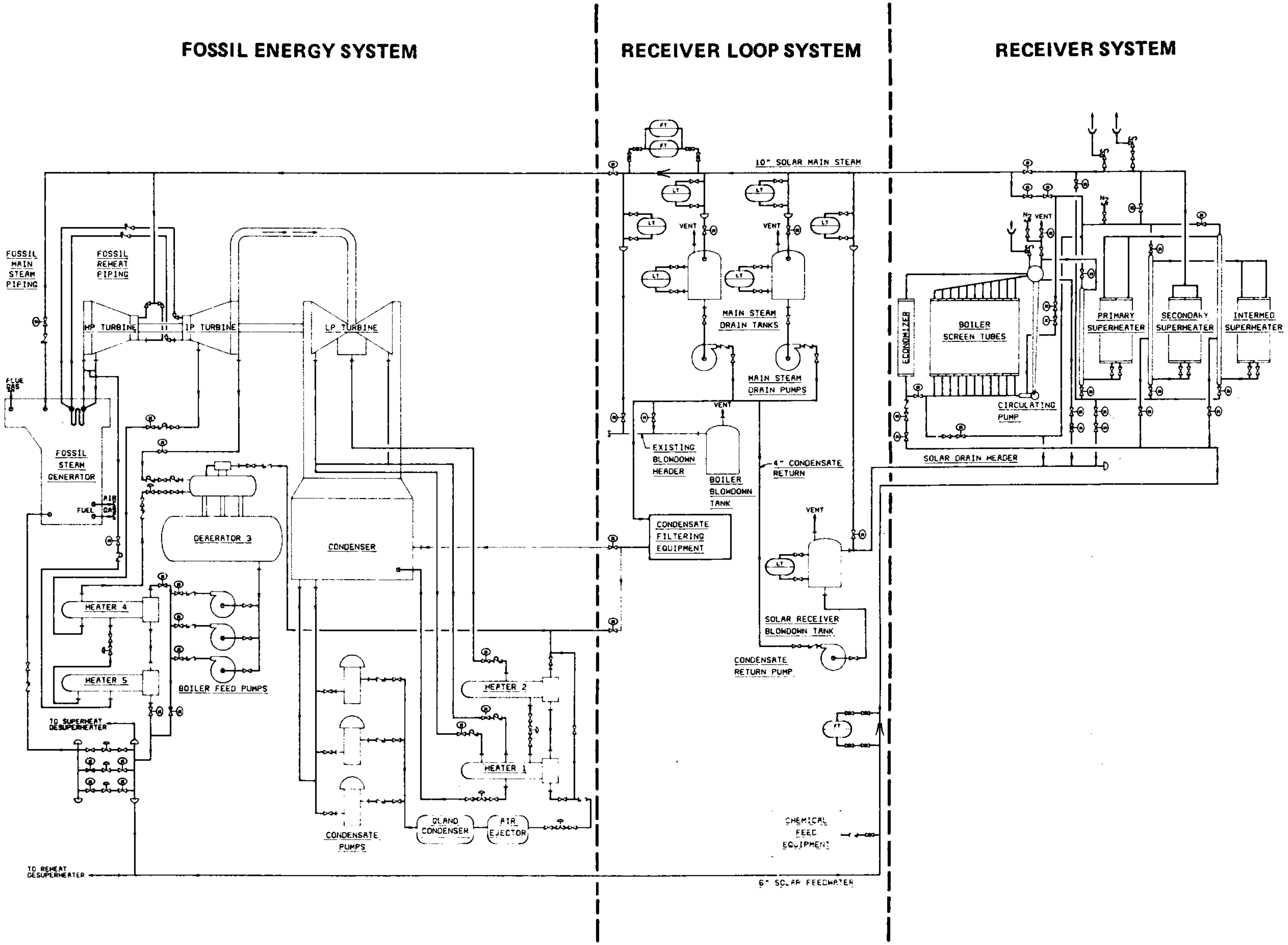
PANEL DETAIL



CROSS-SECTION

SOLAR RECEIVER
SCREEN TUBE CONCEPT

FIGURE 1.2-3



SCHEMATIC FLOW DIAGRAM OF
RECEIVER SYSTEM, RECEIVER LOOP
SYSTEM AND FOSSIL ENERGY SYSTEM

FIGURE 1.2-4

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 Receiver Support Tower. The receiver support tower supports the solar receiver, withstanding the gravitational, wind, and seismic loads. The tower also provides support for the feedwater and steam piping and the electrical cables running up and down the tower.

The tower will be a circular shell of steel-reinforced concrete, similar to a chimney, formed by slip or jump forming techniques. The tower will be tapered, having a larger diameter at the base than at the top; the wall thickness will be uniform from the base to the top. There will be no tower foundation per se; the tower will be anchored directly to competent bedrock via rock anchors.

Tower accessories will include an elevator, caged ladder, interior platforms, doorways, service crane atop the receiver, a ventilation system, lighting, communication equipment, and lightning protection. The elevator and ladder will extend the entire height to provide access to the receiver. Interior platforms will be located at the elevations of aircraft warning lights and near the top of the tower to house equipment. A personnel door and a truck door are located at the base of the tower.

1.2.5 Receiver Loop System

The Receiver Loop System provides the piping interface between the existing Fossil Energy System, and the Receiver System installed with the solar facility. A simplified flow diagram of the Receiver Loop System is shown on Figure 1.2-4. The Receiver Loop System transports feedwater to the Receiver System from the existing Fossil Energy System feedwater piping, for solar boiler feedwater makeup, and for attemperating sprays to control solar receiver steam temperatures. The Receiver Loop System also transports high pressure, high temperature solar steam from the Receiver System to the existing fossil main steam piping for delivery to the high pressure turbine steam chest. Piping, valves, instrumentation, and equipment to recirculate feedwater through the receiver for warming or freeze protection, and to drain the receiver piping and receiver loop piping are included as part of the Receiver Loop System.

Draining of the receiver and piping is necessary to remove collected condensate from the superheater during start-up, to maintain the proper drum water level, and to remove all water during system shutdown in winter months. Draining of all collected condensate from the main steam piping, prior to opening of the solar main steam stop valve, prohibits the potentially damaging introduction of water into the turbine unit. Drains from the receiver and drains from piping near the receiver are taken to the solar receiver blowdown tank located near the receiver base. Drains from the piping near Unit 1 are taken to the existing Fossil Energy System blowdown tank. Drains from the interconnecting main steam piping are taken to main steam drain tanks located adjacent to the piping at drain points. Condensate collected in the solar receiver blowdown tank and in the main steam drain tanks is pumped to the existing fossil blowdown tank for disposal, or alternatively, the condensate is returned to the existing Fossil Energy System condenser or deaerator.

The Receiver Loop System includes phosphate chemical feed additive equipment for chemical treatment of the solar receiver boiler water. The Receiver Loop System also includes filtering equipment for removal of chemical solids from the solar receiver boiler water recirculated to the Fossil Energy System condenser and deaerator.

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 not located within the receiver tower is supported from grade level by concrete and steel structures, with pipe support attachments as required for anchoring and guiding the piping during movement due to thermal expansion. The steam, feedwater, and condensate piping includes sufficient expansion loops to accommodate thermal expansion. The piping is insulated to reduce thermal losses.

1.2.6 Master Control System

The Master Control System will coordinate the operation of the collector, receiver, receiver loop, and fossil energy systems to ensure safe and proper operation of the entire integrated repowered plant. The Master Control System operates at the highest level in the control hierarchy shown on Figure 1.2-5. The 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 Master Control System provides the capability for automatic start-up, normal operation, and shutdown of the Collector, Receiver, and Receiver Loop Systems. The Master Control System will also issue emergency shutdown commands whenever critical process parameters exceed allowable operating limits.

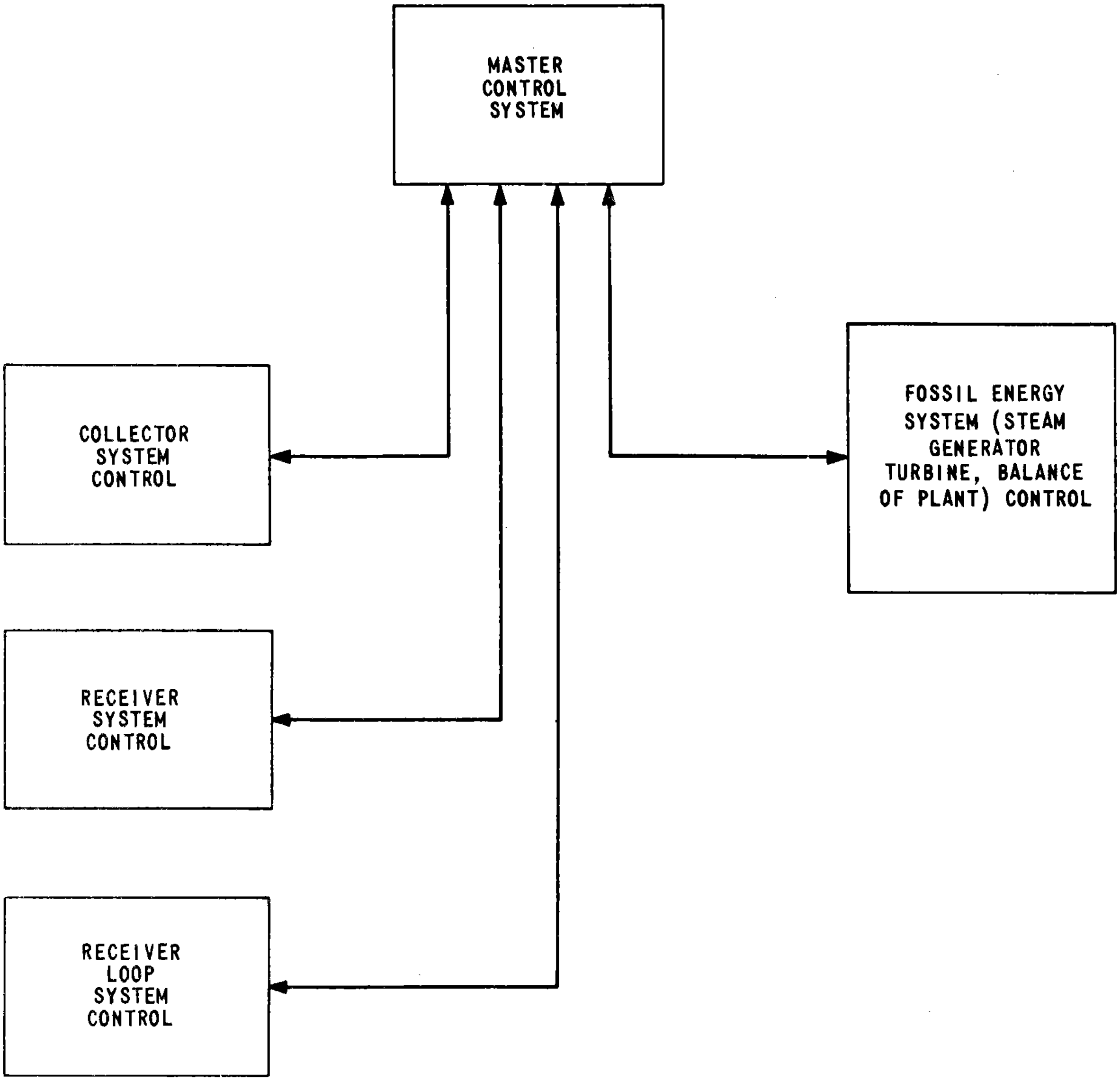
This system will also serve as a central data acquisition system which monitors, analyzes, and displays all critical solar system and subsystem parameters.

Process simulation capabilities which will be used to train the power plant operating personnel will also be provided.

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

1.2.7 Fossil Energy System

The Fossil Energy System provides a fossil energy source which is used to enhance performance and maintain normal plant operation during periods of reduced or no insolation. The Fossil Energy System consists of the existing fuel supply, fuel storage and transfer facilities, steam generator, turbine, condenser, condensate pumps, feedwater heaters, boiler feed pumps, and auxiliary power systems. The Fossil Energy System will provide for the transfer of heat during the combustion of the fuel (primarily natural gas with fuel oil being used as a secondary fuel source) to the feedwater and steam. This heat transfer will produce main steam at the pressure and temperature required by the high pressure turbine. In addition, heat will be transferred through the steam generator reheater to



CONTROL SYSTEM HIERARCHY

FIGURE 1.2-5

increase the temperature of the cold reheat steam to those conditions required by the intermediate pressure turbine.

A simplified flow diagram of the Fossil Energy System is shown as part of Figure 1.2-4. The Fossil Energy System will have two flow patterns: water-steam and fuel-air-flue gas.

Water leaving the condenser is pumped by the condensate pumps through two low pressure feedwater heaters and into the deaerator. The boiler feed pumps then pump the feedwater from the deaerator through the two high pressure feedwater heaters and into the steam generator. As this feedwater leaves the feedwater heaters, a portion of the feedwater is bypassed to the Receiver Loop System. In the steam generator, the feedwater is transformed to superheated steam. This main steam leaves the steam generator, is then mixed with the high pressure, high temperature steam from the solar receiver and enters the high pressure turbine. Steam from the high pressure turbine exhaust (cold reheat) is returned to the steam generator where it passes through the reheater section and returned (hot reheat) to the intermediate pressure turbine. Steam from the intermediate pressure turbine then enters the low pressure turbine and is exhausted to the condenser. Condensate drains and recirculated feedwater from the Receiver and Receiver Loop System are piped back to the Fossil Energy System and routed to either the deaerator, condenser or the existing steam generator blowdown tank as required.

Natural gas is supplied under pressure by the Transok Pipeline Company. The fuel is dehydrated and purified before passing through high and low pressure regulating stations. The fuel is then supplied to Unit 1 through a 0.36-m (14-inch) header. Fuel oil is stored in a single 15,900 m^3 (100,000 barrel), earth berm protected tank located northeast of the central complex area. Fuel delivery is by truck transport. Two fuel oil unloading pumps, each with a capacity of 0.028 $m^3/5$ (450 gallons per minute), are provided for transfer operations. Two centrifugal forced draft fans supply combustion air to the furnace. The combustion gas flows from the furnace through the economizer and air heater, before being discharged to the stack.

1.2.8 Specialized Equipment

The conventional components of the solar repowered plant (i.e., the pumps, motors, piping, and valves, as they are conventional power plant equipment) will be maintained by the existing maintenance facilities and thus do not require specialized treatment. Those components of the solar repowered plant that do require specialized maintenance equipment are the solar receiver of the Receiver System and the heliostats of the Collector System.

1.2.8.1 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 tubes or superheater panels 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 an internal caged ladder and elevator facilitating maintenance personnel access to the solar receiver atop the tower. The elevator will be designed to carry approximately 1,000 kg (2,200 lb). A hoist may be provided inside the tower to lift tools and equipment, loads too heavy for the elevator. The hoist will facilitate replacement of valves and pumps and other small components atop the receiver tower.

Replacement boiler tubes and superheater panels must be lifted into place externally of the support tower. For this operation, a polar crane and hoist, mounted on top of the solar receiver, will be employed. This crane can be rotated 360 degrees, enabling any screen tube or superheater panel to be easily reached. The crane telescopes radially, allowing the hoist to be withdrawn from the path of any "spillage" or misdirected insolation during the operation of the plant.

The polar crane will also facilitate the recoating of the solar receiver's high-absorptivity coating. A personnel scaffold will be supported from the crane, permitting easy access to all of the solar receiver's external surfaces. Reapplication of the coating will be accomplished via conventional spray equipment.

1.2.8.2 Specialized Heliostat Equipment. Unlike the solar receiver, the heliostats of the Collector System may 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 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 controller 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 DEFINITIONS OF TERMS

The definitions of terms used in the System Requirements Specification are as follows.

1.3.1 Solar Repowered Electric Generating Plant

A fossil electric generation plant which uses central receiver technology and solar energy to partially displace oil or natural gas as an energy source.

1.3.2 Capacity Factor, Annual-Nonsolar

Annual nonsolar MWh divided by the product of 8,760 h and plant or unit rating in MW.

1.3.3 Capacity Factor, Annual-Solar

Annual Solar MWh divided by the product of 8,760 h and plant or unit rating in MW.

1.3.4 Capacity Factor, Annual-Overall

Annual solar MWh plus annual nonsolar MWh divided by the product of 8,760 h and plant or unit rating in MW.

1.3.5 Design Point

The time and day of the year at which the system is sized with reference insolation, wind speed, temperature, humidity, dewpoint, and sun angles.

1.3.6 Repowering Per Cent--Design Point

Given design point insolation, the energy supplied to the turbine from the solar receiver is 20 per cent of the total energy supplied to the turbine at rated conditions.

1.3.7 Thermal Power, Fossil Heater Output

Thermal power input to working or transport fluids from the fossil heater after stack and miscellaneous losses.

1.3.8 Thermal Power, Prime Mover

Thermal power input to turbine or other prime mover at design point.

1.3.9 Thermal Power, Receiver Output

Thermal power derived from the receiver; does not include electrical parasitic or downcomer thermal losses.

1.3.10 Solar Fraction-Design Point

Thermal power from the receiver (less downcomer and piping losses) divided by total thermal power to the prime mover.

1.3.11 Solar Fraction-Annual

Ratio of solar energy to the process divided by the total energy consumption, annual average, measured at turbine inlet.

1.3.12 Solar Flux

The rate of solar radiation per unit area (watt/m^2).

1.3.13 Direct Insolation

Nonscattered solar flux falling on a surface of given orientation (watts/m^2).

1.3.14 Receiver Efficiency

Ratio of thermal power from the output of the receiver to the incident solar power upon the receiver.

1.3.15 Field Receiver Power Ratio

Maximum heliostat field power output divided by maximum receiver power absorption capability.

1.3.16 Fluid, Receiver

The fluid used to cool the solar receiver and distribute the absorbed solar energy to other parts of the system; heat transport fluid of the receiver.

1.3.17 Fluid, Working

The fluid used in the turbine or other prime mover.

1.3.18 Geometric Concentration Ratio

The ratio of the projected area of a reflector system (on a plane normal to the insolation) divided by absorber area.

1.3.19 Beam Pointing Error

The angular difference between the aim point and the beam centroid of a mirror.

1.3.20 Conversion Efficiency, Gross

Gross output provided by a conversion device divided by total input power at specified conditions.

1.3.21 Conversion Efficiency, Net

Actual net output (after deducting parasitics) provided by a conversion device divided by the required input power at specified conditions.

1.3.22 Nameplate Rating

The full-load continuous rating of a generator, prime mover, or other electrical equipment under specified conditions as designated by the manufacturer.

1.3.23 Hybrid System

A combination of solar and nonsolar technology to provide a single plant system that is capable of continuous operation.

1.3.24 Demand

The power versus time profile of the energy required to satisfy the energy needs of the final consumer.

1.3.25 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.

1.3.26 Payback Period

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

1.3.27 Present Value

The present value of capital and operating costs (or annual savings, brought over a given time period such as the life of the plant, is a single value of revenue requirement) or savings at a reference time that account for economic factors such as escalation rates and rate of return on the capital.

2.0 REFERENCES

2.1 STANDARDS AND CODES

The standards and codes which apply to the Solar Repowering for Electric Generation Project are listed below.

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

(2) OSHA Regulations.
  - (a) OSHA Title 29, Part 1910--Occupational Safety and Health Standards.

(3) ASME Boiler and Pressure Vessel Code.
  - (a) Section I--Power Boilers, including: ANSI B31.1-1977 Power Piping.
  - (b) Section II--Materials Specification.
  - (c) Section VIII--Unfired Pressure Vessels.

(4) NRC Regulatory Guide 1.60.

(5) NRC Regulatory Guide 1.61.

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

(7) National Fire Protection Association (NFPA) National Fire Codes--1979.

(8) Human Engineering Design Criteria.
  - (a) MIL-STD-810C.
  - (b) MIL-STD-1472.

(9) 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 (Tub. Exchanger Manufacturer's Association).
  - (d) Standard 650 of API (American Petroleum Institute)--Welded Steel Tanks for Oil Storage.
  - (e) Standards of ANSI (American National Standards Institute).

(f) Standards of ASTM (American Society for Testing Materials).

(g) Standards of NEMA (National Electrical Manufacturer's Association).

2.2 OTHER PUBLICATIONS AND DOCUMENTS

Other publications and documents which apply to the Solar Repowering for Electric Generation Project are listed below.

(1) G. J. Miller and J. B. Woodward, STEAEC--Solar Thermal Electric Annual Energy Calculator Documentation, SAND 77-8278, Sandia Laboratories, Livermore, January, 1978.

(2) Soil & Foundation Investigation Report, 5 MW STTF, Sandia Labs.

(3) "Wind Forces on Structures," ASCE Paper No. 3269. Transactions, American Society of Civil Engineers, Vol. 126, Part II, 1961.

(4) J. W. Doane, P. B. Bos, and others, The Cost of Energy from Utility-Owned Solar Electric Systems, A Required Revenue Methodology for ERDA/EPRI Evaluations, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, June, 1976.

(5) Collector Subsystem Requirements Specification, A10772, Issue C, Sandia Laboratories, Albuquerque, New Mexico, Livermore, California, October, 1979.

2.3 PERMITS AND LICENSES REQUIRED

The clearances from federal and state administrative agencies which are required for the Solar Repowering Electric Generation Project are listed below.

(1) Oklahoma Public Service Commission--Certificate of Public Convenience and Necessity.*

(2) Oklahoma Department of Labor--Pressure Vessel Permit and Inspection.

(3) Federal Aviation Administration--Notice of Intent to Construct.

Furthermore, the EPA may require the preparation of an Environmental Assessment and, possibly, an Environmental Impact Statement before federal funds can be allocated to the project.

In addition to the above clearances, there are several clearances which might be required for the project. The following list consists of the relevant agency, the clearance, and what action would necessitate obtaining the clearance.

(1) US Environmental Protection Agency--Wastewater Discharge (NPDES) Permit required if there is any change in the quantity or content of the discharge.

(2) Oklahoma State Department of Health--Open Burning Restrictions (Regulation 1) compliance required if open burning used during land clearing activities.

(3) Oklahoma Water Resources Board--Water Appropriation Permit required if there will be any increased use of ground water or surface water.

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*A Certificate of Public Convenience and Necessity will probably not be required. However, the Oklahoma Public Service Commission should be notified of the intentions of the Solar Repowering Project.

2.4 LAWS AND REGULATIONS

The laws and regulations which apply to the Solar Repowering for Electric Generation Project 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 of 1970.

(8) Oklahoma Department of Health Regulation 6.

(9) Oklahoma Department of Health Regulation 7.

3.0 REQUIREMENTS

The solar repowered plant shall be designed to meet the performance requirements of this section. This specification is applicable as a design requirement only to the new or modified portions of a solar repowered plant. The solar retrofit design specifications shall make maximum use of completed or ongoing DOE solar R&D activities. Design emphasis shall be on the solar/non-solar interfaces.

3.1 SITE

Site preparation work will be minimized to reduce costs and preserve natural drainage systems as much as possible. The dam for the farm pond will be removed and the natural drainage channels will be graded only as necessary to permit access of maintenance vehicles to the heliostats. Grading will be required in the vicinity of the tower and along access roads.

Site development work will primarily consist of construction of access roads and parking, and security fencing. No lighting will be required except at the receiver tower.

3.1.1 Drainage

The natural present site drainage will be preserved, augmented only by drainage ditches adjacent to the access roads, and culverts where the roads cross natural drainage patterns.

3.1.2 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-metre (20-foot-wide) traffic lane, 1.5 metre (5-foot-wide) shoulders, and contoured drainage ditches.

A secondary 3-metre (10-foot-wide) 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.

3.1.3 Security Fencing

The existing primary fencing section which now crosses the heliostat field area will be reused and supplemented with new fencing to surround the solar facility. The existing perimeter fences of barbed wire along the site property boundaries will be removed where security fencing is provided.

3.1.4 Foundations

The competent limestone has a very high load carrying capability. The allowable design bearing capacity has been conservatively established at

7.2 kPa (150 kips per square foot), so the size of foundations bearing on the sound and unweathered limestone formation will be governed by the minimum practical dimensions as determined by stresses due to shears and bending moments within the foundation rather than by the allowable bearing capacity of the limestone.

3.2 SITE FACILITIES

The existing facilities at Northeastern Station will be used to supply most of the auxiliary services required by the new solar repowering equipment. The following paragraphs summarize the required services and the plans to provide these services.

3.2.1 Cooling Water

The receiver fluid circulating pump located in the solar receiver will utilize a closed-loop air to water heat exchanger for providing cooling water to the pump bearings. There are no requirements for utilization of station cooling water.

3.2.2 Service Water

No requirements for service water have been identified. The design will include provisions for possible future connection to the existing plant service water system.

3.2.3 Control Air

Since all control actuators will be electrically powered, there are no requirements for control air.

3.2.4 Service Air

A source of service air will be required during the construction phase and during periodic maintenance of equipment. A portable air supply system will be provided to meet these requirements.

3.2.5 Nitrogen

A separate nitrogen supply system will be provided for the solar repowering equipment. The system will be capable of supplying the maximum demands for inerting the receiver, feedwater pipe, and transport pipe during plant shutdowns. The requirements of the nitrogen storage system are as follows.

	Actual Volume cu m (cu ft)	Nitrogen Volume at 21 kPa (3 psi) and 21 C (70 F) scm (scf)
Receiver		
Superheater	2.0 (74)	2.5 (87)
Screen tubes	3.0 (109)	3.7 (129)

	Actual Volume cu m (cu ft)	Nitrogen Volume at 21 kPa (3 psi) and 21 C (70 F) scm (scf)
Economizer	1.6 (57)	1.9 (67)
Drum	10.2 (360)	12.0 (425)
Total	16.8 (600)	20.1 (788)
Feedwater Pipe	24.3 (857)	28.7 (1,012)
Main Steam Transport Pipe	45.2 (1,596)	53.4 (1,885)
Total	86.3 (3,053)	102.2 (3,605)

During normal overnight shutdowns, the closure doors on the receiver and insulation on the main steam transport 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 1 or 2 days 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 28.3 scm (1,000 scf).

Nitrogen inerting will automatically be initiated whenever the system pressure drops below 0.14 MPa (5 psi).

The nitrogen gas storage containers will be standardized compressed gas bottles with an interconnecting manifold similar to the existing system at Unit 1. The total storage capacity will be sufficient to inert the total system at 0.12 MPa (3 psi) plus 30 to 50 per cent margin to allow for leakage. The system will be capable of being refilled by local suppliers.

3.2.6 Fire Protection

Hand held and moveable 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.

3.2.7 Communications

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

3.2.8 Water Treatment

The existing plant water treatment facilities will be used for analysis and treatment of the solar receiver water. No modifications to the existing facilities are planned.

3.2.9 Control Room

The solar equipment control panel and the Master Control System programmer's console will be located in the main control room for Units 1 and 2. Figure 3.2-1 shows the planned layout of the control room.

3.2.10 Control Equipment Room

The control equipment cabinets and computers will be located in an existing control equipment room adjacent to the main control room. No modifications to this room are planned. Figure 3.2-1 shows the planned arrangement of this equipment.

3.2.11 Personnel Facilities

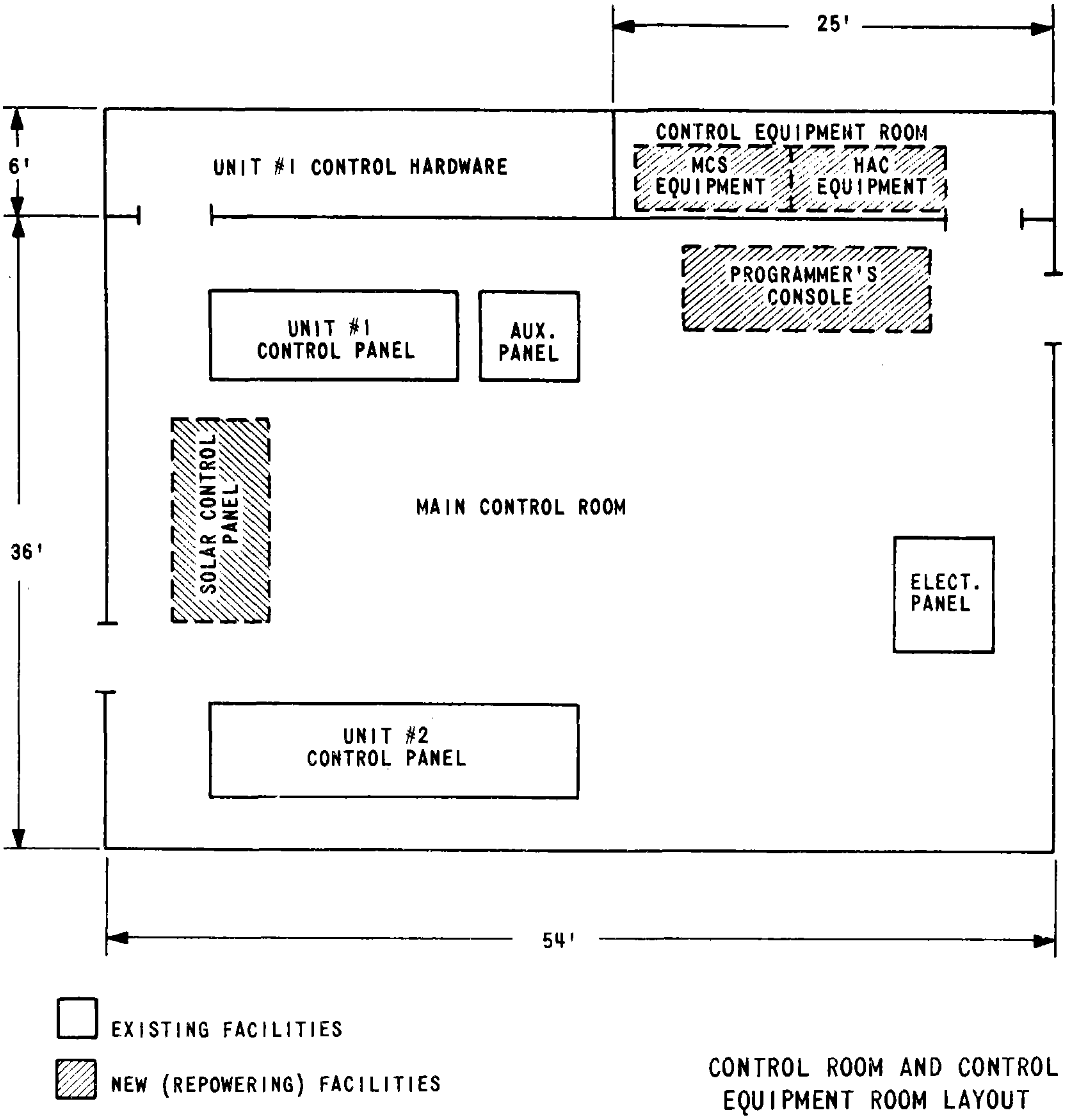
The existing plant office building and parking lot will accommodate the additional personnel needed for solar repowering. No modifications to these facilities are planned.

3.2.12 Storage and Maintenance

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

3.2.13 Electrical Power

Electrical power will be provided to all solar plant loads required by the various auxiliary devices during shutdown, start-up and operation of the solar repowering plant as shown on Table 3.2-1. The electrical power supply can be divided into two categories--normal and uninterruptible auxiliary ac power. Normal ac power, backed up by an emergency standby diesel generator, will be used to supply power to such loads as the heliostat drives, the solar receiver boiler recirculation pump, motor-operated valves, and the receiver tower crane, elevator, aviation obstruction lighting, etc. Uninterruptible ac power will be supplied to specific loads, associated with the master control system, computers, and the multiplexing equipment at the receiver tower, where an interruption of power even for a



CONTROL ROOM AND CONTROL EQUIPMENT ROOM LAYOUT

FIGURE 3.2-1

TABLE 3.2-1. SOLAR PLANT AUXILIARY POWER REQUIREMENTS

Solar Plant System	Design Point kW	Start-up kW	Shutdown kW
Collector System	1,144*	1,144*	1,144*
Receiver System	83	109	70
Master Control System	32	32	32
Miscellaneous	27	27	54
Total	1,286	1,312	1,300

Assumptions:

Line Loss	5 per cent
Transformer Loss	2 per cent
Motor Loss	10 per cent
Inverter Loss	20 per cent

*Peak power for total heliostat field. Average power requirement will be about 68 kW.

few cycles cannot be tolerated under any normal or abnormal operating conditions of the solar repowering plant.

3.2.13.1 Solar Plant Normal Auxiliary AC Power. Figure 3.2-2 shows a one-line diagram of the normal auxiliary ac power system. Power will be tapped from the existing 4,160 volt auxiliary buses of Unit 1 and carried by 5 kV solid dielectric above grade cable routed in conduits to a 4,160 volt metal enclosed switchgear to be located near the base of the receiver tower. In order to obtain redundancy in the power supply system, two sources of power, one normal and the other standby, will be tapped from the existing switchgear buses. Automatic high speed source transfer switching will be provided between normal and standby sources to maintain a high degree of service continuity. In the event of a total loss of plant auxiliary power, an emergency power supply will be required to slew heliostats away from the receiver as quickly as possible to prevent damage to the receiver. This emergency power will be supplied by a quick-start diesel generator unit to be located near the solar tower.

Two 4,160 volt, three phase feeder circuits will distribute power to 10 heliostat field transformers. The heliostat field transformers will be the low profile pad-mounted type with 4,160 volt primary windings and 120/208 volt secondary windings. Each unit will have six load-break primary bushing wells constructed for primary system loop-feed dead front design. Power cable serving the transformers will be direct buried solid dielectric cable.

A reasonable level of reliability is desirable for the primary distribution system serving the heliostats. The system will be designed such that it will normally operate as an open-loop system, as shown in Figure 3.2-2 Distribution switching is 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.

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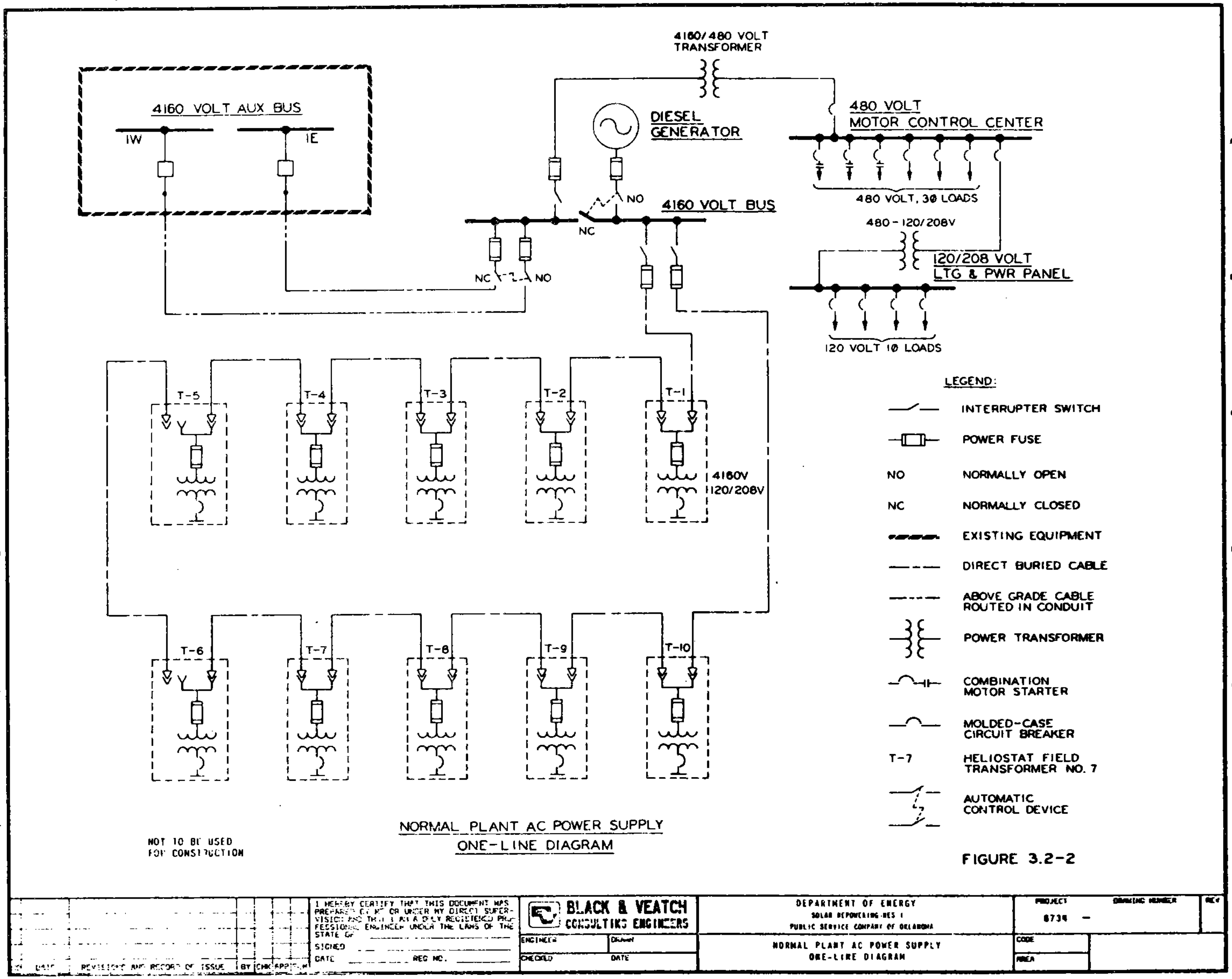


FIGURE 3.2-2

Low voltage three phase power to motors, motor-operated valves and other loads will be distributed by two sections of a 480 volt motor control center to be located at Elevation 106.7 metre (350'-0") of the receiver tower. A 4,160-480 volt pad mounted transformer located near the 4,160 volt switchgear will supply power to the motor control center. The primary side of the transformer will be fed by the 4,160 volt switchgear.

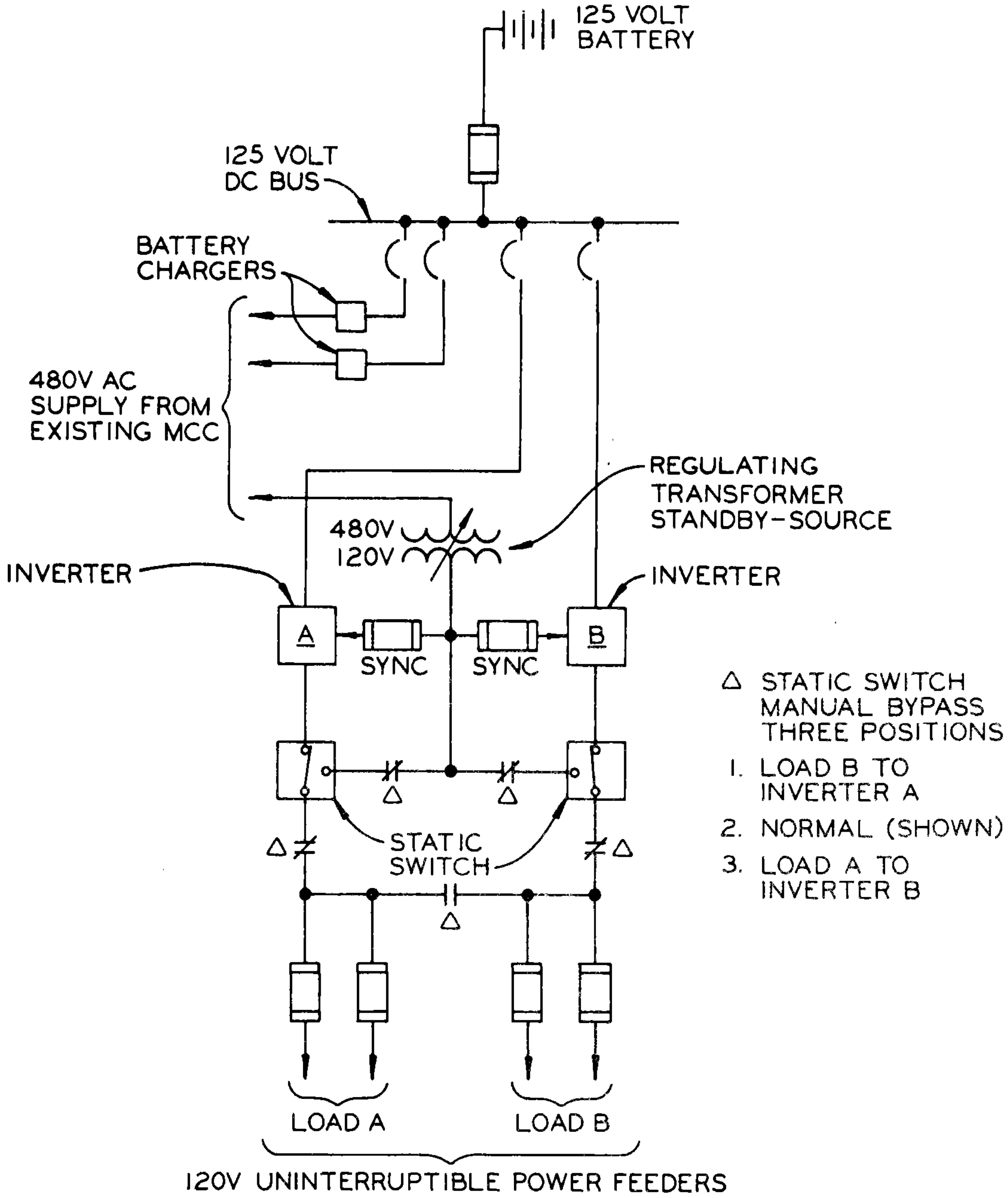
Single phase 120 volt power to lighting, receptacle, and other small single phase loads will be supplied by a 480-120/208 volt indoor dry type transformer and a lighting and power distribution panel.

3.2.13.2 Solar Plant Uninterruptible Auxiliary AC Power. Figure 3.2-3 shows the one-line diagram of the uninterruptible power system. Two full-capacity static inverters will supply single phase 120 volt ac power to all uninterruptible loads. Under normal operating conditions each inverter will carry about half of the total uninterruptible load. In the event of an inverter component failure, a static switch will transfer the inverter load to a regulated station ac supply within 1/4 of a cycle. When the inverter supply is restored, the static switch will automatically transfer the load back to the inverter. To facilitate maintenance, one inverter can be taken out of service, while the other inverter carries the entire uninterruptible load. This transfer of load from one inverter to the other will be accomplished without power interruption to the load by a manual bypass switch.

Synchronism between the inverters and the standby station supply will be maintained at all times so that the transfer of load can be done between systems in synchronism with each other.

A dc input to the inverters will be provided by a 125 volt battery and two full-capacity battery chargers. Under normal operating conditions the chargers will supply the load and the battery will be floating. In the event of a loss of ac supply to chargers, the battery will supply dc power to the inverters. The battery will be sized to keep the inverter running for at least 1 hour after loss of both chargers.

The uninterruptible power supply equipment will be located in the existing main plant building.



SOLAR PLANT UNINTERRUPTIBLE AUXILIARY SUPPLY
ONE LINE DIAGRAM

FIGURE 3.2-3

3.3 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 3.4 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 north half of the receiver while limiting the peak incident heat flux to 660 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 Master Control System for emergency defocusing of the reflected energy or to protect the heliostat array against environmental extremes. Emergency defocusing will reduce peak incident radiation on the receiver to less than 3 per cent of initial value within 120 seconds. 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.

3.3.1 Collector Field

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

(1) Heliostats will be located within the plant site presently owned by Public Service of Oklahoma, as illustrated in Figure 1.2-1. Heliostat pedestals will be located within an area 880 m (2,887 ft) wide, with its western boundary located 60 m (197 ft) east of the Unit 1 & 2 cooling towers, and its eastern boundary 20 m (66 ft) west of the road easement bounding the plant site on the east.

(2) The collector field will direct 82.45 MWt toward the receiver at the design point with a reference insolation of 0.95 kW/m^2.

(3) The collector field will produce an incident heat flux distribution on the receiver which is compatible with the requirements specified in Section 3.4.

(4) The locations of heliostats within the field will be determined by maximizing 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.

3.3.2 Heliostat Performance

Heliostat performance requirements have been based on the requirements specified in the Collector Subsystem Requirements Specification, A10772, Issue C, October 10, 1979, and modified as necessary to reflect specific performance and environmental criteria.

In order to attain overall plant field performance such that 95 per cent of the redirected energy will impinge on the receiver with an incident angle of less than 60 degrees, the following requirements have been established for designing and evaluating individual heliostats.

(1) Maximum beam pointing error (tracking accuracy) will be limited to 1.5 mrad standard deviation for each gimbal axis under the following conditions.

(a) Wind--heliostats operational up to 12 m/s (27 mph) wind.

(b) Temperature-- -27 C to 47 C (-17 F to 117 F).

(c) Gravity Effects--at all elevation and azimuth angles that could occur in a heliostat field.

(d) Azimuth Angles--at all angles except during gimbal lock.

(e) Sun Location--at least 0.26 rad (15 degrees) above horizon, any time of year.

(f) Heliostat Location--any position in the field.

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

(2) Beam quality will be such that a minimum of 90 per cent of the reflected energy at target slant range falls within the area defined by the theoretical beam shape plus a 1.4 mrad fringe width. Heliostat beam quality will be met throughout 60 days without realignment. Beam quality requirements are applicable under the following conditions.

(a) Wind--none.

(b) Temperature-- -27 C to 47 C (-17 F to 117 F).

(c) Gravity effects--at all elevation and azimuth angles that could occur in a heliostat field.

(d) Sun location--at least 0.27 rad above horizon, any time of year.

(e) Heliostat location--any position in the field and any slant range.

(f) Operating mode--tracking on solar receiver.

(g) Facet alignment--each heliostat shall be aligned for its aim point on the solar receiver.

(h) Theoretical beam shape--the theoretical beam contour, determined by HELIOS, is the isoflux contour that contains 90 per cent of the total power. This isoflux contour will be increased by 1.4 mrad fringe. The HELIOS computer code is available through Sandia.

(3) Overall structural support shall limit reflective surface static deflections to an effective 1.7 mrad standard deviation for a field of heliostats in a 12 m/s (27 mph) wind.

Wind deflections of the foundation, pedestal, drive mechanism, torque tube, and mirror support members shall be included, but not the slope errors due to gravity and temperature effects. Wind deflection limits apply to the mirror normal (not reflected beam) for each axis fixed in the reflector plane. Both beam quality and beam pointing are affected.

To assure that the net slope error of a field of heliostats is less than 1.7 mrad, the rms value of the slope error taken over the entire reflective surface of an individual heliostat, computed under the worst conditions of wind and heliostat orientation (but excluding foundation deflection), shall be limited to 3.6 mrad for a single heliostat. This limit represents a 3-sigma value for the field derived by subtracting foundation deflection from the total surface slope error (1.7 - .5 = 1.2) mrad standard deviation x 3 = 3.6 mrad 3-sigma. The conditions under which this requirement applies are as follows.

(a) Wind, including gusts--12 m/s (27 mph) at 10 m (33 ft) elevation.
(b) Temperature-- -27 C to 47 C (-17 F to 117 F).
(c) Heliostat location--any position in the field at any time of the year.
(d) Gravity effects--not included.
(e) Mirror module waviness--none.
(f) Facet alignment error--none.

(4) The allowable tilt and/or torsional rotation of a heliostat foundation shall not exceed ± 1.5 mrad total angular deflection per axis, when the heliostat is subjected to a 12 m/s (27 mph)

operational wind load. This total deflection shall, in addition to elastic response, include the amount of plastic or permanent deflection, including any wobble (looseness) resulting from a prior 22 m/s (50 mph) wind experience. The allowable plastic or permanent deflection of the foundation resulting from a 22 m/s (50 mph) wind load shall not exceed ± 0.45 mrad.

Both deflection allowances are 3-sigma limits expressed for a single heliostat/foundation field position, and are computed under the worst condition of wind and heliostat orientation. For a full field of heliostat foundations, the effective limits will result in one standard deviation or 1/3 of the deflection allowances specified for a single foundation.

The deflections specified are applicable at the foundation-to-heliostat interface located on a plane parallel to and approximately 50.8 mm (2 inches) above the pier concrete surface, which is represented by the underside of the heliostat pedestal mounting flange.

Standard deviation as used in these requirements will be determined from a sample of at least 20 data points from each individual heliostat tested.

3.3.3 Collector Control System

The collector control requirements are as follows.

(1) The Collector System shall function as appropriate for all steady-state modes of plant operation. This will include the capability of controlling the number of heliostats in tracking mode so as to vary the redirected flux to the receiver between zero and the maximum achievable level with step changes no larger than 10 per cent of the total collector field output.

(2) Drive systems must be capable of positioning a heliostat to stowage, cleaning, or maintenance orientation from any operational orientation within 15 minutes.

(3) Elevation and azimuth drives shall not drift from last commanded positions due to environmental loading.

(4) Drive systems must be capable of resolving south field control singularity (i.e., "over-the-shoulder" limits or gimbal lock) within 15 minutes.

(5) Drive system shall provide for cost effective stowage of the reflective surface to minimize reflected beam safety hazards and dust or dirt build-up on the mirrors. Heliostat orientation will be available to master control at all times. Calculated gimbal angles are acceptable; orientation sensors are not required.

(6) Heliostat control shall be accomplished by a computer. Control functions shall be accomplished as follows.

Heliostat Array Controller (HAC) shall:

(a) Initiate operational mode commands to HFC.
(b) Address commands to HFC groups or individual HC.
(c) Respond to MCS commands and requests.
(d) Interface with beam characterization system.
(e) Provide time base.

Heliostat Field Controller (HFC) shall:

(a) Determine individual heliostat azimuth and elevation position requirements.
(b) Transmit position requirements to HC.
(c) Transmit status and data to HAC.
(d) Initiate safe stowage command upon loss of HAC communication.
(e) Control groups of HCs.

Heliostat Controller (HC) shall:

(a) Control drive motors.
(b) Provide heliostat axis position data to HAC.

(7) Reliable plant power is to be supplied to the heliostat array controller, heliostat field controllers, and each heliostat junction box.

(8) The heliostat array controller shall be configured such that the master control system can automatically achieve integrated control of, and alarm the collector system. The overall interface signals for plant operation are as follows.

(a) Control commands.

(b) Operational data requests.

(c) Operational alarm data outputs.

(9) The master control system will perform the data collection function for evaluation of the plant system. The evaluation interface signals for the plant are as follows.

(a) Evaluation of data requests.

(b) Evaluation of data outputs.

Each of these sets of HAC/MCS signals is further designated as either continuous (i.e., automatically generated at regular preprogrammed intervals) or on-demand by an operator (i.e., issued upon request or over selectable intervals). Error checking shall be employed in all message transfers.

(10) The heliostat array controller shall provide heliostat data, control, and positioning required for beam characterization by directing a heliostat to focus on the beam characterization system (BCS) target. The BCS will be commanded to execute data acquisition and return the beam centroid location to the HAC. Additional measurements will be made as needed to resolve all tracking error terms. In cases of large errors, the HAC will be requested by the BCS to adjust the heliostat alignment to bring the heliostat on target.

(11) The HAC is expected to tolerate power transients which are commercially acceptable to the HAC purchased equipment suppliers. The heliostat field controller and heliostat controllers shall operate through the following power transient conditions.

(a) Increasing Transient--one cycle of the fundamental frequency at 1.7 PU voltage followed by an exponential decay back to the original voltage in five cycles.

(b) Decreasing Transients--a voltage dropout (zero volts) for three-cycle maximum of the fundamental frequency.

(12) The Collector System control wiring shall be designed to minimize susceptibility to electromagnetic interference and to minimize the generation of conducted or radiated interference.

3.3.4 Heliostat Foundations

The foundations for the heliostats shall provide a stable support in order that the performance objectives specified in Section 3.3.2 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 RECEIVER SYSTEM

The Receiver System shall provide a means of transferring the incident radiant flux energy from the Collector System into a suitable receiver fluid and transporting the energy charged fluid to the Fossil Energy System.

3.4.1 Structural Design

The receiver and tower shall be designed to provide access for maintenance and inspection of tower structure, receiver, receiver fluid, instruments and controls, power conversion equipment that may be located on the tower, utilities, etc. Consideration will be given to ease of maintenance. Adequate provisions will be made to ensure crew safety at all times for required operations, inspection, maintenance and repair. The receiver design shall be in accordance with ASME Boiler Codes. The structural design of the receiver and support tower will be as shown on Figure 3.4-1.

3.4.2 Receiver

The Receiver will be an external receiver with closure doors. The receiver design and operating parameters will be as follows.

(1) Fully circumferential area of economizer and boiler screen tubes and flat projected area of superheater membrane tubes--597.4 m^2 (6,430 ft^2).

(2) Peak flux at equinox noon--0.62 MWt/m^2.

(3) Average flux at noon of equinox--0.277 MWt/m^2.

(4) Receiver power rating at noon of equinox--82.452 MWt.

(5) Receiver fluid is water and steam.

(6) Receiver fluid velocity at outlet of superheater--29.18 m/sec (95.74 ft/sec).

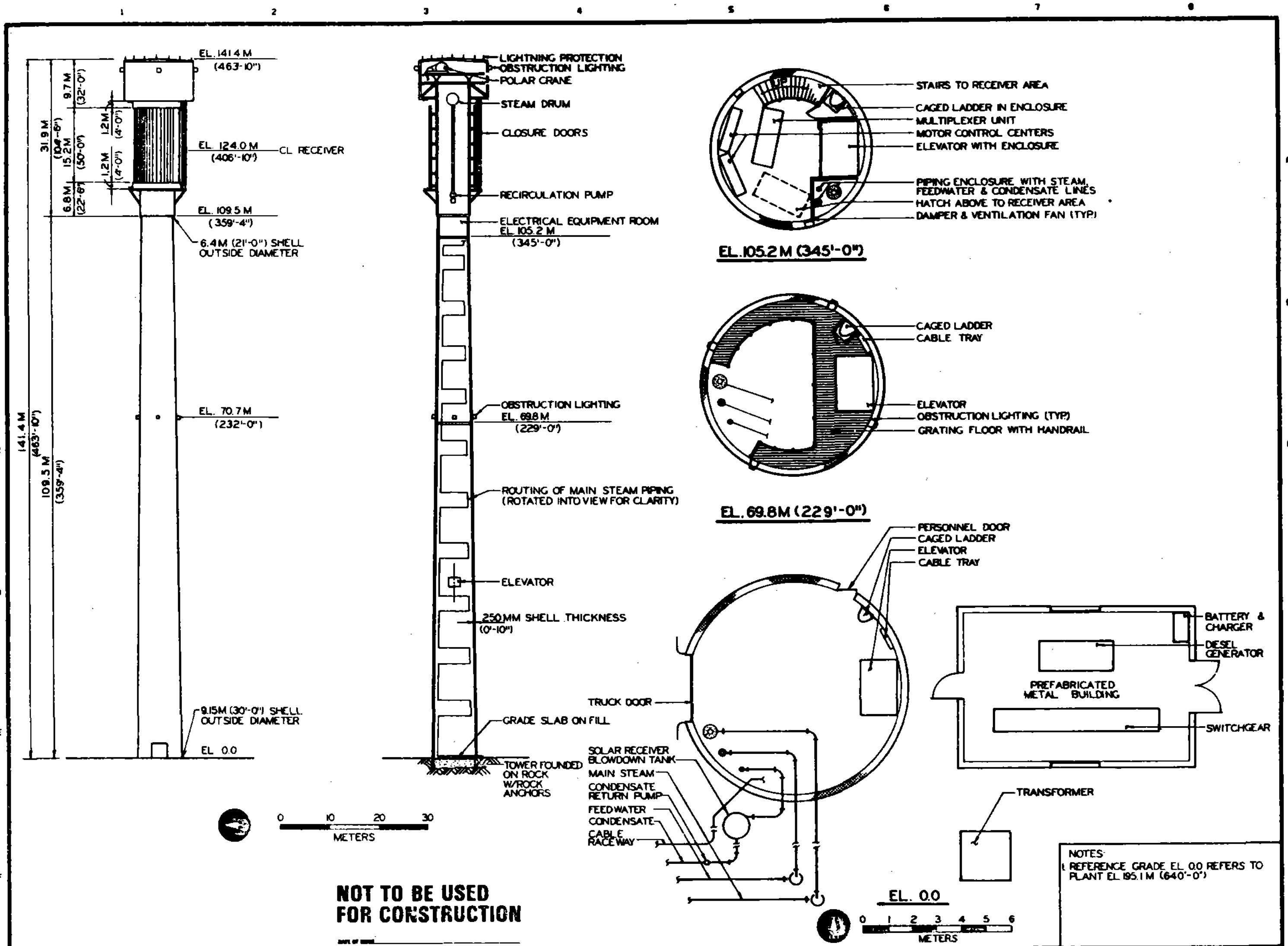
(7) Receiver fluid mass flow rate at outlet of superheater--111,260 kg/h (245,300 lb/h).

(8) Receiver peak upset tube wall temperature--619 C (1,146 F) where tube wall temperature = 1/2 (TOD + TID). TOD = Outside wall temperature, TID = inside wall temperature.

(9) Receiver overall average tube wall temperature--373.38 C (704.08 F).

(10) Receiver fluid inlet temperature--246 C (475 F).

(11) Receiver fluid outlet temperature--544.2 C (1011.6 F).



NOTES:
1. REFERENCE GRADE EL 0.0 REFERS TO PLANT EL 195.1 M (640'-0")

NOT TO BE USED FOR CONSTRUCTION

NO	DATE	REVISIONS AND RECORD OF ISSUE	BY	CHK	APP	FLM

I HEREBY CERTIFY THAT THIS DOCUMENT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF
SIGNED
DATE REG NO.

BLACK & VEATCH CONSULTING ENGINEERS
ENGINEER RPM DRAWN JC
CHECKED DATE

DEPARTMENT OF ENERGY
SOLAR REPOWERING - NCS 1
PUBLIC SERVICE COMPANY OF OKLAHOMA
RECEIVER TOWER

PROJECT 8734 - DRAWING NUMBER REV
CODE
AREA

FIGURE 3.4-1

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

(13) Worst case tube life (fatigue life) per Section 1 ASME Boiler Code.

(14) Overall receiver efficiency--88.9 per cent at equinox noon.

3.4.3 Receiver Fluid

The receiver water quality shall be maintained within the following limits.

Feedwater Limits	
pH	8.8-9.2
Oxygen, ppm	0.007 (max.)
Fe, ppm	0.01 (max.)
Cu, ppm	0.005 (max.)
Total Hardness, ppm	0
$Si\ O_2$, ppm	0.02 (max.)
Organic, ppm	0
Boiler Water Limits	
Total Solids, ppm	15 (max.)
$Na_3\ PO_4$, ppm	3-10
OH^-	1 (max.)
pH	9-10
Silica, ppm	0.32

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

3.4.4 Tower

The tower that supports the receiver, piping, and other elements of the Receiver System shall have the following characteristics.

(1) Tower height--109.5 m (359'-4").

(2) Structural type--reinforced concrete cylinder.

(3) Base outside diameter--9.1 m (30'-0").

(4) Top outside diameter--6.4 m (21'-0").

(5) Description of tower foundation--secured to competent bedrock with rock anchors.

(6) Material--reinforced concrete.

(7) Structural integrity shall be provided in accordance with the environmental criteria presented in Section 4.0.

(8) The following approximate wind profile as a function of height above ground level shall be used for tower design. At height Z, in metres,

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

where

V_z = velocity at height Z

V_{10} = velocity at 10 metres

Wind analyses shall satisfy the requirements of the latest edition of ANSI A58.1.

3.4.5 Receiver Controls

The solar receiver shall be designed to provide the following types of controls.

(1) Feedwater flow control--to maintain proper water level in the drum.
   (a) Normal operation--feedwater flow demand established by measured steam flow less attemperator flow.
   (b) 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.

(2) Economizer Recirculating Valve Control--to provide a flow path for the recirculating pump discharge during start-up and shutdown.

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

(4) 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 are directed away from the hot panel(s).

3.5 RECEIVER LOOP SYSTEM

The Receiver Loop System provides the piping interface between the existing Fossil Energy System and the Receiver System installed with the solar facility. The requirements of the Receiver Loop System are as follows.

3.5.1 Operating Requirements

The Receiver Loop System operation is based on the solar receiver operating modes, including normal operation, routine shutdown and start-up operation, and cold start operation. The Receiver Loop System response to these modes of operation is in accordance with the following.

3.5.1.1 Normal Operation. Under normal operation, feedwater is supplied to the solar receiver to maintain the proper drum level, and solar generated main steam is supplied from the solar receiver superheater outlet to the Fossil Energy System main steam piping. At normal operating pressure and temperature conditions, the accumulation of condensate at drain points in the receiver loop system piping is not expected. The main steam piping drains will be closed under normal operation, except for emergency conditions. The receiver blowdown tank will collect water under normal operation only if water is drained from the solar receiver drum for control of receiver chemistry. The condensate return pumps will operate during these periods of draining based on tank water level. The feedwater supplied to the receiver will be batch treated by the addition of phosphate to control the solar receiver water chemistry within the ranges presented in Section 3.4.3, Receiver Fluid.

3.5.1.2 Routine Shutdown and Start-up Operation. The Receiver Loop System provides feedwater to the receiver, and returns condensate from the receiver, for receiver warming before start-up and for freeze protection during shutdown operation in winter months. After completion of pre-warming by feedwater recirculation, the loop system main steam piping provides steam from the Fossil Energy System for final warming of the receiver above 116 C (240 F) to near the full load saturation temperature in preparation for start-up.

During shutdown and start-up operation, condensate collected in the receiver superheater and the main steam piping is drained to the receiver blowdown tank and main steam drain tanks. The collected condensate is pumped to the Fossil Energy System for return to the deaerator or condenser, or for disposal to the existing fossil steam generator blowdown tank. The draining and pumping of condensate is automatically initiated and terminated by level sensing devices at the piping drain points and in the associated tanks. Condensate returned to the deaerator or condenser is processed through filtering equipment to remove chemicals potentially carried from the receiver drum.

3.5.1.3 Cold Start Operation. The Receiver Loop System provides feedwater for filling the receiver and utilizes main steam from the Fossil Energy System for main steam pipe and receiver superheater warm-up. The condensate collected during warm-up is returned by the loop system to the fossil cycle.

3.5.2 Design Requirements.

The Receiver Loop System piping and valves will be designed in accordance with the ANSI Power Piping Code, B31.1. The loop system pressure vessels will be designed in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. The specific design requirements for major system components will be as follows.

3.5.2.1 Main Steam Piping. The loop system main steam piping design conditions are based on the maximum expected sustained pressure at the piping inlet, plus a suitable margin, as follows.

Design pressure	14.75 MPa (2,140 psi)
Design temperature	549 C (1,020 F)
Steam flow rate	111,260 kg/h (245,300 lb/h)

The main steam piping wall thickness and pipe diameter will be selected to achieve a reasonable fluid velocity, and to limit the piping pressure drop to a value that is compatible with the pressure requirements at the interfaces with the Receiver and Fossil Energy systems.

3.5.2.2 Feedwater Piping. The loop system feedwater piping design conditions are based on the maximum system pressure at feedwater pump shutoff operation as follows.

Design pressure	21.27 MPa (3,085 psi)
Design temperature	260 C (500 F)
Water flow rate	111,260 kg/h (245,300 lb/h)

The feedwater piping size will be selected from standard piping sizes with nominal wall thicknesses. The allowable feedwater piping pressure drop will be compatible with the requirements at the interfaces with the Receiver and Fossil Energy Systems.

3.5.2.3 Condensate Drain Piping. The loop system condensate drain piping design will be based on the maximum expected return water flow conditions as follows.

Design pressure	0.89 MPa (100 psi)
Design temperature	121 C (250 F)
Water flow rate	34,000 kg/h (75,000 lb/h)

3.5.3 Interface Requirements

The requirements at the interfaces with the Receiver Loop System are as follows.

3.5.3.1 Feedwater Interfaces. The Receiver Loop System interfaces with the Fossil Energy System at the feedwater piping after the fifth feedwater heater, ahead of the fossil feedwater regulating valves. The Receiver Loop System interfaces with the Receiver System at the regulating valves at the receiver economizer inlet and attemperating spray headers. The conditions at the feedwater interfaces vary with unit load, feedwater flow rate, and receiver steaming capacity. The maximum and minimum conditions corresponding to the required operating modes are as follows.

Normal Operation - Design Point Conditions

	Fossil Energy System Interface	Receiver System Interface
Feedwater flow	111,260 kg/h (245,300 lb/h)	111,260 kg/h (245,300 lb/h)
Pressure	18.96 MPa (2,750 psi)	17.27 MPa (2,505 psi)
Temperature	247 C (477 F)	246 C (475 F)

Start-up and Shutdown Operation

	Fossil Energy System Interface	Receiver System Interface
Maximum Flow Condition		
Feedwater Recirculation	34,000 kg/h (75,000 lb/h)	34,000 kg/h (75,000 lb/h)
Pressure	20.82 MPa (3,020 psi)	19.68 MPa (2,855 psi)
Temperature	186 C (366.5 F)	185 C (365.5 F)
Minimum Flow Condition		
Feedwater Recirculation	2,300 kg/h (5,000 lb/h)	2,300 kg/h (5,000 lb/h)
Pressure	20.82 MPa (3,020 psi)	19.86 MPa (2,880 psi)
Temperature	186 C (366.5 F)	185 C (365.5 F)

3.5.3.2 Main Steam Interfaces. The Receiver Loop System interfaces with the Receiver System at the solar receiver superheater outlet, after the superheater outlet stop valve. The Receiver Loop System interfaces with the Fossil Energy System at the connection to the existing main steam piping near the fossil steam generator. The steam conditions at the solar receiver superheater outlet, and at the interface with the existing main steam piping, will be as required to match the existing turbine throttle steam conditions as follows.

Normal Operation - Design Point Conditions

	Receiver System Interface	Fossil Energy System Interface
Flow Rate	111,260 kg/h (245,300 lb/h)	111,260 kg/h 245,300 lb/h)
Overpressure	14.86 MPa (2,155 psia)	13.76 MPa (1,995 psia)
Rated Pressure	13.62 MPa (1,975 psia)	12.51 MPa (1,815 psia)
Temperature	544 C (1,011 F)	538 C (1,000 F)

Under start-up conditions, the Receiver Loop System receives steam from the Fossil Energy System, and provides steam to the Receiver System for warm-up. The maximum warming steam flow rate is 18,000 kg/h (40,000 lb/h).

3.5.3.3 Condensate Interfaces. The Receiver Loop System interfaces with the Receiver System at all drain piping connections. The drain recirculates feedwater during warm-up, collects condensate at saturation temperature during start-up, and drains the receiver during period of extended shutdown. The Receiver Loop System interfaces with the Fossil Energy System at the deaerator, condenser, and existing steam generator blowdown tank. The interfaces with the deaerator and condenser allow return of condensate to the fossil cycle, and the interface with the existing blowdown tank allows for the disposal of condensate drained from the receiver.

The interface points will be sized to accommodate the maximum expected recirculation flow and the condensate drain piping design conditions stated previously.

3.6 MASTER CONTROL SYSTEM

3.6.1 Operating Requirements

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

During combined fossil-solar 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 Unit 1 and Unit 2 at Northeastern station. 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 Master Control System (MCS) will be designed to support these operational criteria.

The MCS will coordinate the independent controls of the other systems (Receiver, Collector, and Fossil Energy Systems). The major control functions of the MCS are as follows.

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

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

(3) Coordination of the receiver and fossil boiler during solar operation.

(4) Automated shutdown of the solar equipment.

(5) Emergency shutdown of solar equipment during abnormal situations to prevent equipment damage.

3.6.1.1 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 participation.

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 program for a normal diurnal start-up will consist of several phases as follows.

(1) Prestart Phase--all solar equipment and system controls will be checked to determine that they are in the proper configuration for start-up (all steam lines drained of condensate, all controls on automatic, all heliostats respond to standby commands, etc.)

(2) Receiver Warmup Phase--the receiver water temperature will be slowly increased at a rate of about 4.4 C (8 F) per minute. The water warmup will begin by circulating heated feedwater from the Fossil Energy System through the receiver and back to the Fossil Energy System through the Receiver Loop System. The feedwater warmup sequence will then be augmented by the injection of steam from the Fossil Energy System into the receiver water.

(3) Solar Steam Generation Phase--the mirrors will be focused on the receiver in a predetermined sequence. As the receiver heats up the steam pressure and temperature will rise. The steam temperature will be controlled within allowable limits. When the pressure equals the existing turbine steam inlet pressure the solar steam stop valve will be gradually opened and solar generated steam injected into the turbine.

A mid-day start-up sequence will be slightly more complicated since a significantly greater amount of solar energy is available. During the Solar Steam Generation Phase, mirrors will be sequenced on target more slowly to prevent overheating of the receiver.

This start-up sequence will be automated to the extent that the required operator participation will be limited to push button initiation of each of these phases. The MCS 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.

3.6.1.2 Coordination of Collector and Receiver Systems. The main responsibility of the Master Control System is the prevention of over temperature conditions in the receiver panels.

The coordination requirements of the MCS 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 essentially all normal operating conditions. The MCS 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 MCS 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 MCS will automatically refocus all mirrors.

3.6.1.3 Coordination of Receiver and Fossil Energy Systems. The main requirement is the regulation of the steam pressure to the turbine. The coordination requirements of the MCS are minimal. This is due to the existing steam pressure controls in the Fossil Energy System and the capability of the fossil steam generator to regulate its firing rate to maintain the desired pressure during all normal expected transient conditions of the solar receiver. The fossil steam generator is capable of increasing and decreasing its steam flow generation at a rate of 20,400 kg/h (45,000 lb/h). The MCS will transmit a measurement of the solar receiver steam flow to the existing fossil steam generator control system. This system will use this signal in a feed-forward control strategy to assist in the pressure controls. Should an unexpectedly severe solar transient cause a very rapid change in receiver steam flow which exceeds the capability of the fossil steam generator to compensate, one of two things will occur. If the pressure drops rapidly, this may cause a small reduction in load output of the turbine until the steam generator steam flow can respond. If the pressure rises rapidly, a pressure relief valve in the Fossil Energy System will be actuated. Neither one of these eventualities is a serious operational problem.

3.6.1.4 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. The shutdown program for a normal shutdown will consist of the following phases.

(1) Shutdown Phase--all heliostats will be placed in the standby position. When the steam flow from the solar receiver drops to zero, the solar steam stop valve will be closed.

(2) Storage Phase--all heliostats will be commanded to their stow positions. All receiver panel bias valves will be closed to minimize heat loss from the receiver during shutdown.

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

3.6.1.5 Emergency Shutdown. The MCS 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 MCS 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 solar steam stop valve.
(3) Open all receiver superheater and steamline drain valves.
(4) Close all lines that may be capable of water injection to the turbine.
(5) Start-up of the standby emergency diesel generator.

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

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

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 control motors.

(6) Loss of main source of electrical power to control system.

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

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

(1) Data Acquisition--the MCS will scan plant input data at individual point adjustable scan rates from once a second to once every 30 seconds. The MCS 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	2,255

(2) Data Analysis--the MCS will perform real-time 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 MCS will also perform periodic performance calculations to determine the performance of the unit and the unit solar components.

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

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

3.6.1.7 Operator Training. The primary operation of the MCS will be automatic. However, manual over-ride controls will be provided. The MCS will provide training facilities for the MCS operators in the use of the control system.

The MCS will contain a simulation of the solar related process equipment. During periods when the solar equipment is not utilized (i.e., evenings or cloudy days) the operator will be able to enter a simulation mode of operation. In this mode, all control outputs to the real process will be deenergized. These outputs will be channeled instead to the process simulation. The simulation will output all process measurements.

The operator will be able to operate all controls and see realistic displays of all feedback information from the process. The simulation will provide realistic process simulation for normal operation, including equipment start-up. A limited number of abnormal and emergency conditions will be simulated for operator training.

3.6.2 Design Requirements

The hardware configuration of the MCS is shown in Figure 3.6-1. The basic element of the MCS will be a single mini-computer that will perform all data acquisition, control logic, and peripheral control function. This computer 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

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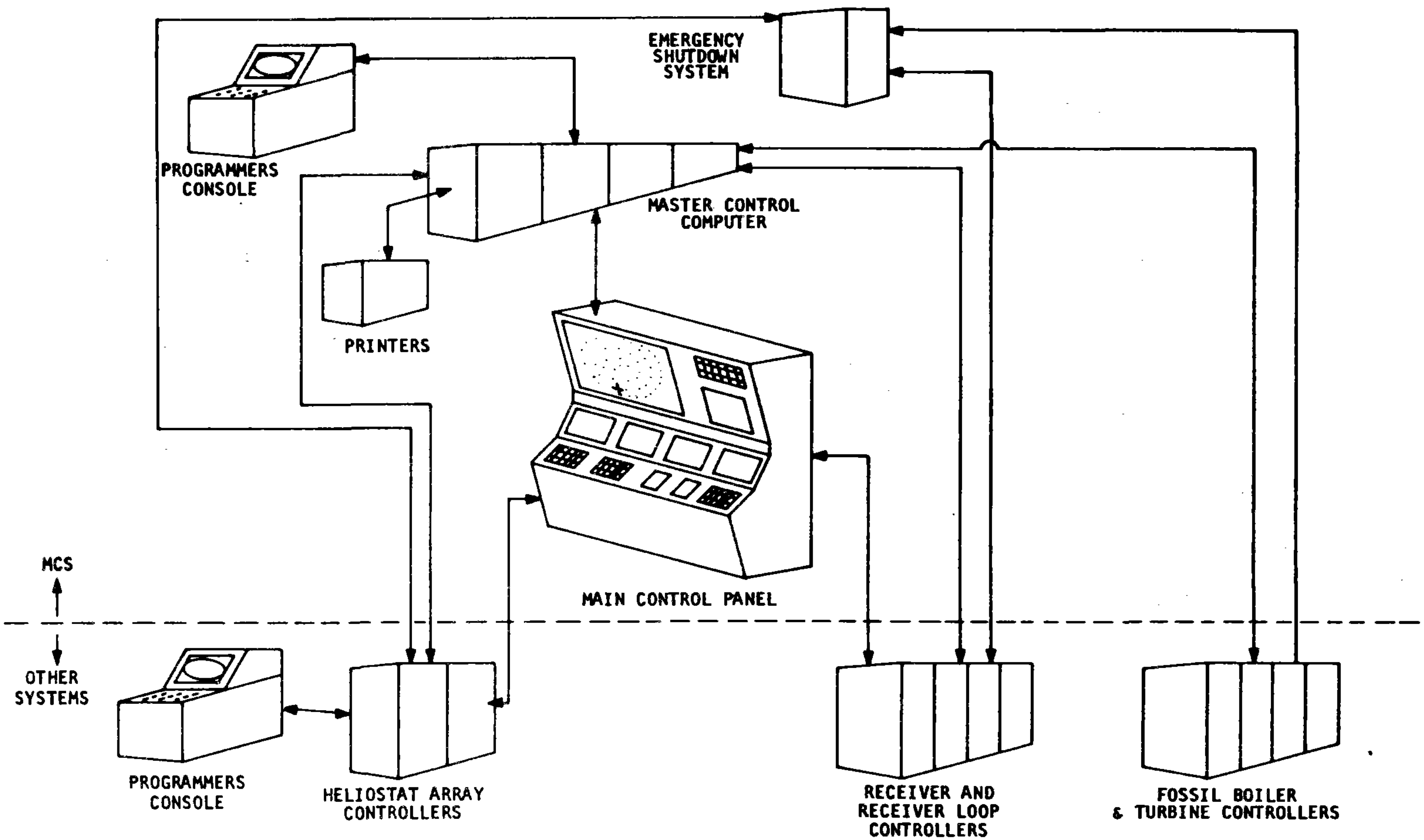

<u>MCS EQUIPMENT CONFIGURATION</u>

FIGURE 3.6-1

in a room adjacent to the control room. Remote multiplexing equipment will be located in the receiver tower. The MCS will include a control panel, located in the Unit 1 control room, which will contain all displays and manual controls for operating the solar equipment.

The MCS equipment must meet the following design criteria.

(1) Reliability--the MCS 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.

(2) Flexibility--the MCS shall have the capabilities to modify control strategies easily at the plant site without extensive hardware or wiring changes.

(3) Cost Effectiveness--the MCS shall use commercially available equipment throughout. All equipment supplied shall be generically similar throughout the MCS. 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 metres (10 feet). All manual controls shall be such as to allow all operations by a single plant operator.

(6) Operating Environment--any equipment located in the receiver tower shall be capable of continuous operation over an ambient temperature range of -29 C (-20 F) to 54 C (130 F) and a relative humidity of 5 per cent to 95 per cent noncondensing. All equipment in the centralized control room shall be capable of continuous operation over an ambient temperature range of 4 C (40 F) to 32 C (90 F). Electrical power for the MCS will be a nominal 120 volt, single phase, 60 hertz alternating current.

(7) Expandibility--the computer system shall have the capability of adding at least 25 per cent additional working memory for future expansion. The central processing unit 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.

3.6.3 Interface Requirements

The MCS will communicate with all other systems. The communications will be control commands from the MCS to the other systems and status information from the other systems to the MCS.

The interface between the MCS and the Collector System will consist of a digital data transmission link between the Master Control computer and the Heliostat Array Controller. Typical communication signals between the two systems are shown on Figure 3.6-2.

The interface between the MCS and the Receiver System and between the MCS and the Receiver Loop System will consist of a digital data transmission link between the Master Control computer and the Receiver Control System. Typical communications signals between the systems are shown on Figures 3.6-3 and 3.6-4.

The interface between the MCS and the Fossil Energy System will consist of signal cables between the Control computer and the turbine and fossil steam generator control systems. Since the existing fossil steam generator control system is pneumatic, electric to pneumatic and pneumatic to electric signal converters will be used. Typical communications between these systems are shown on Figure 3.6-5.

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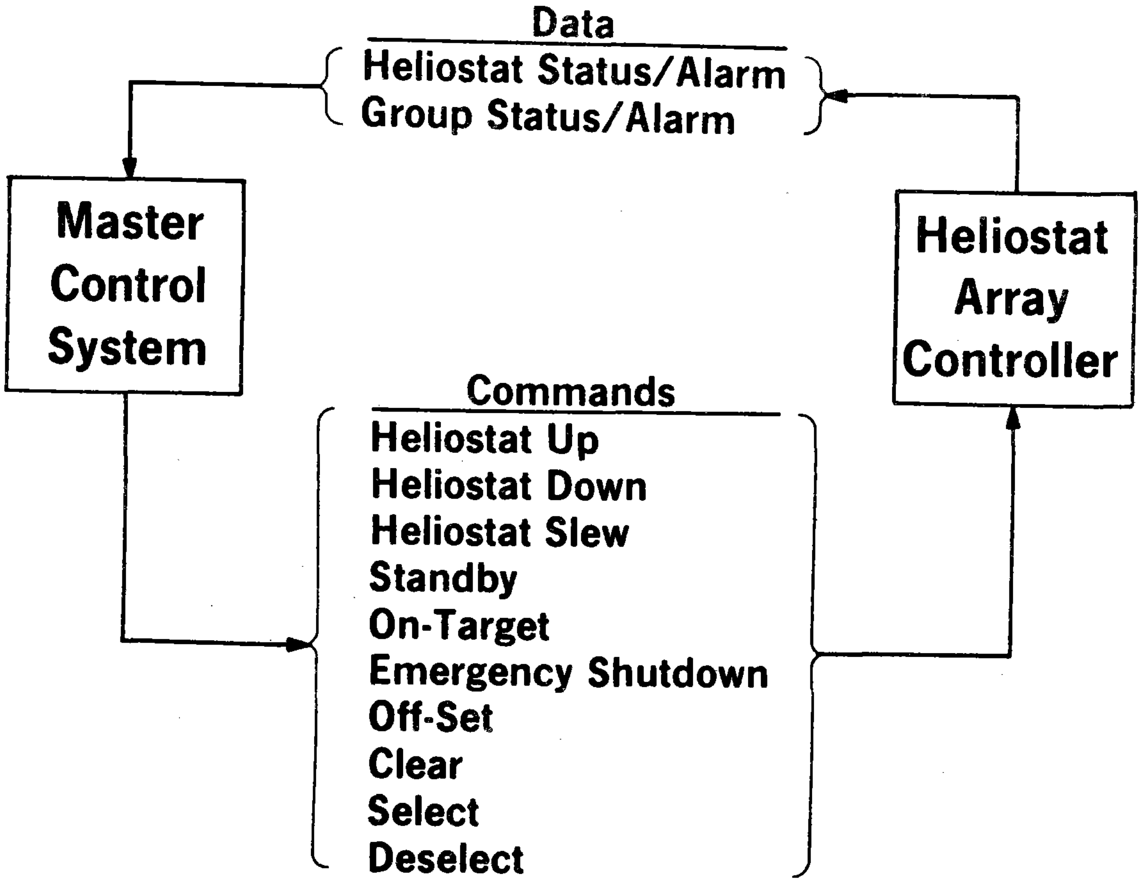
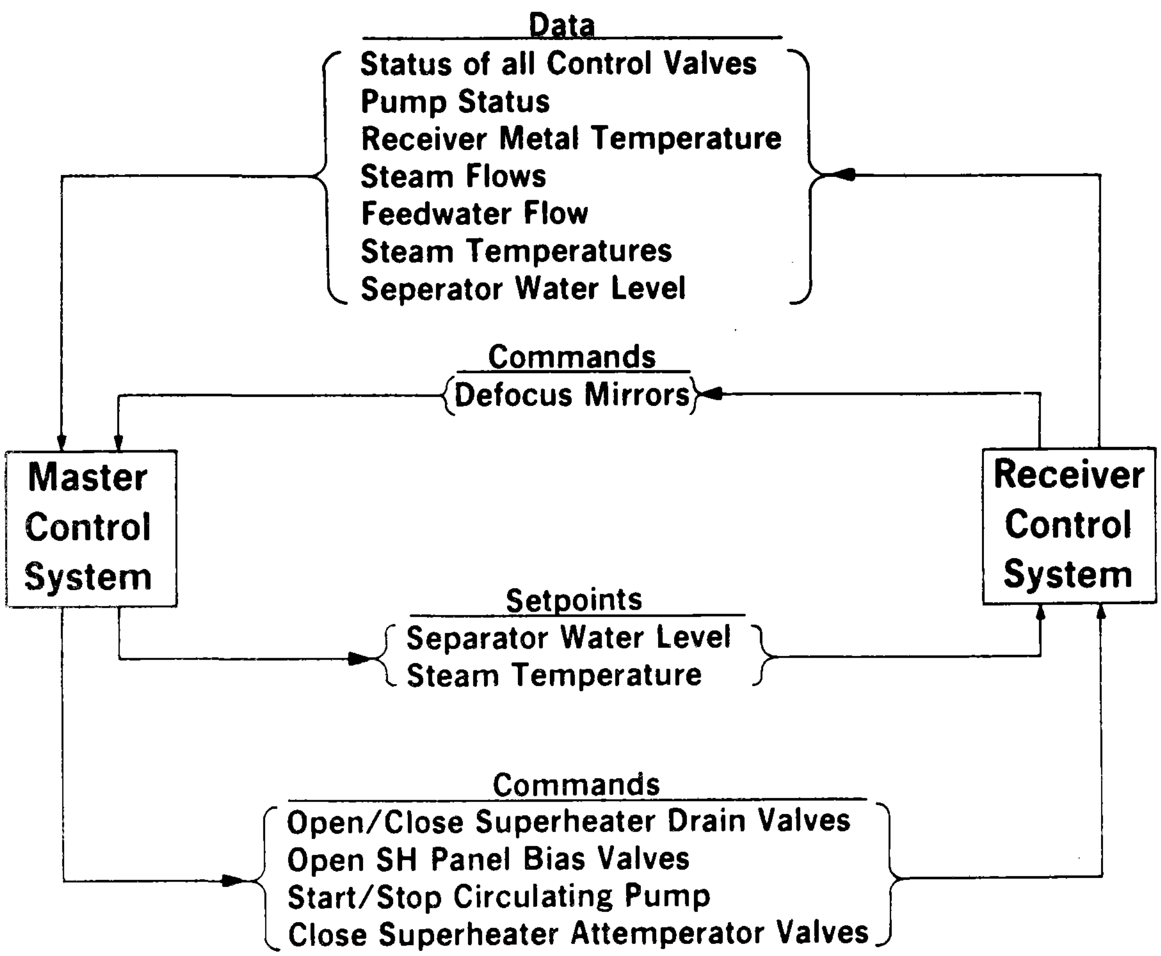


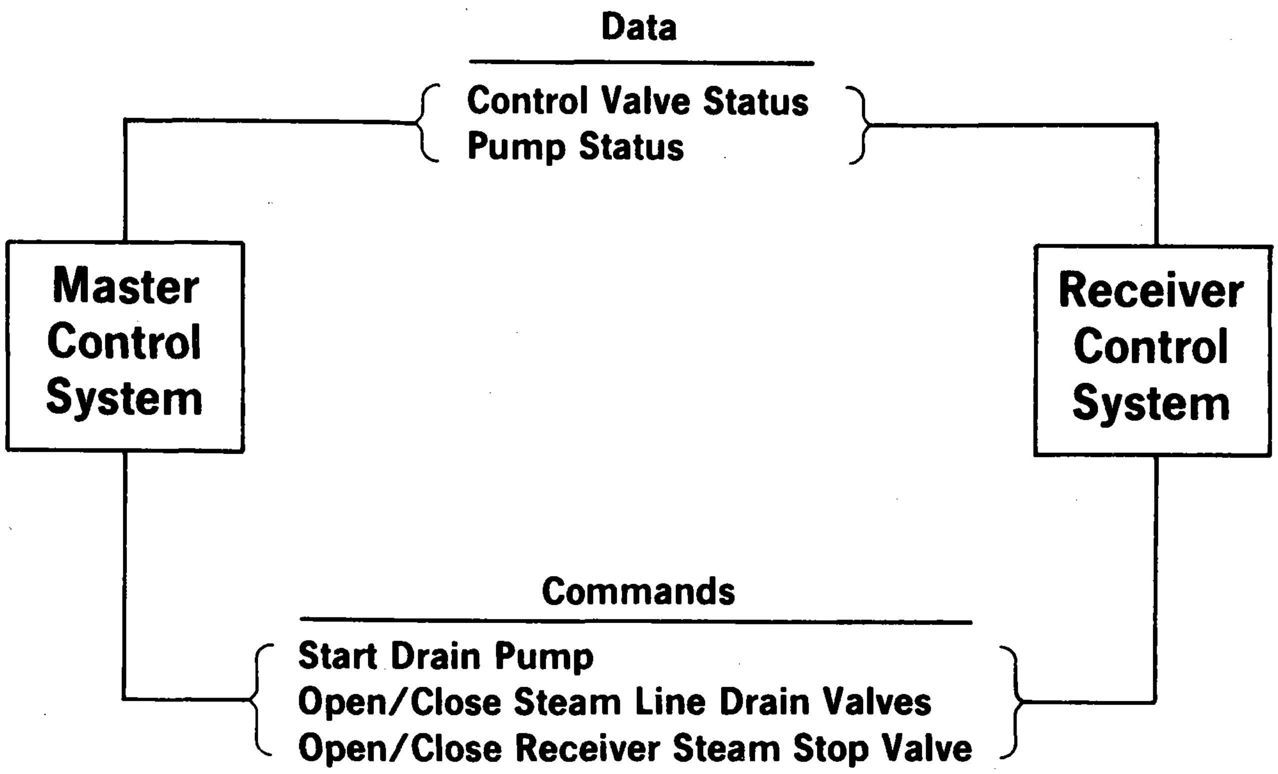
MCS/COLLECTOR SYSTEM INTERFACE

FIGURE 3.6-2



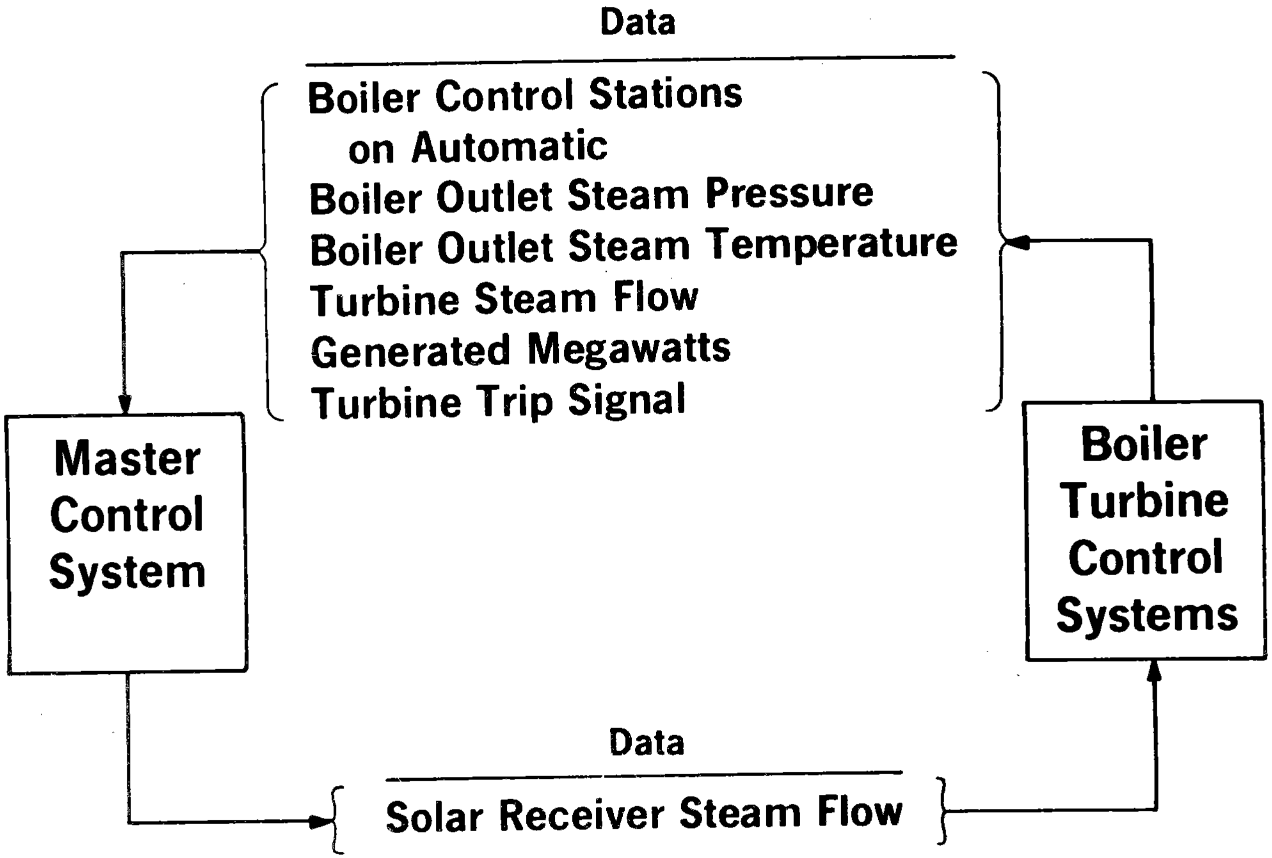
MCS/RECEIVER SYSTEM INTERFACE

FIGURE 3.6-3



MCS/RECEIVER LOOP SYSTEM INTERFACE

FIGURE 3.6-4



MCS/FOSSIL ENERGY SYSTEM INTERFACE

FIGURE 3.6-5

3.7 FOSSIL ENERGY SYSTEM

The Fossil Energy System provides a fossil energy source which is used to enhance performance and maintain normal plant operation during periods of reduced or no insolation. The requirements of the Fossil Energy System are as follows.

3.7.1 Operating Requirements

The solar receiver has three modes of operation which include normal operation, routine shutdown and start-up operation and cold start operation. The Fossil Energy System responds to these modes of operation according to the following.

3.7.1.1 Normal Operation. Under normal operating conditions, the fossil steam generator will respond to load changes and fluctuations in solar output. During overnight periods, the fossil steam generator will operate at minimum boiler turndown, 30 per cent of maximum load, or about 50 MW. During sunlit hours, the fossil steam generator operating range with solar power available is from minimum boiler turndown, up to a maximum turbine generator load of 155 MW.

3.7.1.2 Routine Shutdown and Start-up Operation. During routine shutdown and start-up of the solar systems in the winter months, the fossil steam generator will be maintained at minimum load (30 per cent). For freeze protection during shutdown operation feedwater will be circulated to the receiver and then returned to the deaerator so that the receiver temperature will be maintained above 4.4 C (40 F). Prior to sunrise, feedwater flow will be increased to warm up the receiver water to about 116 C (240 F). The water flow will be controlled to limit the rate of temperature rise in the receiver to about 4.4 C (8 F) per minute. Just before sunrise, superheated steam from the fossil steam generator superheater outlet will be back fed through the receiver loop piping for heating the solar receiver to near the full load saturation temperature. Spargers will be used to introduce the steam from the fossil steam generator (via the mainsteam line) to the solar receiver boiler water circulating pump suction line.

Energy requirements during receiver start-up are further described in Section 5.1.4, Receiver Data. Condensate is collected and returned through the Receiver Loop System.

3.7.1.3 Cold Start Operation. During periods of prolonged shutdown or scheduled maintenance, the Receiver System will be drained and inerted with nitrogen gas. Prior to start-up of the Receiver System, the Fossil Energy System boiler feed pumps will fill the receiver with approximately 4,500 kg (10,000 pounds) of warm feedwater. The receiver will be filled at a controlled rate to avoid thermal shock. Makeup to the Fossil Energy System will be through the condenser from the existing 379 m^3 (100,000 gallon) capacity deionized water storage tank. After the receiver is filled, start-up will be similar to diurnal start-ups described previously with the exception that start-up times will be extended to allow for warm-up of the main steam transport pipe.

3.7.2 Design Requirements

No modifications to the existing Fossil Energy System are required except for the interfaces. Requirements at the interfaces are described below.

3.7.3 Interface Requirements

The requirements at the interfaces with the Fossil Energy System will be as follows.

3.7.3.1 Feedwater Interfaces. The Fossil Energy System interfaces with the Receiver Loop System at the feedwater line after the fifth feedwater heater.

The conditions at the interface will vary with unit load and receiver steaming capacity. The maximum and minimum conditions corresponding to the required operating modes are as follows.

Normal Operation, Design Point Conditions

Feedwater flow to receiver	111,260 kg/h (245,300 lb/h)
Pressure	18.96 MPa (2,750 psi)
Temperature	247 C (477 F)

Start-up and Shutdown Operation

Minimum Feedwater Recirculation	2,300 kg/h (5,000 lb/h)
Maximum Feedwater Recirculation	34,000 kg/h (75,000 lb/h)
Pressure	20.82 MPa (3,020 psi)
Temperature	186 C (366.5 F)

3.7.3.2 Main Steam Interfaces. The Fossil Energy System also interfaces with the Receiver Loop System at the connection of the transport pipeline and the fossil main steam piping near the fossil steam generator. Steam conditions at the interface will match the existing Unit 1 steam conditions as follows.

Normal Operation, Design Point Conditions

Flow rate	111,260 kg/h (245,300 lb/h)
Over Pressure	13.76 MPa (1,995 psia)
Rated Pressure	12.51 MPa (1,815 psia)
Temperature	538 C (1,000 F)

Under start-up conditions, the Fossil Energy System will supply steam to the Receiver Loop System for receiver warm-up at a flow rate of about 18,000 kg/h (40,000 lb/h).

3.7.3.3 Drain Lines. Drain lines from the receiver will interface with the Fossil Energy System at the deaerator, condenser, and existing steam generator blowdown tank. The interface points will be sized to accommodate the maximum expected recirculation flow stated above.

3.8 SERVICE LIFE

The integration of the solar repowering system into NES 1 is expected to increase the projected annual output of the plant and delay its retirement. Commercial operation of the solar repowered unit is scheduled to begin in 1985, and plant life shall be extended to 1999. The system shall be designed for a 15-year service life with no major component replacement required.

3.9 PLANT AVAILABILITY AND RELIABILITY

The solar repowered plant is required to have an availability of at least 85 per cent. The solar portion of the repowered plant, exclusive of scheduled outages and insolation-related outages, shall be in an operative state at least 85 per cent of the time. The availability of the solar portion of the repowered plant will be the product of the operational probabilities of its three constituents: the solar receiver, the heliostats, and the fluid circulation loop.

3.10 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, Plant Cost Data.

3.10.1 Conventional Components

The conventional components of the solar repowered plant modifications, including the piping, pumps, valves, and motors, will be maintained via the existing maintenance facilities. The existing personnel and facilities currently maintain the four fossil-fired electrical generating units adjacent to the repowering site. Maintenance of the conventional components of the solar repowered plant modifications shall require no new skills or specialized equipment; an additional inventory of spare parts and replacement equipment may be required for the solar repowering system.

3.10.2 Solar Specific Components

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

3.10.2.1 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 the absorptive surface.

Excessive leakage from the receiver shall 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 conventional steam generator of the repowered plant. The receiver tower includes a crane and elevator to facilitate receiver maintenance.

Depending on the severity of the leakage, it may be practical to continue the collection of solar energy throughout the day, waiting until nighttime to perform the corrective maintenance on the solar receiver. In any case, maintenance on the solar receiver cannot begin until the receiver has sufficiently cooled. Due to the external configuration of the receiver, however, cooling will occur rapidly from natural heat losses; forced cooling of the receiver via water circulation is also feasible.

3.10.2.2 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, washing whenever heliostat reflectivity drops below a threshold value.

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

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 a fork lift and/or a mobile crane.

3.10.3 Control Components

The control components of the solar repowered plant modifications, primarily the heliostat control system, shall be maintained utilizing procedures and facilities consistent with those currently employed for the maintenance of the control systems of the four fossil-fired electrical generating units on site. Maintenance shall be primarily corrective. An adequate inventory of spare components shall be stored on site to facilitate corrective repairs.

3.11 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.

3.11.1 Specialized Solar Receiver Equipment

The solar receiver is designed for a 15-year lifetime and does not require 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 tubes or superheater panels or the recoating of the receiver's high-absorptivity coating.

Specialized equipment to be included with the solar receiver and receiver tower includes the following.

(1) Tower personnel elevator.

(2) Small equipment chain hoist.

(3) Polar crane.

3.11.2 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) Motorized elevated platform.

(3) Heliostat alignment tools.

4.0 ENVIRONMENTAL CRITERIA

4.1 ENVIRONMENTAL DESIGN REQUIREMENTS

4.1.1 Site Climatology

While considerable data is available from various weather stations in the northeastern section of Oklahoma, the first order station of the National Weather Service at Tulsa is utilized as the base line reference source for the establishment of the climatology for the plant site.

The following sections describe the climatology of the plant site as extrapolated from a composite of the above data. Seasonal data are averaged as follows: Summer (June, July, and August); Fall (September, October, and November); Spring (March, April, and May); and Winter (December, January, and February).

4.1.1.1 Dry Bulb Temperature. The average summer temperature is approximately 27 C (81 F), with an average daily minimum temperature of 21 C (70 F) and an average daily maximum temperature of 33 C (91 F). The extreme temperatures for the summer months were 9 C (48 F) and 44 C (111 F). Spring-fall temperatures average about 16 C (61 F) with an average daily minimum of 10 C (50 F) and an average daily maximum of 22 C (72 F) . There is a 62 C (111 F) range of extreme temperatures during the spring-fall months. There is also a wide range of extreme temperatures for the winter months, -22 C (-8 F) to 30 C (90 F). For design purposes, the ambient temperature range at the site shall be assumed to be -27 C (-17 F) to 47 C (117 F).

4.1.1.2 Precipitation and Snowfall. The average annual precipitation for the area is 966 mm (38.03 in.). May is the wettest month with an average of 132 mm (5.21 in.) of precipitation. The average annual snowfall is 236 mm (9.3 in.). The plant shall be designed to withstand an average annual rainfall of 940 mm (37.1 in.) and a maximum 24-hour rate of 230 mm (9.0 in.) based on a 100-year mean recurrence interval. The plant shall be designed to survive a static snow load of 300 Pa (6.25 lb/ft^2), based on a 100-year mean recurrence interval and a snow deposition rate of 0.25 m (10 in.) in 24 hours, based on the recorded maximum.

4.1.1.3 Wind. Wind data is presented on Figure 4.1-1. The extreme mile wind recorded was 33.5 m/s (75 mph) in May, 1949. The average wind speed in all months ranges between 4.1 m/s (9.1 mph) and 5.7 m/s (12.7 mph). Wind roses for the four seasons are presented on Figure 4.1-2. These wind roses show the frequency with which the wind blows from a particular direction. The Tulsa region is subject to violent windstorms and tornadoes which occur mostly during spring and early summer although occurrences have been noted throughout the year.

The plant shall be designed to survive winds with a maximum speed, including gusts of 47 m/s (105 mph), based on 100-year mean recurrence interval, and ratio of gust speed to fastest mile wind of 1.3, without damage. Specific requirements for the solar receiver tower are given in Section 3.4.

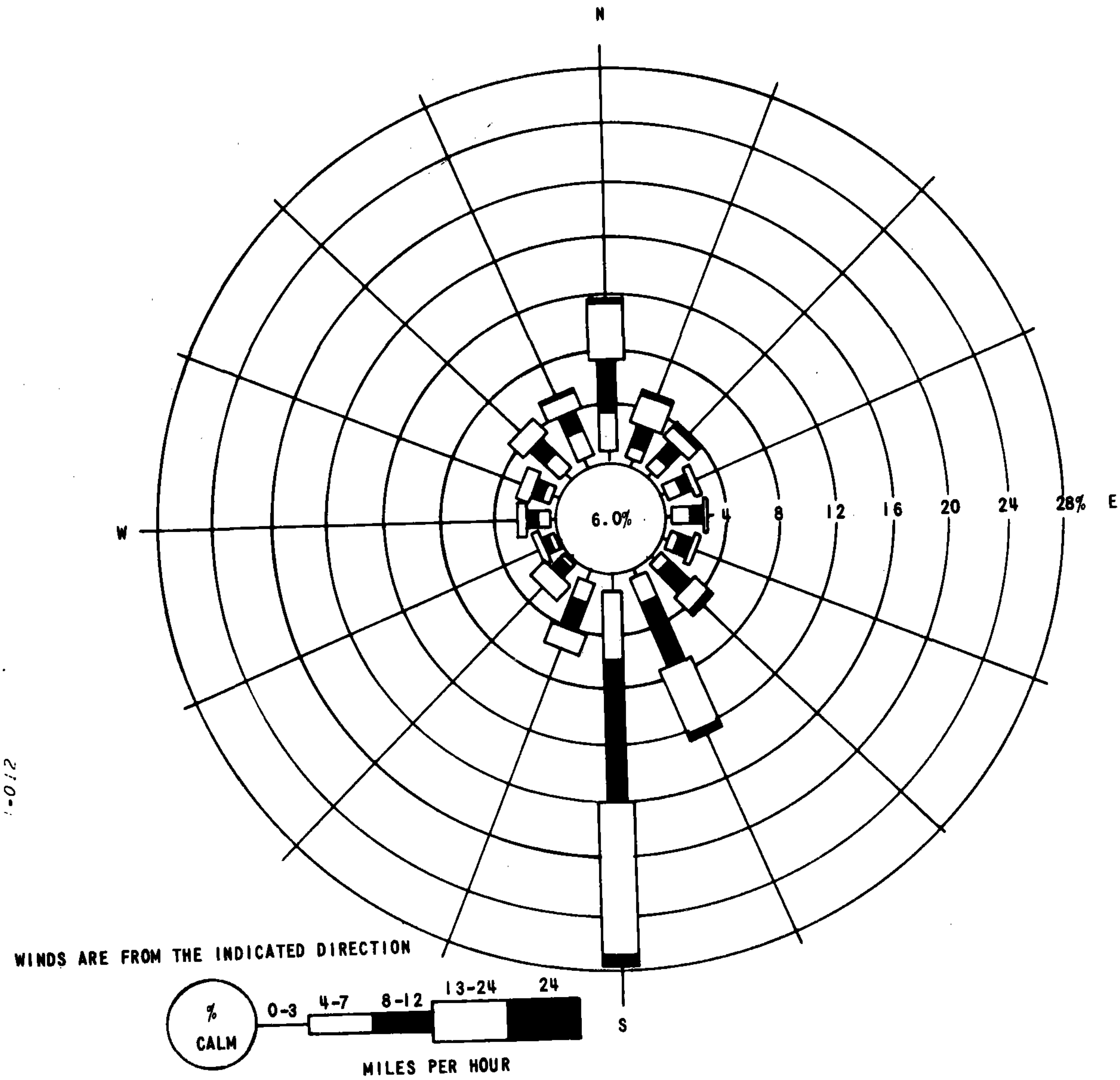
4.1.1.4 Wind Rise Rate. A maximum wind rise rate of 0.01 m/s^2 (1.3 mph/min) shall be used in calculating wind loads on heliostats during stowage. However, the heliostats shall withstand, without catastrophic failure, a maximum wind of 22 m/s (50 mph) from any direction, for any heliostat orientation,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

4.1.1.5 Dust Devils. For design purposes, dust devils with wind speeds up to 18 m/s (40 mph) shall be survived without damage to the plant.

4.1.1.6 Sandstorm Environment. The plant shall be designed to withstand flowing dust comparable to the conditions described by Method 510 of MIL-STD-810C or other conditions which may be found more appropriate during final design.

4.1.2 Seismology

Northeastern Station is situated in a region of minor to moderate seismic risk. The site area is classified by the Uniform Building Code (UBC) as Zone 1 of seismic risk for the continuous United States. In this zone, minor damage from earthquake activity may be expected. Zone 1 indicates the possibility of an earthquake with a maximum intensity of VI on the Modified Mercalli Scale occurring in this area, or minor damage resulting from a major distant disturbance. Peak ground accelerations shall be



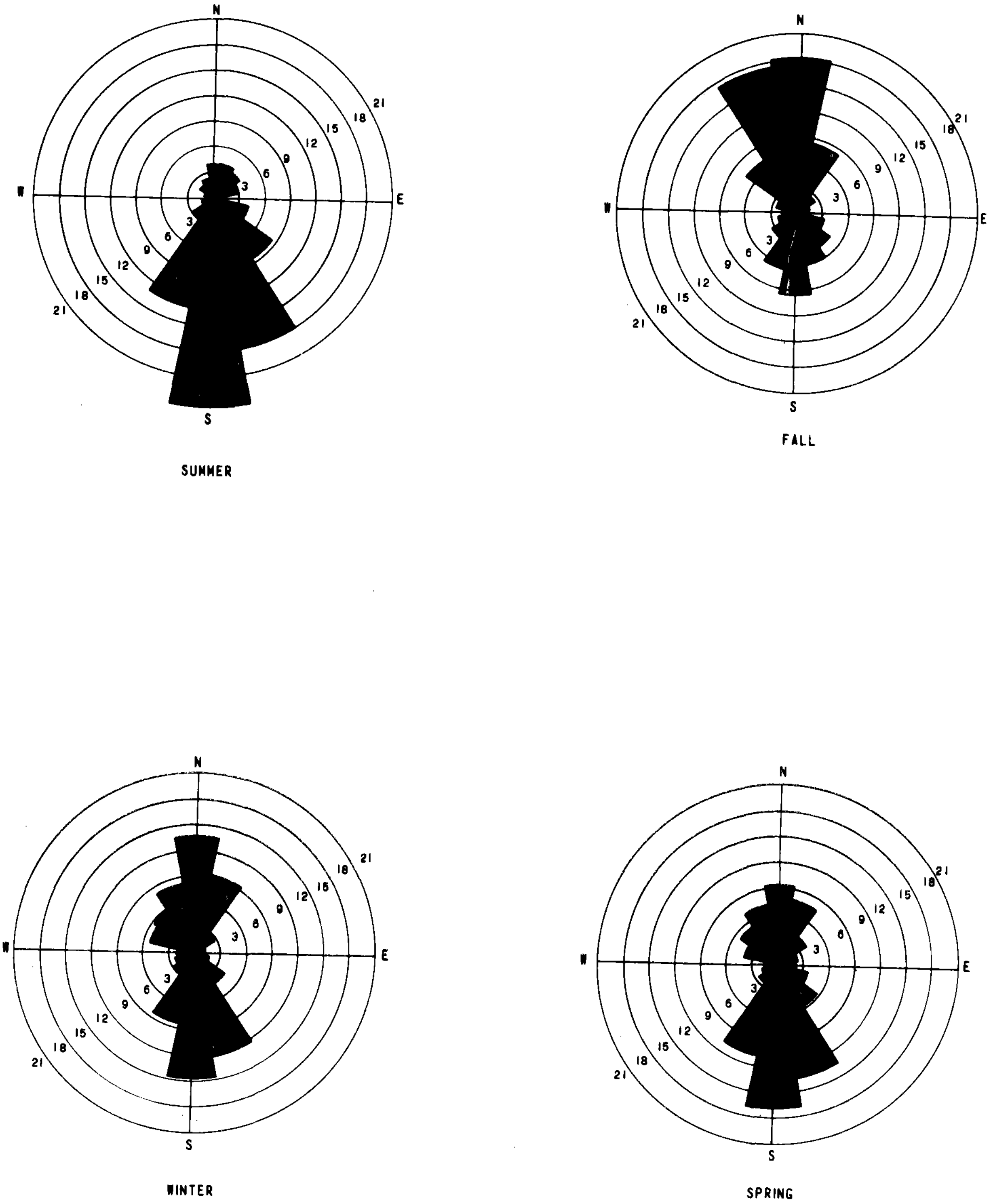
CALMS ARE DISTRIBUTED INTO THE 0-3 MPH CATEGORY AND THUS INCLUDED IN THE AVERAGE WIND SPEEDS SHOWN AT THE END OF EACH BAR.

PERIOD OF RECORD: 1962 THROUGH 1971

DATA SOURCE: ENVIRONMENTAL DATA SERVICE, MONTHLY AND ANNUAL WIND DISTRIBUTION BY PASQUILL STABILITY CLASSES (7)-STAR PROGRAM-TULSA, OKLAHOMA, 1962-1971, U.S. DEPARTMENT OF COMMERCE, ASHEVILLE, N.C., SEPT. 14, 1973

ANNUAL WIND ROSE
TULSA, OKLAHOMA
1962-1971

FIGURE 4.1-1



SEASONAL WIND ROSES

FIGURE 4.1-2

as required for UBC Zone 1. An operational design acceleration of 0.05 g is sufficient for Northeastern Station. The plant shall be designed to survive a ground acceleration of 0.10 g.

4.1.3 Lightning Considerations

The plant shall be provided with a lightning protection system. The receiver tower, being the tallest structure in the area, will be the most vulnerable target of a direct lightning discharge. Lightning rods shall be located on the top of the receiver tower to provide shielding against direct lightning strokes. Precautions shall be taken to prevent any damage to these rods by the concentrated energy of the reflected solar radiation.

The heliostat field also provides a potential ground plane for lightning discharge. Economic considerations may preclude the use of lightning masts to shield the entire heliostat field. Therefore, the total destruction of a single heliostat and its controller when subjected to a direct lightning discharge will be acceptable. However, the heliostats shall be designed and spaced in such a way that a direct lightning strike on a single heliostat will cause minimum damage to the adjacent heliostats. The central controller and the local controllers of heliostats adjacent to a direct lightning strike will be protected or alternate control methods will be provided to minimize the loss of collector subsystem control.

Lightning considerations will also include the local isokeraunic level, the corresponding ground flash density and the shielding effect of the receiver tower on the heliostat field. An estimate of the probability of direct lightning strike for heliostats in the various regions of the field will be made and factored into overall reliability/availability calculations. This information shall be used in the final arrangement of the heliostat field and any additional shielding will be provided if economically justified.

4.2 ENVIRONMENTAL STANDARDS

4.2.1 Ambient Air Quality Standards

(1) Federal Standards. Pursuant to a requirement in the Clean Air Act of 1970, 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 follow.

(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 Northeastern Station are as follow.

	3-Hour Average µg/m³ (ppm)	24-Hour Average* µg/m³ (ppm)	Annual Average** µg/m³ (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.

(2) Oklahoma Standards. The Division of Air Pollution Control of the Oklahoma State Board of Health adopted ambient air quality standards on December 4, 1976 which are identical to those promulgated by EPA for sulfur dioxide, particulate matter, and nitrogen dioxide.

4.2.2 Emission Limitations.

There are no Federal Emission limits applicable to NES 1. However, the Oklahoma Department of Health Regulations has established emission limitations for particulate matter, visible emissions, hydrocarbons, sulfur oxides, carbon monoxide, and nitrogen 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. An existing source which is altered, replaced, or rebuilt in such a manner that its air contaminant emissions are increased is designated as a new source under Oklahoma Regulation 3. Since the Solar Repowering Project would not cause an emissions increase at NES 1, the unit will 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 are governed by Figure 1 of Oklahoma Regulation 6. Figure 1 is a graph showing a decreasing emission limit, expressed in pounds per million Btu, for boilers rated between 1 and 1,000 million Btu per hour heat input. The equation for this decreasing emission limit is given in the following equation.

$$\log_{10} Y = -0.25938 \log_{10} X + 0.03753$$

where Y = particulate emission rate (lb/MBtu heat input)

X = heat input rate (MBtu/h heat input)

Oklahoma Regulation 7 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 or more than 20 minutes in any 24-hour period.

(2) Sulfur Dioxide Emission Limitations--Oklahoma does not impose a uniform sulfur dioxide emission rate limitation on existing fuel-burning sources. Instead, the maximum sulfur dioxide emission rate for each facility cannot exceed that required to prevent that source's ground level impact outside the property of the owner/operator from exceeding the following time dependent ambient concentrations.

Time Period	Maximum Allowable Impact (mg/m^3)
5 minutes	1,350
1 hour	1,200
3 hours	650
24 hours	130

(3) Nitrogen Oxide Emission Limitations--Oklahoma has not established any nitrogen oxide emission rate limitations applicable to existing sources.

4.2.3 Water Quality Standards

The proposed design of the solar repowering systems at Unit 1 will not result in increased usage of ground or surface water. The proposed design will also not significantly change the quantity or quality of water discharged from the plant. The repowered plant operation will be consistent with the water quality standards and regulations currently in effect at Unit 1.

5.0 CONCEPTUAL DESIGN DATA

This section contains data on the conceptual design which was developed to satisfy the requirements described in the previous sections. In order to enable DOE to assess the value of the conceptual design, the information in this section includes performance and characteristics for both the solar repowered plant and the existing plant, capital and O&M cost data, economic evaluation data, and descriptions of the simulation models used in the PSO assessment.

5.1 PLANT CHARACTERISTICS AND PERFORMANCE DATA

The following data characterize the solar portion of the repowering plant and describe its performance. Where appropriate, performance data are presented for the design point and annual average.

5.1.1 Site Data

(1) Roads and Parking. The main road and the parking area will be permanent-type construction with a crowned 6-metre (20-foot-wide) traffic lane, 1.5-metre (5-foot-wide) shoulders, and contoured drainage ditches. Approximately 3,800 square metres (4,550 square yards) will be surfaced with a 7.6 cm (3-inch) asphaltic course on a 20 cm (8-inch) crushed rock prepared basecourse. The crushed rock basecourse will be underlain by a prepared subgrade of site materials selected for drainability. Drainage slope will be to the outer shoulder at about 20 mm per metre (1/4 inch per foot). Shoulders will not be paved, but will be oiled, and will be sloped to the ditches at about 42 mm per metre (1/2 inch per foot).

(2) Security Fence. Approximately 1,600 metres (5,200 lineal feet) of new security fencing will be installed and 1,000 metres (3,400 lineal feet) of existing security fencing relocated.

The fencing will be galvanized steel chain link type with a three-strand barbed wire extension mounted at 45 degrees. The fabric height will be 1.8 metres (6 feet), and the overall height 2 metres (7 feet). It will not be necessary to provide gates.

5.1.2 Site Facilities Data

Design data for the nitrogen gas system and the auxiliary electrical power system required to support the new solar repowering equipment are as follows.

5.1.2.1 Nitrogen Gas Systems. Nitrogen gas will be stored in individual cylinders, 130 cm (51 inches high), with a capacity of 7 cubic metres (225 cubic feet) at a fill pressure of 15 MPa (2,200 psig). Two 12-cylinder modules with common fill and discharge manifolds will be utilized providing a total storage capacity of 167 cubic metres (5,400 cubic feet).

5.1.2.2 Solar Plant Normal Auxiliary AC Power.

(1) One metal-enclosed switchgear, 4,160 volt, 60 BIL, three-phase, 60 hertz, 1,200 ampere mainbus, rated for 37,500 ampere rms symmetrical shortcircuit interrupting current. The switchgear is an assembly of three incoming modules, three feeder modules, one bus sectionalizing module and auxiliary modules for automatic transfer control devices.

Circuit switching is performed by power-operated interrupter switches. Power fuses are provided for fault protection. Two automatic control devices complete with sensing devices are provided. One automatic control device is used for high speed source transfer control. The other control device controls the switching of the third incoming feeder connected to an emergency standby generator and prevents its paralleling with other incoming feeders by opening the bus sectionalizing switch.

(2) One diesel-generator 930 kw, .8 power factor, 4,160 volt, three-phase, 60 hertz. The unit has fast-start features (10-second starting time). The unit is complete with radiator, fuel storage tank 1,000 litres (265 US gallon) capacity, exhaust silencer, automatic starting system with heavy-duty nickel-cadmium storage battery and battery charger. Generator control panel includes metering, fully automatic start-stop control, automatic voltage regulator equipment, exerciser, generator protection package and annunciator panel.

(3) One motor control center, three-phase, 480 volt, 60 hertz, indoor, NEMA 1 gasketed, with 12 vertical sections divided in two bus sections. Each section is nominally 38 cm (15 inches) deep, 51 cm (20 inches) wide, and 229 cm (90 inches) high. The main bus is 600 ampere and vertical buses are 300 ampere. There are 55 size 1 full voltage reversing combination starters, one size 4 full voltage non-reversing combination starter, and 100 ampere molded case circuit breakers, as required. Each starter and breaker unit is a plug-in module. Each combination circuit

breaker is equipped with a magnetic-only trip device to provide protection against short circuit current. Manually resettable thermal overloads are provided on all starters for motor overload protection. Each feeder circuit breaker is provided with a thermal magnetic trip device.

(4) One outdoor oil-filled pad-mounted distribution transformer rated 300 kVA, three-phase, 60 hertz, 4,160 volt delta primary, 480/277 volt wye secondary with standard no load taps. High voltage bushings are radial feed, live front design. Standard accessories include terminals, filter and drain valves, removable front sill, oil gauge, dial type thermometer, lifting and jacking provisions and grounding pads in high and low voltage compartments.

(5) Ten low profile outdoor oil-filled pad-mounted transformers, each rated 150 kVA, 4,160 volt, three-phase, 60 hertz, delta primary, 120/208 volt wye secondary. Each unit has six load-break primary bushing wells contructed for primary system feed-through and the units are dead-front design. Primary protection of each transformer in provided with fuses and secondary protection is provided with a circuit breaker. Standard accessories include terminals, filter and drain valves, removable front sill, oil gauge, dial type thermometer, lifting and jacking provisions and grounding pads in high and low voltage compartments.

5.1.2.3 <u>Solar Plant Uninterruptibale Auxiliary AC Power</u>.

(1) Two static inverters, 37.5 kVA, 125 volt dc input, 120 volt 60 hertz, single-phase ac output voltages. Output voltage is automatically regulated to no more than plus or minus 2.0 per cent from zero load to full load. The ac wave form does not have harmonic distortion of more than 5 per cent. The inverter has a solid state oscillator designed to automatically maintain its output in synchronism with station standby ac supply. A static switch is provided with each inverter to transfer the load to this standby supply within 1/4 of a cycle in the event of inverter failure. Each inverter is protected against overloads, short

circuits and transient overvoltages in the line. A manual bypass switch is provided with each inverter to transfer the load from one inverter to the other without circuit interruptions. Each inverter is equipped with meters to measure the output current, voltage and frequency. Alarm contacts are provided to annunciate any abnormal input or output conditions.

(2) Two battery chargers, rated output 400 ampere at 125 volt dc, 480 volt, three-phase, ac input voltage. Each charger is a self-regulating solid state silicon-controlled fullwave rectifier type, designed for parallel operation with the battery. Each charger is supplied with input and output voltmeters, ammeters, circuit breakers, equalizing charge timer, voltage adjusters, charge failure alarm, and ground detection circuitry.

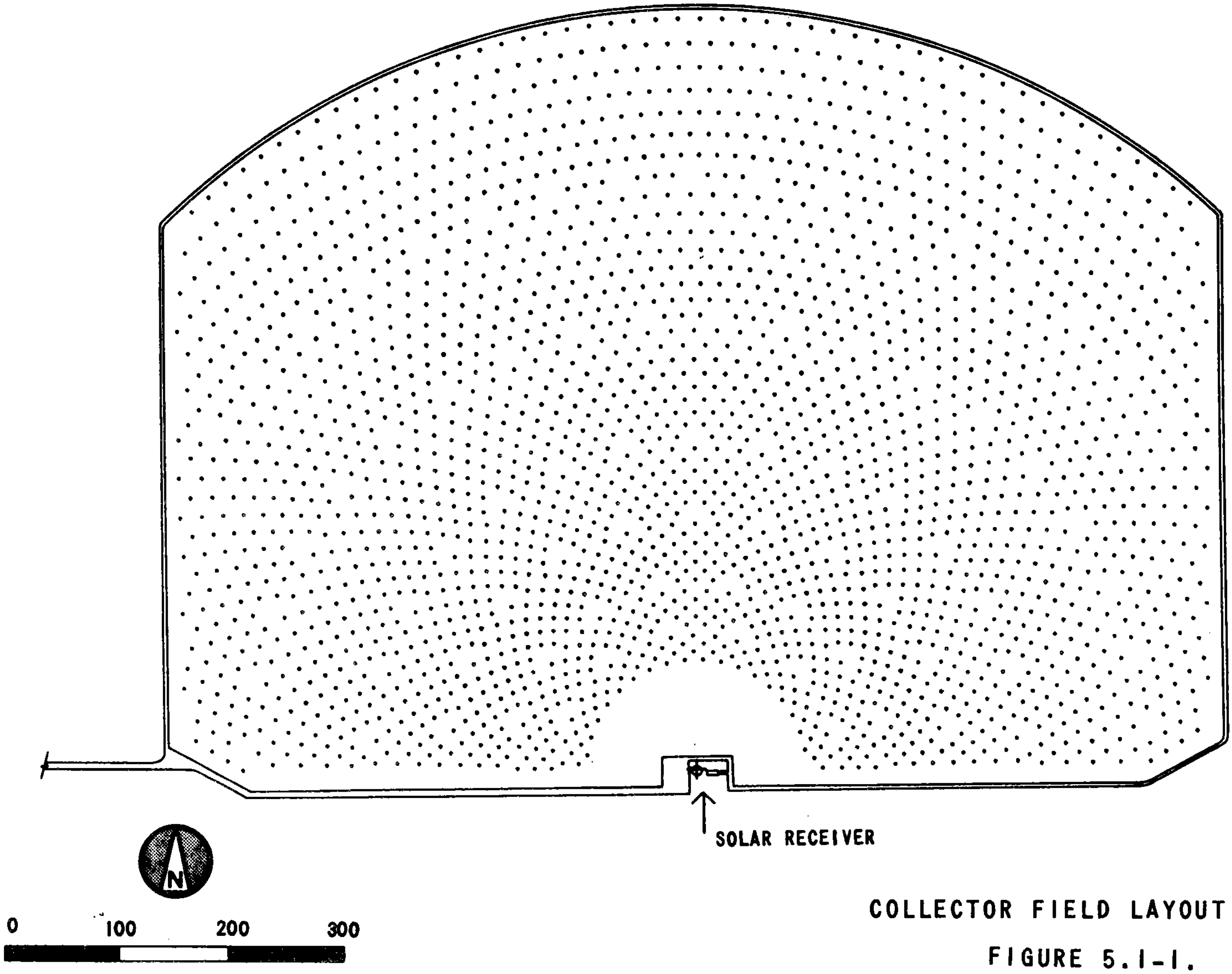
(3) One battery, nominal 125 volt dc output. The battery consists of 60 heavy-duty lead-acid cells. Each cell has 860 ampere-hour capacity on a 8-hour discharge basis. Cell container is a sealed, heat resistant, clear, shock absorbing plastic. Electrolyte in a fully charged cell maintains a specific gravity of 1.220 and a cell voltage of 2.22 volts when floated with the battery chargers. Maximum per cell voltage during equalizing is 2.33 volts. Standard battery accessories include battery racks, intercell connectors, terminal lugs, thermometer, hydrometer syringe and cell lifting facilities.

(4) One voltage regulating transformer, static-magnetic type 37.5 kVA, single-phase, 480 volt primary, 120 volt secondary. Output voltage is regulated to plus or minus 1 per cent. Maximum harmonic content in the output voltage wave form is 3 per cent.

5.1.3 <u>Collector Data</u>

(1) <u>Design characteristics</u>.

(a) The collector field lies north of the receiver tower, occupying a space 880 m (2,887 ft) wide and 5.1×10^5 m^2 (126 acres) in area, as illustrated in Figure 5.1-1. The field contains



COLLECTOR FIELD LAYOUT

FIGURE 5.1-1.

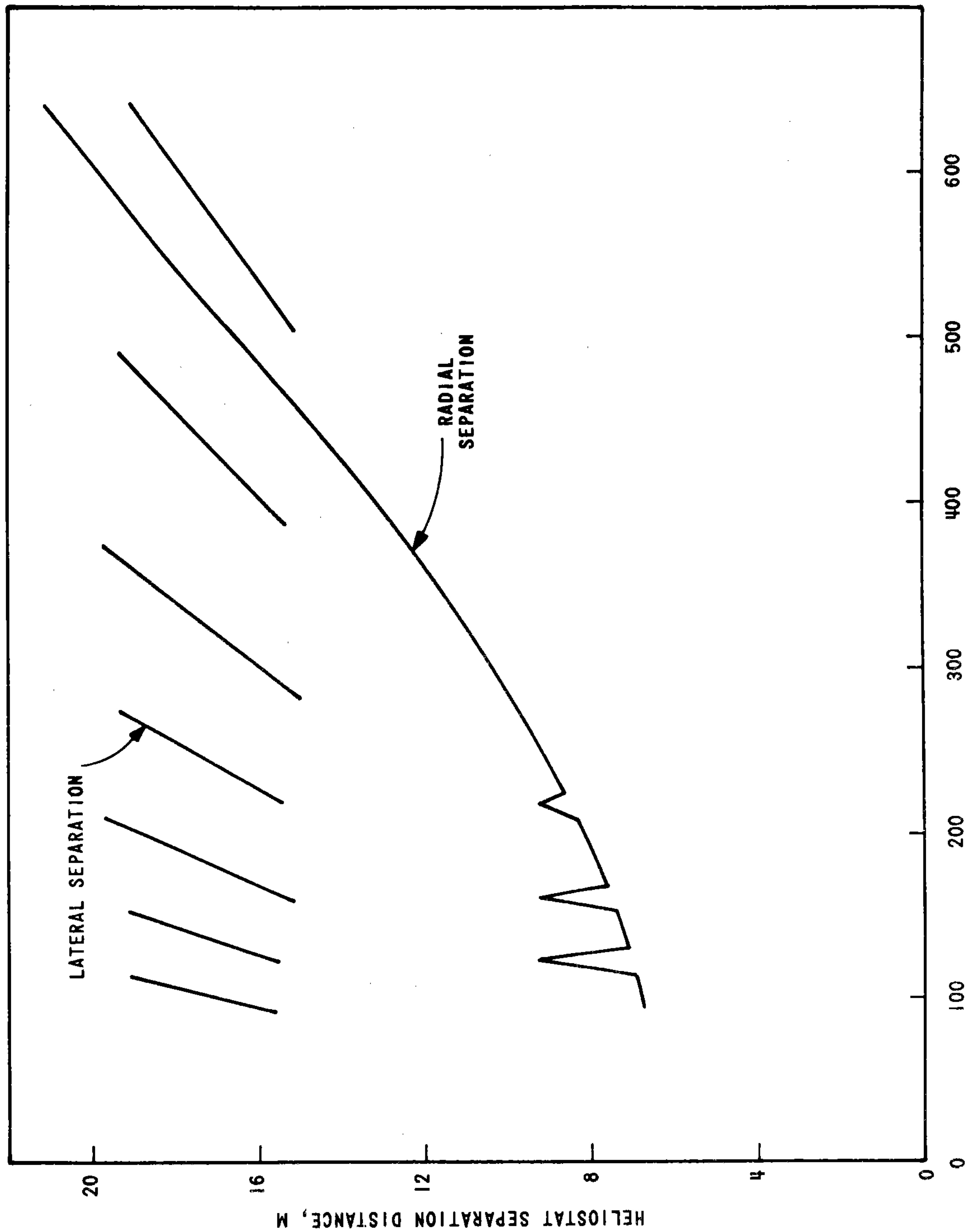
a total of 2,255 heliostats placed in 48 circular arcs surrounding the receiver support tower. The inner and outer rows lie 93.8 m (308 ft) and 640 m (2,100 ft) from the tower centerline, respectively.

Heliostats are located in a staggered pattern formed by circular arcs and diverging radial lines; the staggering arrangement allows close packing with a minimum of optical interference (blocking) among heliostats.

Because heliostats are located on diverging radial lines, the lateral spacings of heliostats within the rows (rdr) increase with distance from the tower. When the lateral separation between radial lines becomes unacceptably large, the angular separation between radial lines is reduced by a factor of 0.75, causing the periodic readjustment in lateral separation shown in Figure 5.1-2. Counting outward from the tower, transitions in angular separation occur in rows 5, 10, 17, 24, 33, and 41; within those transition rows heliostats are periodically deleted to avoid mechanical and optical interference.

Figure 5.1-2 shows that radial separation between rows also increases with distance from the tower, allowing heliostats to see over the neighboring heliostats in front without blocking. To prevent mechanical interference, the transition rows 5, 10, and 17 were given slightly larger spacings as illustrated in the figure.

The actual X and Y locations of the heliostats are listed on Table 5.1-1. The heliostats are numbered from 1 to 2,255 and are listed in order from the inner row to the outer row and from the western end of the rows clockwise to the east. The X and Y coordinates are listed in metres, with positive X East and positive Y North of the tower centerline.



HELIOSTAT SEPARATION

FIGURE 5.1-2

TABLE 5.1-1. HELIOSTAT X-Y COORDINATES

HSTAT	*X*	*Y*	*HSTAT*	*X*	*Y*	*HSTAT*	*X*	*Y*
1	-92.87	12.96	51	72.15	79.59	101	-99.87	84.40
2	-89.43	28.20	52	84.36	66.51	102	-88.55	96.20
3	-83.51	42.66	53	94.24	51.58	103	-75.86	106.50
4	-75.26	55.93	54	101.49	35.21	104	-61.98	115.13
5	-64.93	67.65	55	105.93	17.87	105	-47.13	121.96
6	-52.80	77.49	56	107.43	.04	106	-31.54	126.89
7	-39.20	85.19	57	-114.14	6.31	107	-15.46	129.84
8	-24.51	90.51	58	-111.51	25.18	108	.86	130.75
9	-9.14	93.32	59	-105.78	43.34	109	17.17	129.62
10	6.48	93.55	60	-97.11	60.30	110	33.21	126.46
11	21.92	91.17	61	-85.75	75.59	111	48.73	121.33
12	36.76	86.27	62	-72.01	88.78	112	63.49	114.30
13	50.57	78.97	63	-56.27	99.50	113	77.26	105.49
14	62.98	69.48	64	-38.97	107.47	114	89.82	95.02
15	73.64	58.05	65	-20.58	112.44	115	100.97	83.07
16	82.26	45.02	66	-1.63	114.30	116	110.55	69.82
17	88.59	30.74	67	17.37	112.99	117	118.40	55.48
18	92.46	15.60	68	35.89	108.53	118	124.39	40.28
19	-100.46	5.56	69	53.41	101.07	119	128.45	24.44
20	-98.14	22.16	70	69.45	90.80	120	130.49	8.22
21	-93.10	38.15	71	83.56	78.00	121	-137.90	1.87
22	-85.47	53.07	72	95.36	63.05	122	-136.59	19.06
23	-75.47	66.53	73	104.50	46.34	123	-133.14	35.96
24	-63.38	78.14	74	110.74	28.34	124	-127.62	52.29
25	-49.53	87.58	75	113.91	9.56	125	-120.09	67.80
26	-34.30	94.58	76	-123.67	1.68	126	-110.69	82.26
27	-18.12	98.97	77	-122.49	17.09	127	-99.56	95.43
28	-1.43	100.60	78	-119.40	32.25	128	-86.88	107.11
29	15.29	99.44	79	-107.70	60.81	129	-72.83	117.11
30	31.59	95.52	80	-99.27	73.77	130	-57.65	125.28
31	47.01	88.95	81	-89.29	85.58	131	-41.57	131.50
32	61.13	79.91	82	-65.32	105.03	132	-24.83	135.66
33	73.55	68.65	83	-51.70	112.36	133	-7.71	137.70
34	83.93	55.49	84	-37.28	117.93	134	9.53	137.58
35	91.97	40.78	85	-6.92	123.49	135	26.62	135.32
36	97.47	24.95	86	8.55	123.39	136	43.30	130.94
37	100.26	8.42	87	23.88	121.36	137	59.30	124.51
38	-106.40	14.85	88	53.18	111.66	138	74.37	116.14
39	-102.45	32.31	89	66.70	104.16	139	88.28	105.95
40	-95.67	48.87	90	79.17	95.02	140	100.82	94.11
41	-86.23	64.08	91	100.24	72.46	141	111.77	80.79
42	-74.39	77.50	92	108.49	59.38	142	120.98	66.21
43	-60.49	88.78	93	115.06	45.38	143	128.29	50.60
44	-44.91	97.59	94	122.71	15.48	144	133.61	34.20
45	-28.08	103.69	95	123.68	.04	145	136.83	17.26
46	-10.47	106.92	96	-130.37	9.94	146	137.91	.05
47	7.42	107.17	97	-128.11	26.13	147	-144.75	11.04
48	25.11	104.45	98	-123.85	41.91	148	-142.24	29.01
49	42.11	98.83	99	-117.65	57.04	149	-137.51	46.54
50	57.93	90.47	100	-109.62	71.28	150	-130.63	63.33

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
151	▾121.70	79.13	201	▾145.70	70.64	251	149.97	79.06
152	▾110.88	93.70	202	▾138.44	83.98	252	156.72	64.66
153	▾98.32	106.81	203	▾120.34	108.33	253	162.08	49.69
154	▾84.22	118.24	204	▾109.66	119.13	254	166.03	34.29
155	▾68.81	127.82	205	▾98.02	128.88	255	168.51	18.58
156	▾52.32	135.41	206	▾72.25	144.90	256	169.51	2.71
157	▾35.02	140.88	207	▾58.36	151.03	257	▾176.76	13.48
158	▾17.16	144.15	208	▾43.95	155.84	258	▾174.72	29.98
159	.96	145.16	209	▾14.11	161.30	259	▾171.14	46.22
160	19.06	143.91	210	1.07	161.91	260	▾166.06	62.05
161	36.87	140.41	211	16.23	161.10	261	▾159.51	77.33
162	54.10	134.71	212	46.00	155.24	262	▾151.56	91.94
163	70.49	126.90	213	60.35	150.25	263	▾142.28	105.74
164	85.78	117.12	214	74.16	143.94	264	▾131.75	118.60
165	99.72	105.50	215	99.71	127.57	265	▾120.06	130.42
166	112.10	92.23	216	111.22	117.67	266	▾107.31	141.10
167	122.74	77.52	217	121.76	106.73	267	▾93.62	150.53
168	131.45	61.60	218	139.53	82.14	268	▾79.10	158.64
169	138.11	44.72	219	146.62	68.71	269	▾63.89	165.35
170	142.61	27.13	220	152.41	54.67	270	▾48.12	170.61
171	144.88	9.13	221	159.93	25.27	271	▾31.92	174.37
172	▾152.51	2.07	222	161.60	10.18	272	▾15.44	176.60
173	▾151.06	21.08	223	▾169.46	4.95	273	1.17	177.27
174	▾147.25	39.77	224	▾168.25	20.80	274	17.77	176.38
175	▾141.14	57.83	225	▾165.56	36.48	275	34.22	173.94
176	▾132.82	74.99	226	▾161.41	51.83	276	50.37	169.96
177	▾122.42	90.98	227	▾155.85	66.72	277	66.07	164.50
178	▾110.11	105.54	228	▾148.91	81.03	278	81.19	157.58
179	▾96.08	118.46	229	▾140.66	94.63	279	95.60	149.28
180	▾80.55	129.52	230	▾131.18	107.39	280	109.16	139.67
181	▾63.76	138.56	231	▾120.54	119.21	281	121.77	128.83
182	▾45.97	145.43	232	▾108.84	129.98	282	133.30	116.85
183	▾27.47	150.03	233	▾96.19	139.60	283	143.67	103.85
184	▾8.53	152.29	234	▾82.68	148.00	284	152.76	89.93
185	10.54	152.16	235	▾68.45	155.10	285	160.52	75.22
186	29.44	149.66	236	▾53.62	160.83	286	166.86	59.85
187	47.89	144.81	237	▾38.32	165.14	287	171.73	43.95
188	65.58	137.71	238	▾22.67	168.01	288	175.10	27.67
189	82.25	128.45	239	▾6.83	169.39	289	176.92	11.14
190	97.64	117.18	240	9.07	169.29	290	▾185.06	5.40
191	111.50	104.08	241	24.89	167.69	291	▾183.74	22.72
192	123.61	89.35	242	40.49	164.62	292	▾180.81	39.83
193	133.80	73.23	243	55.74	160.11	293	▾176.28	56.60
194	141.89	55.96	244	70.49	154.18	294	▾170.20	72.87
195	147.76	37.82	245	84.63	146.90	295	▾162.62	88.49
196	151.33	19.09	246	98.02	138.32	296	▾153.62	103.34
197	152.53	.05	247	110.55	128.53	297	▾143.26	117.28
198	▾161.45	12.31	248	122.10	117.61	298	▾131.64	130.18
199	▾159.59	27.38	249	132.59	105.65	299	▾118.86	141.95
200	▾151.67	56.68	250	141.90	92.76	300	▾105.04	152.46

HSTAT	*X*	*Y*	*HSTAT*	*X*	*Y*	*HSTAT*	*X*	*Y*
301	-90.30	161.63	351	166.45	97.99	401	-110.71	178.02
302	-74.76	169.38	352	174.90	81.96	402	-93.55	187.61
303	-58.56	175.64	353	181.81	65.21	403	-75.56	195.55
304	-41.84	180.35	354	187.12	47.89	404	-56.90	201.76
305	-24.76	183.48	355	190.79	30.15	405	-37.75	206.21
306	-7.46	184.99	356	192.77	12.14	406	-18.26	208.84
307	9.90	184.88	357	-201.23	5.88	407	1.38	209.63
308	27.18	183.14	358	-199.79	24.70	408	21.02	208.58
309	44.22	179.78	359	-196.60	43.31	409	40.47	205.69
310	60.87	174.85	360	-191.68	61.54	410	59.56	201.00
311	76.98	168.38	361	-185.07	79.23	411	78.13	194.53
312	92.42	160.42	362	-176.83	96.22	412	96.01	186.36
313	107.05	151.06	363	-167.04	112.37	413	113.05	176.54
314	120.73	140.36	364	-155.77	127.52	414	129.10	165.17
315	133.35	128.44	365	-143.14	141.56	415	144.00	152.35
316	144.79	115.38	366	-129.25	154.35	416	157.64	138.19
317	154.97	101.30	367	-114.22	165.78	417	169.90	122.81
318	163.78	86.34	368	-98.18	175.75	418	180.66	106.35
319	171.15	70.61	369	-81.29	184.18	419	189.83	88.96
320	177.01	54.27	370	-63.67	190.98	420	197.33	70.78
321	181.32	37.44	371	-45.50	196.11	421	203.09	51.98
322	184.03	20.29	372	-26.93	199.51	422	207.07	32.72
323	185.12	2.96	373	-8.11	201.15	423	209.22	13.18
324	-192.59	14.69	374	10.77	201.03	424	-218.88	6.39
325	-190.37	32.67	375	29.56	199.13	425	-217.88	21.77
326	-186.47	50.36	376	48.08	195.49	426	-212.68	52.12
327	-180.94	67.61	377	66.19	190.12	427	-208.49	66.94
328	-173.80	84.26	378	83.71	183.09	428	-203.26	81.43
329	-165.15	100.18	379	100.50	174.44	429	-189.83	109.14
330	-155.03	115.21	380	116.40	164.26	430	-181.68	122.22
331	-143.56	129.23	381	131.27	152.63	431	-172.64	134.69
332	-130.82	142.11	382	145.00	139.66	432	-152.04	157.58
333	-116.93	153.74	383	157.44	125.46	433	-140.58	167.88
334	-102.01	164.02	384	168.51	110.15	434	-128.43	177.35
335	-86.19	172.86	385	178.09	93.88	435	-102.28	193.61
336	-69.62	180.17	386	186.10	76.78	436	-88.41	200.33
337	-52.43	185.90	387	192.47	59.01	437	-74.11	206.05
338	-34.78	190.00	388	197.16	40.72	438	-44.47	214.41
339	-16.83	192.42	389	200.10	22.06	439	-29.29	217.00
340	1.27	193.15	390	201.29	3.22	440	-13.96	218.52
341	19.37	192.18	391	-209.03	15.94	441	16.84	218.32
342	37.29	189.52	392	-206.62	35.45	442	32.15	216.60
343	54.88	185.19	393	-202.39	54.66	443	47.30	213.80
344	71.99	179.24	394	-190.37	73.38	444	76.82	205.05
345	88.47	171.70	395	-188.64	91.45	445	91.05	199.14
346	104.16	162.66	396	-179.24	108.73	446	104.83	192.25
347	118.95	152.19	397	-168.26	125.04	447	130.76	175.64
348	132.68	140.37	398	-155.81	140.26	448	142.79	166.01
349	145.25	127.32	399	-141.98	154.24	449	154.11	155.56
350	156.54	113.15	400	-126.90	166.86	450	174.40	132.40

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
451	183.28	119.81	501	227.35	11.65	551	▾231.04	83.26
452	191.25	106.63	502	▾236.42	6.90	552	▾224.62	99.30
453	204.32	78.74	503	▾235.35	23.51	553	▾217.08	114.84
454	209.35	64.18	504	▾233.11	40.00	554	▾208.46	129.82
455	213.35	49.30	505	▾229.72	56.29	555	▾198.82	144.16
456	218.15	18.89	506	▾225.20	72.31	556	▾188.19	157.78
457	218.94	3.50	507	▾219.55	87.96	557	▾176.63	170.63
458	▾227.18	14.65	508	▾212.83	103.18	558	▾164.20	182.62
459	▾225.59	30.58	509	▾205.04	117.89	559	▾150.95	193.72
460	▾222.88	46.37	510	▾196.25	132.02	560	▾136.95	203.85
461	▾219.07	61.93	511	▾186.48	145.49	561	▾122.28	212.98
462	▾214.17	77.18	512	▾175.79	158.24	562	▾107.00	221.05
463	▾208.21	92.04	513	▾164.22	170.21	563	▾91.20	228.02
464	▾201.22	106.46	514	▾151.85	181.34	564	▾74.94	233.87
465	▾193.24	120.34	515	▾138.72	191.56	565	▾58.31	238.56
466	▾184.30	133.63	516	▾124.91	200.84	566	▾41.39	242.07
467	▾174.45	146.26	517	▾110.48	209.13	567	▾24.26	244.38
468	▾163.73	158.17	518	▾95.50	216.38	568	▾7.02	245.48
469	▾152.21	169.29	519	▾80.05	222.56	569	10.26	245.37
470	▾139.93	179.57	520	▾64.20	227.64	570	27.49	244.04
471	▾126.95	188.96	521	▾48.04	231.59	571	44.58	241.50
472	▾113.35	197.42	522	▾31.63	234.39	572	61.45	237.77
473	▾99.19	204.90	523	▾15.07	236.04	573	78.02	232.86
474	▾84.54	211.37	524	1.56	236.51	574	94.20	226.80
475	▾69.46	216.79	525	18.19	235.82	575	109.91	219.62
476	▾54.05	221.14	526	34.72	233.96	576	125.08	211.34
477	▾38.36	224.39	527	51.09	230.93	577	139.63	202.03
478	▾22.49	226.54	528	67.20	226.77	578	153.49	191.71
479	▾6.51	227.56	529	82.98	221.48	579	166.59	180.44
480	9.51	227.45	530	98.35	215.10	580	178.87	168.28
481	25.48	226.22	531	113.23	207.65	581	190.26	155.29
482	41.32	223.87	532	127.55	199.18	582	200.71	141.52
483	56.96	220.41	533	141.24	189.72	583	210.16	127.06
484	72.32	215.86	534	154.23	179.32	584	218.57	111.97
485	87.32	210.24	535	166.46	168.03	585	225.91	96.32
486	101.88	203.58	536	177.86	155.91	586	232.12	80.20
487	115.95	195.91	537	188.38	143.02	587	237.18	63.68
488	129.44	187.27	538	197.97	129.42	588	241.08	46.84
489	142.28	177.71	539	206.58	115.17	589	243.77	29.78
490	154.43	167.26	540	214.17	100.36	590	245.26	12.56
491	165.81	155.99	541	220.70	85.06	591	▾254.75	7.44
492	176.36	143.95	542	226.13	69.33	592	▾253.60	25.33
493	186.05	131.19	543	230.44	53.26	593	▾251.19	43.10
494	194.81	117.78	544	233.62	36.92	594	▾247.54	60.66
495	202.61	103.79	545	235.64	20.40	595	▾242.66	77.91
496	209.41	89.29	546	236.49	3.78	596	▾236.58	94.78
497	215.17	74.34	547	▾245.08	15.80	597	▾229.33	111.18
498	219.86	59.03	548	▾243.36	32.99	598	▾220.94	127.03
499	223.47	43.42	549	▾240.44	50.02	599	▾211.46	142.25
500	225.97	27.60	550	▾236.32	66.80	600	▾200.94	156.77

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
601	▾189.42	170.51	651	▾115.18	237.94	701	▾17.47	273.52
602	▾176.96	183.41	652	▾98.17	245.45	702	1.81	274.07
603	▾163.62	195.40	653	▾80.66	251.75	703	21.08	273.27
604	▾149.48	206.42	654	▾62.76	256.80	704	40.24	271.11
605	▾134.60	216.42	655	▾44.55	260.57	705	59.20	267.61
606	▾119.05	225.35	656	▾26.12	263.06	706	77.87	262.78
607	▾102.91	233.16	657	▾7.56	264.25	707	96.16	256.66
608	▾86.26	239.82	658	11.04	264.12	708	113.97	249.26
609	▾69.18	245.29	659	29.59	262.69	709	131.21	240.63
610	▾51.76	249.55	660	47.99	259.96	710	147.81	230.81
611	▾34.09	252.57	661	66.15	255.94	711	163.67	219.85
612	▾16.24	254.34	662	83.98	250.66	712	178.72	207.79
613	1.68	254.85	663	101.40	244.13	713	192.89	194.71
614	19.60	254.10	664	118.31	236.40	714	206.11	180.67
615	37.42	252.10	665	134.64	227.50	715	218.30	165.73
616	55.05	248.84	666	150.30	217.47	716	229.41	149.97
617	72.41	244.36	667	165.22	206.36	717	239.39	133.47
618	89.41	238.66	668	179.32	194.23	718	248.18	116.30
619	105.97	231.73	669	192.54	181.14	719	255.74	98.56
620	122.01	223.76	670	204.80	167.15	720	262.04	80.34
621	137.44	214.62	671	216.04	152.34	721	267.04	61.71
622	152.19	204.43	672	226.22	136.77	722	270.72	42.78
623	166.19	193.22	673	235.28	120.53	723	273.06	23.64
624	179.36	181.06	674	243.17	103.68	724	274.04	4.38
625	191.65	168.00	675	249.86	86.33	725	▾283.74	13.28
626	202.99	154.11	676	255.31	68.55	726	▾280.76	43.11
627	213.32	139.45	677	259.50	50.43	727	▾278.10	57.86
628	222.60	124.11	678	262.40	32.05	728	▾274.66	72.45
629	230.78	108.15	679	264.01	13.52	729	▾265.49	100.98
630	237.81	91.65	680	▾273.96	8.00	730	▾259.80	114.85
631	243.67	74.70	681	▾272.72	27.24	731	▾253.38	128.39
632	248.31	57.39	682	▾270.13	46.35	732	▾238.44	154.38
633	251.74	39.78	683	▾266.20	65.23	733	▾229.96	166.74
634	253.91	21.98	684	▾260.96	83.79	734	▾220.84	178.64
635	254.83	4.08	685	▾254.42	101.93	735	▾200.79	200.91
636	▾263.81	17.01	686	▾246.62	119.57	736	▾189.91	211.23
637	▾261.96	35.51	687	▾237.61	136.61	737	▾178.51	220.95
638	▾258.81	53.85	688	▾227.41	152.98	738	▾154.23	238.53
639	▾254.39	71.91	689	▾216.09	168.59	739	▾141.43	246.34
640	▾248.70	89.62	690	▾203.70	183.37	740	▾128.24	253.45
641	▾241.78	106.88	691	▾190.30	197.24	741	▾100.82	265.55
642	▾233.67	123.62	692	▾175.97	210.13	742	▾86.67	270.50
643	▾224.40	139.75	693	▾160.75	221.99	743	▾72.28	274.70
644	▾214.02	155.18	694	▾144.75	232.74	744	▾42.94	280.79
645	▾202.57	169.84	695	▾128.02	242.34	745	▾28.06	282.66
646	▾190.13	183.67	696	▾110.67	250.74	746	▾13.11	283.75
647	▾176.75	196.58	697	▾92.76	257.91	747	16.86	283.55
648	▾162.49	208.52	698	▾74.40	263.79	748	31.79	282.27
649	▾147.42	219.43	699	▾55.66	268.37	749	46.64	280.20
650	▾131.63	229.25	700	▾36.66	271.62	750	75.90	273.72

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
751	90.24	269.34	801	40.64	291.46	851	▾108.18	284.93
752	104.32	264.20	802	55.96	288.91	852	▾93.00	290.24
753	131.58	251.74	803	71.12	285.55	853	▾77.56	294.74
754	144.67	244.45	804	86.09	281.40	854	▾61.90	298.42
755	157.37	236.47	805	100.82	276.47	855	▾46.07	301.27
756	181.41	218.58	806	115.26	270.77	856	▾30.11	303.28
757	192.69	208.70	807	129.38	264.31	857	▾14.07	304.45
758	203.43	198.25	808	143.15	257.12	858	2.01	304.77
759	223.18	175.71	809	156.51	249.21	859	18.09	304.24
760	232.14	163.69	810	169.44	240.60	860	34.11	302.86
761	240.45	151.22	811	181.90	231.33	861	50.04	300.64
762	255.05	125.04	812	193.85	221.41	862	65.83	297.58
763	261.29	111.41	813	205.26	210.87	863	81.44	293.69
764	266.80	97.47	814	216.10	199.75	864	96.82	288.99
765	275.59	68.82	815	226.34	188.07	865	111.93	283.48
766	278.83	54.18	816	235.94	175.87	866	126.73	277.18
767	281.30	39.40	817	244.89	163.18	867	141.18	270.11
768	283.89	9.54	818	253.16	150.03	868	155.23	262.28
769	▾294.22	6.00	819	260.72	136.47	869	168.85	253.73
770	▾293.49	21.51	820	267.56	122.52	870	182.00	244.47
771	▾291.95	36.97	821	273.65	108.24	871	194.64	234.53
772	▾289.59	52.32	822	278.98	93.65	872	206.74	223.93
773	▾286.43	67.52	823	283.53	78.80	873	218.27	212.71
774	▾282.47	82.54	824	287.29	63.74	874	229.19	200.90
775	▾277.72	97.33	825	290.26	48.49	875	239.47	188.53
776	▾272.20	111.84	826	292.41	33.11	876	249.08	175.63
777	▾265.92	126.04	827	293.75	17.64	877	258.00	162.25
778	▾258.90	139.90	828	294.27	2.12	878	266.20	148.41
779	▾251.16	153.36	829	▾304.44	14.25	879	273.66	134.16
780	▾242.72	166.40	830	▾303.27	30.29	880	280.35	119.54
781	▾233.60	178.97	831	▾301.25	46.25	881	286.27	104.58
782	▾223.83	191.04	832	▾298.39	62.08	882	291.39	89.33
783	▾213.44	202.59	833	▾294.70	77.73	883	295.70	73.84
784	▾202.46	213.57	834	▾290.18	93.17	884	299.18	58.14
785	▾190.91	223.95	835	▾284.87	108.35	885	301.83	42.27
786	▾178.83	233.71	836	▾278.75	123.23	886	303.64	26.29
787	▾166.25	242.82	837	▾271.86	137.76	887	304.60	10.23
788	▾153.21	251.25	838	▾264.22	151.91	888	▾315.49	6.43
789	▾139.74	258.98	839	▾255.84	165.64	889	▾314.71	23.07
790	▾125.88	265.99	840	▾246.74	178.91	890	▾313.06	39.64
791	▾111.68	272.26	841	▾236.96	191.67	891	▾310.53	56.10
792	▾97.16	277.78	842	▾226.52	203.91	892	▾307.14	72.40
793	▾82.37	282.52	843	▾215.44	215.57	893	▾302.89	88.51
794	▾67.35	286.47	844	▾203.77	226.64	894	▾297.80	104.36
795	▾52.14	289.62	845	▾191.53	237.07	895	▾291.88	119.93
796	▾36.79	291.97	846	▾178.76	246.85	896	▾285.15	135.16
797	▾21.34	293.50	847	▾165.49	255.93	897	▾277.62	150.01
798	▾5.82	294.22	848	▾151.75	264.31	898	▾269.32	164.45
799	9.71	294.12	849	▾137.60	271.95	899	▾260.27	178.43
800	25.21	293.20	850	▾123.06	278.83	900	▾250.49	191.91

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
901	240.02	204.86	951	319.79	66.53	1001	312.29	95.74
902	228.88	217.24	952	315.84	83.31	1002	316.91	79.14
903	217.10	229.01	953	311.00	99.86	1003	320.64	62.31
904	204.72	240.14	954	305.30	116.13	1004	323.48	45.30
905	191.76	250.61	955	298.75	132.07	1005	325.42	28.18
906	178.27	260.38	956	291.37	147.65	1006	326.46	10.97
907	164.29	269.42	957	283.17	162.81	1007	337.97	6.89
908	149.85	277.71	958	274.19	177.52	1008	337.14	24.71
909	134.99	285.23	959	264.44	191.74	1009	335.36	42.46
910	119.75	291.95	960	253.96	205.43	1010	332.66	60.10
911	104.18	297.86	961	242.77	218.54	1011	329.0)	77.56
912	88.32	302.95	962	230.90	231.04	1012	324.47	94.81
913	72.22	307.18	963	218.39	242.90	1013	319.02	111.80
914	55.91	310.57	964	205.27	254.08	1014	312.68	128.47
915	39.45	313.08	965	191.58	264.56	1015	305.46	144.79
916	22.88	314.73	966	177.36	274.30	1016	297.40	160.70
917	6.24	315.50	967	162.64	283.27	1017	288.51	176.17
918	10.41	315.39	968	147.47	291.46	1018	278.81	191.14
919	27.03	314.40	969	131.89	298.83	1019	268.34	205.59
920	43.58	312.54	970	115.94	305.37	1020	257.12	219.46
921	60.01	309.80	971	99.67	311.06	1021	245.18	232.71
922	76.27	306.20	972	83.12	315.89	1022	232.57	245.32
923	92.32	301.75	973	66.34	319.83	1023	219.30	257.25
924	108.11	296.46	974	49.37	322.89	1024	205.42	268.46
925	123.60	290.35	975	32.27	325.04	1025	190.97	278.93
926	138.74	283.42	976	15.08	326.29	1026	175.99	288.61
927	153.50	275.71	977	2.16	326.63	1027	160.52	297.50
928	167.83	267.23	978	19.38	326.07	1028	144.60	305.55
929	181.69	258.00	979	36.56	324.59	1029	128.28	312.75
930	195.05	248.06	980	53.63	322.21	1030	111.61	319.09
931	207.87	237.42	981	70.56	318.93	1031	94.62	324.53
932	220.10	226.12	982	87.28	314.76	1032	77.37	329.07
933	231.73	214.20	983	103.77	309.72	1033	59.90	332.69
934	242.70	201.67	984	119.96	303.82	1034	42.26	335.39
935	253.00	188.59	985	135.82	297.06	1035	24.51	337.15
936	262.60	174.98	986	151.30	289.49	1036	6.69	337.97
937	271.47	160.88	987	166.37	281.10	1037	11.15	337.86
938	279.58	146.34	988	180.96	271.93	1038	28.96	336.80
939	286.91	131.38	989	195.06	262.01	1039	46.69	334.80
940	293.44	116.07	990	208.61	251.35	1040	64.28	331.87
941	299.15	100.42	991	221.58	240.00	1041	81.70	328.02
942	304.03	84.50	992	233.93	227.97	1042	98.89	323.25
943	308.07	68.35	993	245.63	215.31	1043	115.81	317.58
944	311.25	52.00	994	256.65	202.06	1044	132.40	311.03
945	313.56	35.51	995	266.95	188.24	1045	148.62	303.61
946	314.99	18.91	996	276.51	173.89	1046	164.44	295.35
947	315.55	2.27	997	285.30	159.06	1047	179.79	286.27
948	326.28	15.28	998	293.29	143.79	1048	194.64	276.38
949	325.02	32.47	999	300.47	128.12	1049	208.95	265.73
950	322.86	49.57	1000	306.81	112.09	1050	222.68	254.34

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
1051	235.78	242.23	1101	93.46	337.05	1151	▾82.81	352.25
1052	248.23	229.46	1102	111.11	331.65	1152	▾64.12	356.12
1053	259.99	216.04	1103	128.46	325.33	1153	▾45.24	359.01
1054	271.03	202.03	1104	145.44	318.10	1154	▾26.24	360.90
1055	281.31	187.45	1105	162.02	309.98	1155	▾7.16	361.78
1056	290.81	172.34	1106	178.15	301.00	1156	11.93	361.65
1057	299.49	156.76	1107	193.78	291.19	1157	31.00	360.52
1058	307.35	140.75	1108	208.87	280.56	1158	49.97	358.38
1059	314.34	124.33	1109	223.38	269.15	1159	68.81	355.25
1060	320.47	107.58	1110	237.27	256.99	1160	87.46	351.12
1061	325.69	90.52	1111	250.49	244.11	1161	105.86	346.02
1062	330.02	73.21	1112	263.02	230.56	1162	123.96	339.95
1063	333.42	55.70	1113	274.82	216.36	1163	141.73	332.94
1064	335.89	38.04	1114	285.85	201.56	1164	159.09	325.00
1065	337.43	20.26	1115	296.09	186.20	1165	176.02	316.15
1066	338.03	2.43	1116	305.50	170.32	1166	192.45	306.43
1067	▾349.39	16.36	1117	314.06	153.97	1167	208.35	295.85
1068	▾348.04	34.77	1118	321.74	137.19	1168	223.67	284.44
1069	▾345.72	53.08	1119	328.53	120.02	1169	238.36	272.25
1070	▾342.44	71.24	1120	334.41	102.52	1170	252.39	259.30
1071	▾338.20	89.21	1121	339.35	84.74	1171	265.72	245.62
1072	▾333.03	106.93	1122	343.35	66.72	1172	278.31	231.26
1073	▾326.92	124.35	1123	346.39	48.51	1173	290.12	216.25
1074	▾319.91	141.42	1124	348.47	30.17	1174	301.12	200.65
1075	▾312.00	158.10	1125	349.57	11.74	1175	311.29	184.48
1076	▾303.22	174.34	1126	▾361.77	7.38	1176	320.59	167.80
1077	▾293.60	190.09	1127	▾360.88	26.45	1177	328.99	150.66
1078	▾283.17	205.32	1128	▾358.98	45.46	1178	336.48	133.09
1079	▾271.94	219.97	1129	▾356.08	64.33	1179	343.04	115.16
1080	▾259.96	234.01	1130	▾352.20	83.03	1180	348.63	96.90
1081	▾247.25	247.40	1131	▾347.32	101.49	1181	353.26	78.37
1082	▾233.85	260.10	1132	▾341.49	119.67	1182	356.90	59.63
1083	▾219.81	272.07	1133	▾334.70	137.52	1183	359.55	40.71
1084	▾205.15	283.29	1134	▾326.98	154.99	1184	361.20	21.69
1085	▾189.92	293.72	1135	▾318.35	172.02	1185	361.84	2.60
1086	▾174.16	303.33	1136	▾308.83	188.58	1186	▾373.88	17.50
1087	▾157.91	312.09	1137	▾298.45	204.61	1187	▾372.44	37.20
1088	▾141.23	319.99	1138	▾287.24	220.06	1188	▾369.96	56.80
1089	▾124.15	327.00	1139	▾275.23	234.91	1189	▾366.45	76.24
1090	▾106.73	333.09	1140	▾262.45	249.10	1190	▾361.92	95.46
1091	▾89.01	338.26	1141	▾248.95	262.60	1191	▾356.37	114.42
1092	▾71.04	342.48	1142	▾234.75	275.37	1192	▾349.84	133.07
1093	▾52.87	345.75	1143	▾219.89	287.37	1193	▾342.34	151.34
1094	▾34.56	348.06	1144	▾204.43	298.57	1194	▾333.87	169.19
1095	▾16.15	349.40	1145	▾188.39	308.94	1195	▾324.48	186.56
1096	2.31	349.76	1146	▾171.83	318.45	1196	▾314.19	203.42
1097	20.76	349.15	1147	▾154.79	327.07	1197	▾303.02	219.71
1098	39.15	347.57	1148	▾137.32	334.78	1198	▾291.01	235.39
1099	57.43	345.02	1149	▾119.47	341.56	1199	▾278.18	250.42
1100	75.55	341.51	1150	▾101.28	347.39	1200	▾264.59	264.75

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
1201	-250.25	278.34	1251	-367.00	123.20	1301	381.83	63.79
1202	-235.22	291.15	1252	-356.10	151.84	1302	384.06	48.63
1203	-219.53	303.15	1253	-349.82	165.81	1303	386.70	18.10
1204	-203.23	314.31	1254	-342.98	179.53	1304	387.11	2.79
1205	-186.37	324.60	1255	-327.71	206.09	1305	-400.21	10.80
1206	-168.98	333.98	1256	-319.29	218.90	1306	-399.47	26.63
1207	-151.13	342.43	1257	-310.38	231.36	1307	-398.10	42.42
1208	-132.86	349.92	1258	-291.11	255.18	1308	-396.11	58.14
1209	-114.21	356.44	1259	-280.79	266.50	1309	-393.50	73.77
1210	-95.25	361.97	1260	-270.02	277.41	1310	-390.27	89.29
1211	-76.02	366.49	1261	-247.23	297.89	1311	-386.43	104.66
1212	-56.58	369.99	1262	-235.25	307.44	1312	-381.99	119.87
1213	-36.98	372.46	1263	-222.90	316.51	1313	-376.95	134.90
1214	-17.28	373.90	1264	-197.17	333.15	1314	-371.31	149.71
1215	2.47	374.29	1265	-183.83	340.69	1315	-365.10	164.29
1216	22.21	373.63	1266	-170.20	347.70	1316	-358.31	178.61
1217	41.89	371.94	1267	-142.17	360.07	1317	-350.96	192.65
1218	61.46	369.21	1268	-127.81	365.42	1318	-343.06	206.39
1219	80.85	365.46	1269	-113.25	370.19	1319	-334.63	219.80
1220	100.02	360.68	1270	-83.62	377.99	1320	-325.66	232.87
1221	118.90	354.91	1271	-68.59	381.00	1321	-316.19	245.58
1222	137.46	348.14	1272	-53.46	383.41	1322	-306.23	257.90
1223	155.64	340.40	1273	-22.97	386.44	1323	-295.78	269.81
1224	173.38	331.72	1274	-7.66	387.05	1324	-284.87	281.31
1225	190.64	322.11	1275	7.66	387.05	1325	-273.52	292.36
1226	207.36	311.60	1276	38.25	385.23	1326	-261.73	302.96
1227	223.51	300.23	1277	53.46	383.41	1327	-249.54	313.08
1228	239.04	288.02	1278	68.60	381.00	1328	-236.95	322.71
1229	253.90	275.01	1279	98.51	374.38	1329	-224.00	331.83
1230	268.06	261.23	1280	113.25	370.19	1330	-210.69	340.44
1231	281.47	246.73	1281	127.81	365.42	1331	-197.05	348.51
1232	294.09	231.53	1282	156.31	354.16	1332	-183.10	356.03
1233	305.89	215.70	1283	170.21	347.70	1333	-168.87	363.00
1234	316.85	199.26	1284	183.83	340.69	1334	-154.37	369.40
1235	326.92	182.27	1285	210.20	325.09	1335	-139.63	375.22
1236	336.08	164.76	1286	222.90	316.51	1336	-124.68	380.45
1237	344.30	146.81	1287	235.25	307.44	1337	-109.52	385.09
1238	351.57	128.44	1288	258.83	287.88	1338	-94.20	389.12
1239	357.85	109.71	1289	270.02	277.41	1339	-78.72	392.54
1240	363.14	90.68	1290	280.79	266.50	1340	-63.13	395.35
1241	367.42	71.40	1291	300.98	243.46	1341	-47.43	397.54
1242	370.68	51.91	1292	310.38	231.36	1342	-31.66	399.10
1243	372.90	32.29	1293	319.30	218.90	1343	-15.84	400.04
1244	374.08	12.57	1294	335.61	192.96	1344	.00	400.36
1245	-387.11	2.79	1295	342.98	179.53	1345	15.84	400.04
1246	-385.68	33.39	1296	349.82	165.81	1346	31.66	399.10
1247	-384.06	48.63	1297	361.83	137.63	1347	47.43	397.54
1248	-381.83	63.79	1298	367.00	123.20	1348	63.13	395.35
1249	-375.59	93.79	1299	371.59	108.58	1349	78.72	392.54
1250	-371.58	108.58	1300	379.01	78.85	1350	94.20	389.12

HSTAT	*X*	*Y*	*HSTAT*	*X*	*Y*	*HSTAT*	*X*	*Y*
1351	109.52	385.09	1401	-311.33	272.91	1451	374.12	177.33
1352	124.68	380.45	1402	-300.29	285.02	1452	380.84	162.38
1353	139.64	375.22	1403	-288.78	296.68	1453	386.97	147.19
1354	154.37	369.40	1404	-276.81	307.87	1454	392.49	131.76
1355	168.87	363.00	1405	-264.41	318.59	1455	397.40	116.12
1356	183.11	356.03	1406	-251.59	328.80	1456	401.68	100.30
1357	197.05	348.51	1407	-238.38	338.50	1457	405.34	84.33
1358	210.69	340.44	1408	-224.80	347.67	1458	408.36	68.22
1359	224.00	331.83	1409	-210.87	356.29	1459	410.74	52.01
1360	236.95	322.71	1410	-196.60	364.36	1460	412.47	35.71
1361	249.54	313.08	1411	-182.03	371.85	1461	413.56	19.36
1362	261.73	302.96	1412	-167.17	378.77	1462	-427.17	28.48
1363	273.52	292.36	1413	-152.05	385.08	1463	-425.71	45.36
1364	284.87	281.31	1414	-136.69	390.80	1464	-423.58	62.18
1365	295.78	269.81	1415	-121.12	395.90	1465	-420.79	78.89
1366	306.23	257.90	1416	-105.35	400.39	1466	-417.33	95.48
1367	316.19	245.57	1417	-89.43	404.24	1467	-413.23	111.92
1368	325.67	232.87	1418	-73.36	407.46	1468	-408.48	128.19
1369	334.63	219.80	1419	-57.18	410.05	1469	-403.08	144.25
1370	343.06	206.38	1420	-40.90	411.99	1470	-397.06	160.09
1371	350.96	192.65	1421	-24.57	413.29	1471	-390.41	175.68
1372	358.31	178.61	1422	-8.19	413.93	1472	-383.15	190.99
1373	365.10	164.29	1423	8.19	413.93	1473	-375.29	206.00
1374	371.31	149.71	1424	24.57	413.29	1474	-366.85	220.69
1375	376.95	134.90	1425	40.91	411.99	1475	-357.83	235.04
1376	381.99	119.87	1426	57.18	410.05	1476	-348.24	249.02
1377	386.43	104.66	1427	73.36	407.46	1477	-338.12	262.60
1378	390.27	89.29	1428	89.43	404.24	1478	-327.46	275.78
1379	393.50	73.77	1429	105.36	400.39	1479	-316.29	288.52
1380	396.11	58.14	1430	121.12	395.90	1480	-304.62	300.81
1381	398.10	42.42	1431	136.69	390.80	1481	-292.48	312.63
1382	399.47	26.63	1432	152.05	385.08	1482	-279.88	323.96
1383	400.21	10.80	1433	167.17	378.76	1483	-266.84	334.78
1384	-413.56	19.36	1434	182.03	371.85	1484	-253.38	345.08
1385	-412.47	35.71	1435	196.60	364.36	1485	-239.53	354.84
1386	-410.74	52.01	1436	210.87	356.29	1486	-225.30	364.04
1387	-408.36	68.22	1437	224.80	347.67	1487	-210.71	372.67
1388	-405.34	84.33	1438	238.38	338.50	1488	-195.80	380.72
1389	-401.68	100.30	1439	251.59	328.80	1489	-180.58	388.17
1390	-397.40	116.12	1440	264.41	318.59	1490	-165.08	395.01
1391	-392.49	131.76	1441	276.81	307.87	1491	-149.32	401.23
1392	-386.97	147.19	1442	288.78	296.68	1492	-133.32	406.83
1393	-380.84	162.39	1443	300.29	285.02	1493	-117.12	411.79
1394	-374.12	177.33	1444	311.33	272.91	1494	-100.73	416.10
1395	-366.80	192.00	1445	321.89	260.37	1495	-84.18	419.76
1396	-358.92	206.36	1446	331.94	247.43	1496	-67.50	422.76
1397	-350.47	220.40	1447	341.47	234.10	1497	-50.72	425.10
1398	-341.47	234.10	1448	350.47	220.40	1498	-33.86	426.78
1399	-331.94	247.43	1449	358.92	206.36	1499	-16.94	427.78
1400	-321.89	260.37	1450	366.81	192.00	1500	.00	428.12

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
1501	16.94	427.78	1551	-354.93	264.57	1601	383.77	220.65
1502	33.86	426.78	1552	-344.18	278.40	1602	392.20	205.29
1503	50.72	425.10	1553	-332.89	291.81	1603	400.02	189.61
1504	67.51	422.76	1554	-321.08	304.75	1604	407.21	173.63
1505	84.18	419.76	1555	-308.77	317.22	1605	413.76	157.38
1506	100.73	416.10	1556	-295.98	329.19	1606	419.67	140.88
1507	117.12	411.79	1557	-282.72	340.65	1607	424.91	124.16
1508	133.32	406.83	1558	-269.01	351.57	1608	429.50	107.25
1509	149.32	401.23	1559	-254.89	361.94	1609	433.40	90.17
1510	165.08	395.01	1560	-240.37	371.74	1610	436.63	72.95
1511	180.58	388.17	1561	-225.47	380.96	1611	-436.74	137.06
1512	195.80	380.72	1562	-210.21	389.59	1612	-430.97	154.23
1513	210.71	372.67	1563	-194.63	397.60	1613	-424.53	171.17
1514	225.30	364.04	1564	-178.74	404.99	1614	-417.42	187.83
1515	239.53	354.84	1565	-162.58	411.75	1615	-409.66	204.20
1516	253.38	345.08	1566	-146.15	417.86	1616	-401.26	220.26
1517	266.84	334.78	1567	-129.50	423.32	1617	-392.23	235.96
1518	279.88	323.96	1568	-112.65	428.11	1618	-382.58	251.30
1519	292.48	312.63	1569	-95.62	432.23	1619	-372.34	266.25
1520	304.62	300.81	1570	-78.44	435.68	1620	-361.51	280.77
1521	316.29	288.52	1571	-61.14	438.44	1621	-350.12	294.86
1522	327.46	275.78	1572	-43.74	440.52	1622	-338.17	308.48
1523	338.12	262.60	1573	-26.27	441.90	1623	-325.70	321.62
1524	348.25	249.02	1574	-8.76	442.60	1624	-312.72	334.26
1525	357.83	235.04	1575	8.76	442.60	1625	-299.24	346.38
1526	366.85	220.69	1576	26.27	441.90	1626	-285.30	357.95
1527	375.30	206.00	1577	43.74	440.52	1627	-270.91	368.96
1528	383.15	190.99	1578	61.14	438.44	1628	-256.10	379.39
1529	390.41	175.68	1579	78.44	435.68	1629	-240.88	389.23
1530	397.06	160.09	1580	95.62	432.23	1630	-225.29	398.46
1531	403.08	144.25	1581	112.65	428.11	1631	-209.35	407.06
1532	408.48	128.19	1582	129.50	423.32	1632	-193.07	415.02
1533	413.23	111.92	1583	146.16	417.86	1633	-176.50	422.34
1534	417.33	95.48	1584	162.58	411.75	1634	-159.65	428.99
1535	420.79	78.89	1585	178.75	404.99	1635	-142.54	434.98
1536	423.58	62.17	1586	194.63	397.60	1636	-125.22	440.28
1537	425.71	45.36	1587	210.21	389.59	1637	-107.70	444.89
1538	427.17	28.48	1588	225.47	380.96	1638	-90.01	448.80
1539	-436.63	72.95	1589	240.37	371.74	1639	-72.17	452.01
1540	-433.40	90.17	1590	254.89	361.94	1640	-54.23	454.51
1541	-429.49	107.25	1591	269.01	351.57	1641	-36.20	456.30
1542	-424.91	124.16	1592	282.72	340.65	1642	-18.11	457.38
1543	-419.67	140.88	1593	295.98	329.19	1643	.00	457.74
1544	-413.76	157.38	1594	308.77	317.22	1644	18.12	457.38
1545	-407.21	173.63	1595	321.08	304.75	1645	36.20	456.30
1546	-400.02	189.61	1596	332.89	291.81	1646	54.23	454.51
1547	-392.20	205.29	1597	344.18	278.40	1647	72.18	452.01
1548	-383.77	220.65	1598	354.93	264.56	1648	90.01	448.80
1549	-374.74	235.67	1599	365.12	250.31	1649	107.70	444.89
1550	-365.12	250.31	1600	374.74	235.67	1650	125.22	440.28

HSTAT	*X*	*Y*	*HSTAT*	*X*	*Y*	*HSTAT*	*X*	*Y*
1651	142.55	434.98	1701	▾83.86	465.81	1751	▾240.87	426.01
1652	159.65	428.99	1702	▾65.36	468.77	1752	▾223.83	435.21
1653	176.50	422.34	1703	▾46.76	470.98	1753	▾206.43	443.73
1654	193.08	415.02	1704	▾28.09	472.47	1754	▾188.71	451.55
1655	209.35	407.06	1705	▾9.37	473.21	1755	▾170.69	458.66
1656	225.29	398.45	1706	9.37	473.21	1756	▾152.40	465.06
1657	240.89	389.23	1707	28.09	472.47	1757	▾133.88	470.73
1658	256.10	379.39	1708	46.76	470.98	1758	▾115.15	475.66
1659	270.91	368.96	1709	65.37	468.76	1759	▾96.23	479.84
1660	285.30	357.95	1710	83.87	465.81	1760	▾77.17	483.27
1661	299.25	346.38	1711	102.23	462.13	1761	▾57.98	485.95
1662	312.72	334.26	1712	120.44	457.72	1762	▾38.70	487.86
1663	325.70	321.62	1713	138.46	452.59	1763	▾19.37	489.01
1664	338.17	308.48	1714	156.26	446.76	1764	.00	489.40
1665	350.12	294.86	1715	173.82	440.23	1765	19.37	489.01
1666	361.51	280.77	1716	191.11	433.00	1766	38.71	487.86
1667	372.34	266.24	1717	208.09	425.10	1767	57.98	485.95
1668	382.58	251.30	1718	224.75	416.53	1768	77.17	483.27
1669	392.23	235.96	1719	241.06	407.31	1769	96.23	479.84
1670	401.26	220.26	1720	256.99	397.45	1770	115.15	475.66
1671	409.66	204.20	1721	272.52	386.97	1771	133.88	470.73
1672	417.42	187.83	1722	287.62	375.88	1772	152.40	465.06
1673	424.53	171.17	1723	302.27	364.21	1773	170.69	458.66
1674	430.97	154.23	1724	316.45	351.96	1774	188.71	451.55
1675	436.74	137.05	1725	330.13	339.16	1775	206.43	443.73
1676	▾435.37	185.64	1726	343.29	325.83	1776	223.83	435.21
1677	▾427.69	202.72	1727	355.92	311.99	1777	240.88	426.01
1678	▾419.33	219.49	1728	367.98	297.66	1778	257.55	416.15
1679	▾410.31	235.91	1729	379.48	282.86	1779	273.81	405.63
1680	▾400.66	251.97	1730	390.37	267.62	1780	289.65	394.47
1681	▾390.37	267.62	1731	400.66	251.96	1781	305.04	382.70
1682	▾379.48	282.86	1732	410.32	235.91	1782	319.94	370.33
1683	▾367.98	297.66	1733	419.33	219.49	1783	334.35	357.38
1684	▾355.92	311.99	1734	427.69	202.72	1784	348.23	343.87
1685	▾343.29	325.83	1735	435.38	185.64	1785	361.56	329.82
1686	▾330.13	339.16	1736	▾438.00	218.33	1786	374.33	315.25
1687	▾316.45	351.96	1737	▾429.01	235.49	1787	386.52	300.19
1688	▾302.27	364.21	1738	▾419.36	252.28	1788	398.09	284.66
1689	▾287.62	375.88	1739	▾409.04	268.68	1789	409.05	268.68
1690	▾272.52	386.97	1740	▾398.09	284.66	1790	419.36	252.28
1691	▾256.99	397.45	1741	▾386.51	300.19	1791	429.01	235.49
1692	▾241.06	407.31	1742	▾374.33	315.25	1792	438.00	218.33
1693	▾224.75	416.53	1743	▾361.56	329.82	1793	▾438.69	252.26
1694	▾208.09	425.10	1744	▾348.23	343.87	1794	▾428.38	269.40
1695	▾191.11	433.00	1745	▾334.35	357.38	1795	▾420.19	282.00
1696	▾173.82	440.23	1746	▾319.94	370.33	1796	▾402.72	306.43
1697	▾156.26	446.76	1747	▾305.03	382.70	1797	▾393.44	318.25
1698	▾138.46	452.59	1748	▾289.65	394.48	1798	▾383.82	329.79
1699	▾120.44	457.72	1749	▾273.81	405.63	1799	▾363.57	351.99
1700	▾102.23	462.13	1750	▾257.54	416.15	1800	▾352.97	362.62

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
1801	-342.05	372.94	1851	-401.91	335.09	1901	299.17	429.31
1802	-319.31	392.58	1852	-391.78	346.87	1902	311.78	420.24
1803	-307.52	401.89	1853	-381.31	358.35	1903	324.12	410.80
1804	-295.45	410.84	1854	-370.51	369.51	1904	336.17	401.00
1805	-270.55	427.65	1855	-359.38	380.35	1905	347.93	390.84
1806	-257.74	435.49	1856	-347.93	390.85	1906	359.38	380.34
1807	-244.70	442.95	1857	-336.17	401.00	1907	370.51	369.51
1808	-217.98	456.69	1858	-324.12	410.80	1908	381.31	359.35
1809	-204.33	462.96	1859	-311.78	420.24	1909	391.78	346.87
1810	-190.50	468.82	1860	-299.17	429.31	1910	401.91	335.09
1811	-162.34	479.30	1861	-286.30	438.01	1911	411.68	323.01
1812	-148.04	483.91	1862	-273.17	446.31	1912	421.08	310.65
1813	-133.61	488.09	1863	-259.80	454.22	1913	430.12	298.01
1814	-104.41	495.16	1864	-246.20	461.73	1914	438.78	285.11
1815	-89.67	498.04	1865	-232.39	468.84	1915	-430.61	327.66
1816	-74.84	500.48	1866	-218.37	475.53	1916	-420.70	340.30
1817	-45.01	504.04	1867	-204.15	481.80	1917	-410.41	352.64
1818	-30.03	505.15	1868	-189.76	487.65	1918	-399.76	364.66
1819	-15.02	505.82	1869	-175.20	493.07	1919	-388.76	376.37
1820	15.02	505.82	1870	-160.49	498.05	1920	-377.42	387.74
1821	30.03	505.15	1871	-145.63	502.60	1921	-365.74	398.78
1822	45.01	504.04	1872	-130.65	506.70	1922	-353.74	409.46
1823	74.84	500.48	1873	-115.55	510.35	1923	-341.43	419.78
1824	89.67	498.04	1874	-100.35	513.56	1924	-328.82	429.73
1825	104.41	495.16	1875	-85.06	516.31	1925	-315.92	439.30
1826	133.61	488.09	1876	-69.70	518.61	1926	-302.74	448.48
1827	148.04	483.91	1877	-54.27	520.45	1927	-289.29	457.27
1828	162.34	479.30	1878	-38.80	521.83	1928	-275.59	465.66
1829	190.50	468.82	1879	-23.29	522.75	1929	-261.65	473.63
1830	204.33	462.96	1880	-7.77	523.21	1930	-247.47	481.19
1831	217.98	456.69	1881	7.77	523.21	1931	-233.08	488.33
1832	244.70	442.95	1882	23.30	522.75	1932	-218.48	495.03
1833	257.74	435.49	1883	38.80	521.83	1933	-203.69	501.30
1834	270.55	427.65	1884	54.28	520.45	1934	-188.72	507.12
1835	295.45	410.84	1885	69.70	518.61	1935	-173.58	512.50
1836	307.52	401.89	1886	85.07	516.31	1936	-158.29	517.43
1837	319.31	392.58	1887	100.35	513.56	1937	-142.87	521.90
1838	342.05	372.94	1888	115.55	510.35	1938	-127.31	525.91
1839	352.97	362.62	1889	130.65	506.70	1939	-111.64	529.46
1840	363.58	351.99	1890	145.64	502.60	1940	-95.88	532.54
1841	383.82	329.79	1891	160.49	498.05	1941	-80.03	535.15
1842	393.44	318.25	1892	175.20	493.07	1942	-64.11	537.29
1843	402.72	306.43	1893	189.76	487.65	1943	-48.13	538.95
1844	420.19	281.99	1894	204.16	481.80	1944	-32.11	540.15
1845	428.38	269.40	1895	218.37	475.53	1945	-16.06	540.86
1846	438.69	252.26	1896	232.39	468.84	1946	.00	541.10
1847	-438.78	285.11	1897	246.20	461.73	1947	16.06	540.86
1848	-430.12	298.01	1898	259.80	454.22	1948	32.11	540.15
1849	-421.08	310.65	1899	273.17	446.31	1949	48.13	538.95
1850	-411.68	323.01	1900	286.30	438.00	1950	64.11	537.29

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
1951	80.03	535.15	2001	-107.31	549.16	2051	-264.65	514.58
1952	95.88	532.54	2002	-90.96	552.11	2052	-249.25	522.21
1953	111.64	529.46	2003	-74.53	554.56	2053	-233.64	529.38
1954	127.31	525.91	2004	-58.04	556.53	2054	-217.83	536.08
1955	142.87	521.90	2005	-41.49	558.01	2055	-201.82	542.31
1956	158.30	517.43	2006	-24.91	559.00	2056	-185.63	548.06
1957	173.59	512.50	2007	-8.31	559.49	2057	-169.28	553.33
1958	188.72	507.12	2008	8.31	559.49	2058	-152.78	558.11
1959	203.69	501.30	2009	24.91	559.00	2059	-136.14	562.40
1960	218.48	495.03	2010	41.49	558.01	2060	-119.39	566.19
1961	233.08	488.33	2011	58.04	556.53	2061	-102.53	569.49
1962	247.47	481.19	2012	74.53	554.56	2062	-85.58	572.28
1963	261.65	473.63	2013	90.96	552.11	2063	-68.55	574.57
1964	275.59	465.66	2014	107.31	549.16	2064	-51.47	576.35
1965	289.30	457.27	2015	123.57	545.74	2065	-34.34	577.63
1966	302.74	448.48	2016	139.71	541.83	2066	-17.18	578.39
1967	315.92	439.30	2017	155.73	537.44	2067	.00	578.65
1968	328.82	429.73	2018	171.62	532.58	2068	17.18	578.39
1969	341.43	419.78	2019	187.35	527.25	2069	34.34	577.63
1970	353.74	409.46	2020	202.92	521.46	2070	51.47	576.35
1971	365.74	398.78	2021	218.31	515.21	2071	68.56	574.57
1972	377.42	387.74	2022	233.51	508.50	2072	85.58	572.28
1973	388.76	376.37	2023	248.50	501.34	2073	102.53	569.49
1974	399.76	364.66	2024	263.27	493.75	2074	119.39	566.19
1975	410.41	352.64	2025	277.81	485.71	2075	136.15	562.40
1976	420.70	340.30	2026	292.11	477.25	2076	152.78	558.11
1977	430.61	327.66	2027	306.15	468.37	2077	169.28	553.33
1978	-429.77	358.32	2028	319.91	459.08	2078	185.63	548.06
1979	-418.94	370.92	2029	333.40	449.38	2079	201.82	542.31
1980	-407.75	383.19	2030	346.59	439.28	2080	217.83	536.08
1981	-396.19	395.13	2031	359.48	428.80	2081	233.64	529.38
1982	-384.29	406.71	2032	372.05	417.94	2082	249.25	522.21
1983	-372.05	417.94	2033	384.29	406.71	2083	264.65	514.58
1984	-359.48	428.80	2034	396.20	395.13	2084	279.80	506.50
1985	-346.59	439.28	2035	407.75	383.19	2085	294.72	497.97
1986	-333.40	449.38	2036	418.95	370.92	2086	309.37	489.00
1987	-319.91	459.08	2037	429.77	358.32	2087	323.75	479.60
1988	-306.14	468.37	2038	-438.89	377.11	2088	337.84	469.78
1989	-292.11	477.25	2039	-427.50	389.97	2089	351.64	459.54
1990	-277.81	485.71	2040	-415.74	402.49	2090	365.12	448.90
1991	-263.27	493.75	2041	-403.60	414.65	2091	378.29	437.87
1992	-248.50	501.34	2042	-391.12	426.45	2092	391.12	426.45
1993	-233.51	508.50	2043	-378.29	437.87	2093	403.61	414.65
1994	-218.31	515.21	2044	-365.12	448.91	2094	415.74	402.48
1995	-202.92	521.46	2045	-351.64	459.55	2095	427.50	389.97
1996	-187.35	527.25	2046	-337.84	469.78	2096	438.89	377.10
1997	-171.62	532.58	2047	-323.75	479.60	2097	-436.06	409.80
1998	-155.73	537.44	2048	-309.37	489.00	2098	-423.71	422.57
1999	-139.71	541.83	2049	-294.72	497.97	2099	-410.98	434.96
2000	-123.56	545.74	2050	-279.80	506.50	2100	-397.88	446.97

HSTAT	X	Y	HSTAT	X	Y	HSTAT	X	Y
2101	-384.44	458.58	2153	-431.65	443.46	2205	431.65	443.46
2102	-370.66	469.79	2154	-418.29	456.08	2206	-425.54	478.03
2103	-356.55	480.58	2155	-404.57	468.29	2207	-411.16	490.45
2104	-342.13	490.96	2156	-390.49	480.10	2208	-396.42	502.44
2105	-327.40	500.90	2157	-376.07	491.48	2209	-381.33	513.99
2106	-312.39	510.39	2158	-361.31	502.42	2210	-365.91	525.08
2107	-297.10	519.44	2159	-346.24	512.93	2211	-350.16	535.71
2108	-281.55	528.03	2160	-330.86	522.98	2212	-334.10	545.87
2109	-265.75	536.16	2161	-315.19	532.57	2213	-317.75	555.55
2110	-249.72	543.81	2162	-299.25	541.69	2214	-301.12	564.74
2111	-233.47	550.98	2163	-283.03	550.34	2215	-284.23	573.42
2112	-217.01	557.67	2164	-266.57	558.50	2216	-267.08	581.61
2113	-200.36	563.87	2165	-249.88	566.16	2217	-249.70	589.28
2114	-183.53	569.57	2166	-232.96	573.33	2218	-232.09	596.43
2115	-166.55	574.76	2167	-215.84	579.99	2219	-214.29	603.06
2116	-149.41	579.45	2168	-198.53	586.14	2220	-196.29	609.16
2117	-132.14	583.63	2169	-181.04	591.78	2221	-178.12	614.71
2118	-114.76	587.30	2170	-163.39	596.89	2222	-159.80	619.73
2119	-97.28	590.45	2171	-145.60	601.48	2223	-141.33	624.20
2120	-79.71	593.07	2172	-127.69	605.54	2224	-122.74	628.12
2121	-62.07	595.18	2173	-109.65	609.06	2225	-104.04	631.49
2122	-44.37	596.76	2174	-91.53	612.05	2226	-85.25	634.30
2123	-26.64	597.81	2175	-73.32	614.49	2227	-66.38	636.55
2124	-8.88	598.34	2176	-55.04	616.40	2228	-47.46	638.24
2125	8.88	598.34	2177	-36.72	617.76	2229	-28.49	639.37
2126	26.64	597.81	2178	-18.37	618.58	2230	-9.50	639.93
2127	44.37	596.76	2179	.00	618.85	2231	9.50	639.93
2128	62.07	595.18	2180	18.37	618.58	2232	28.49	639.37
2129	79.71	593.07	2181	36.73	617.76	2233	47.46	638.24
2130	97.28	590.45	2182	55.05	616.40	2234	66.38	636.55
2131	114.76	587.30	2183	73.32	614.49	2235	85.25	634.30
2132	132.15	583.63	2184	91.53	612.05	2236	104.04	631.49
2133	149.41	579.45	2185	109.66	609.06	2237	122.74	628.12
2134	166.55	574.76	2186	127.69	605.54	2238	141.33	624.20
2135	183.54	569.57	2187	145.61	601.48	2239	159.80	619.73
2136	200.36	563.87	2188	163.40	596.89	2240	178.12	614.71
2137	217.01	557.67	2189	181.04	591.78	2241	196.29	609.15
2138	233.47	550.98	2190	198.53	586.14	2242	214.29	603.06
2139	249.72	543.81	2191	215.84	579.99	2243	232.10	596.43
2140	265.76	536.16	2192	232.96	573.33	2244	249.70	589.28
2141	281.55	528.03	2193	249.88	566.16	2245	267.08	581.61
2142	297.10	519.44	2194	266.57	558.49	2246	284.23	573.42
2143	312.39	510.39	2195	283.04	550.34	2247	301.12	564.73
2144	327.40	500.90	2196	299.25	541.69	2248	317.75	555.55
2145	342.13	490.96	2197	315.19	532.57	2249	334.11	545.87
2146	356.55	480.58	2198	330.86	522.98	2250	350.16	535.71
2147	370.66	469.79	2199	346.24	512.93	2251	365.91	525.08
2148	384.44	458.58	2200	361.32	502.42	2252	381.33	513.99
2149	397.89	446.96	2201	376.07	491.48	2253	396.42	502.44
2150	410.98	434.96	2202	390.49	480.10	2254	411.16	490.45
2151	423.71	422.57	2203	404.57	468.29	2255	425.54	478.03
2152	436.07	409.80	2204	418.30	456.08			

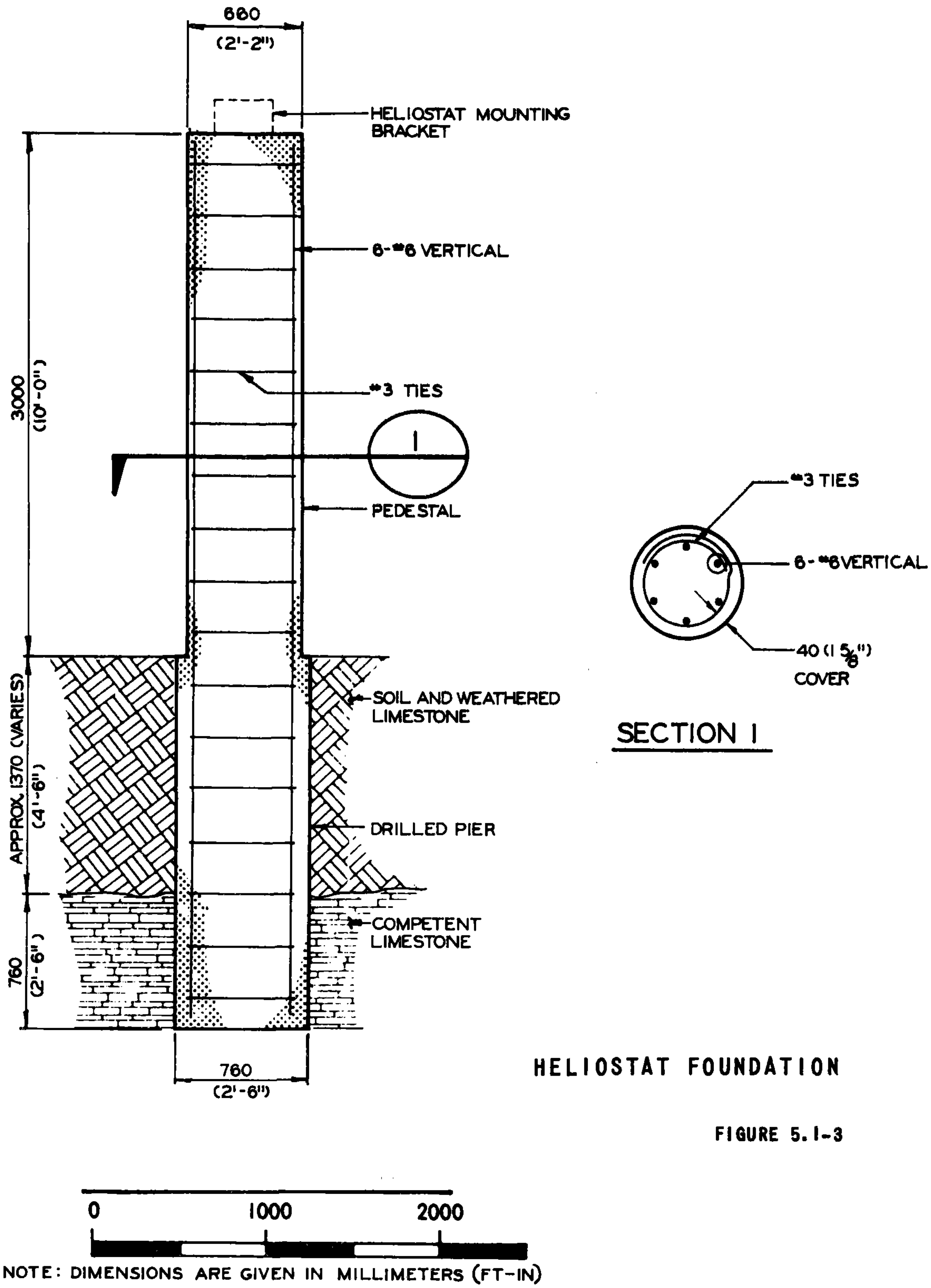
No contingency heliostats have been included in the collector design to replace those temporarily disabled during repair or routine maintenance.

(b) All 2,255 heliostats are identical in configuration to the second generation heliostat design developed in the DOE Heliostat Development Program.

(c) Each heliostat is supported by a reinforced concrete foundation as illustrated in Figure 5.1-3. Below grade the foundation is constructed as a drilled pier socketed into the competent limestone. Above grade the pedestal is constructed as a circular column. A reinforcing cage extends the full height of the foundation. The dimensions and design forces are based on data produced for the second generation heliostat design in the DOE Heliostat Development Program.

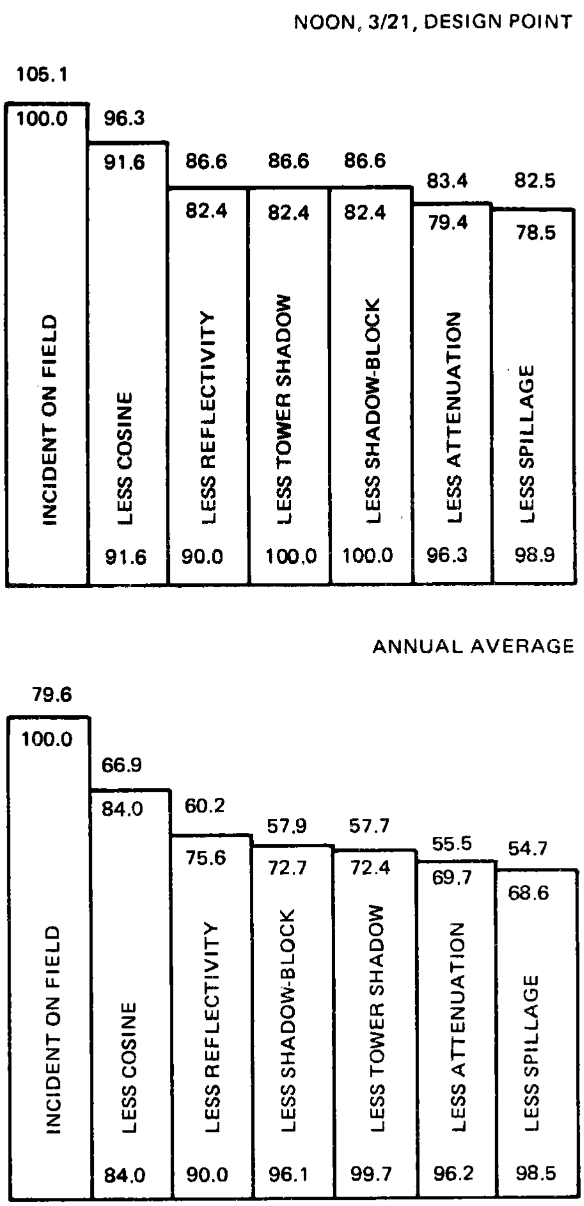
(2) Performance Characteristics. A detailed breakdown of the collector system performance at the design point (noon, March 21) is presented in the stairstep chart in Figure 5.1-4. The collector is specifically designed to direct 82.5 MWt to the receiver at the design point, with an insolation of 0.95 kW/m^2. Similarly, Figure 5.1-4 illustrates the annual average field performance stairstep; the reference insolation of 0.72 kW/m^2 is an annual average value based on the clear air insolation model described in Section 5.5.1.

Figure 5.1-5 demonstrates the relative effectiveness of heliostats in various portions of the collector field for the design point and on an annual average basis. The isopleths represent the power per unit of mirror area redirected to the receiver surface, and indicate the most efficient heliostats will be those directly north of the tower; heliostats with the lowest efficiency will be those in the southwest and southeast corners of the field. The current field design represents a departure from optimum since heliostats in the southwest and southeast corners would deliver more annual energy to the receiver if they



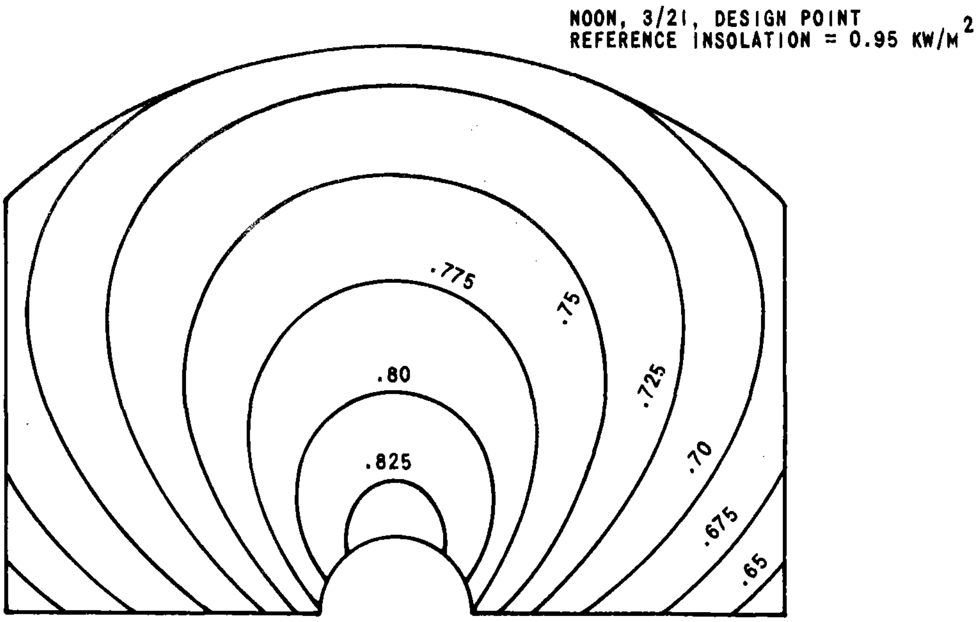
HELIOSTAT FOUNDATION

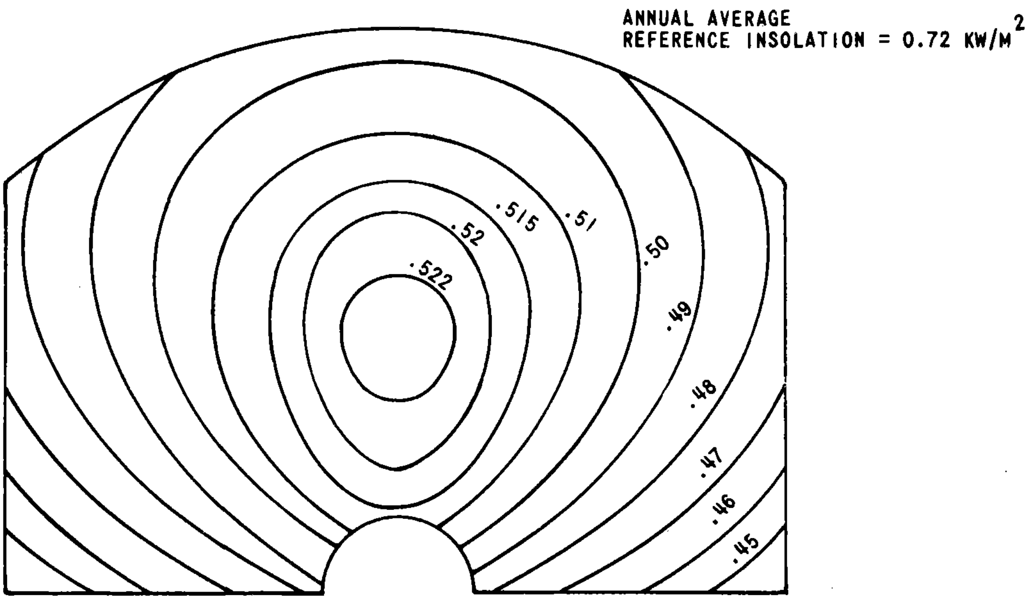
FIGURE 5.1-3



COLLECTOR SYSTEM
EFFICIENCY STAIR STEPS

FIGURE 5.1-4





POWER INCIDENT ON RECEIVER
PER UNIT OF MIRROR AREA

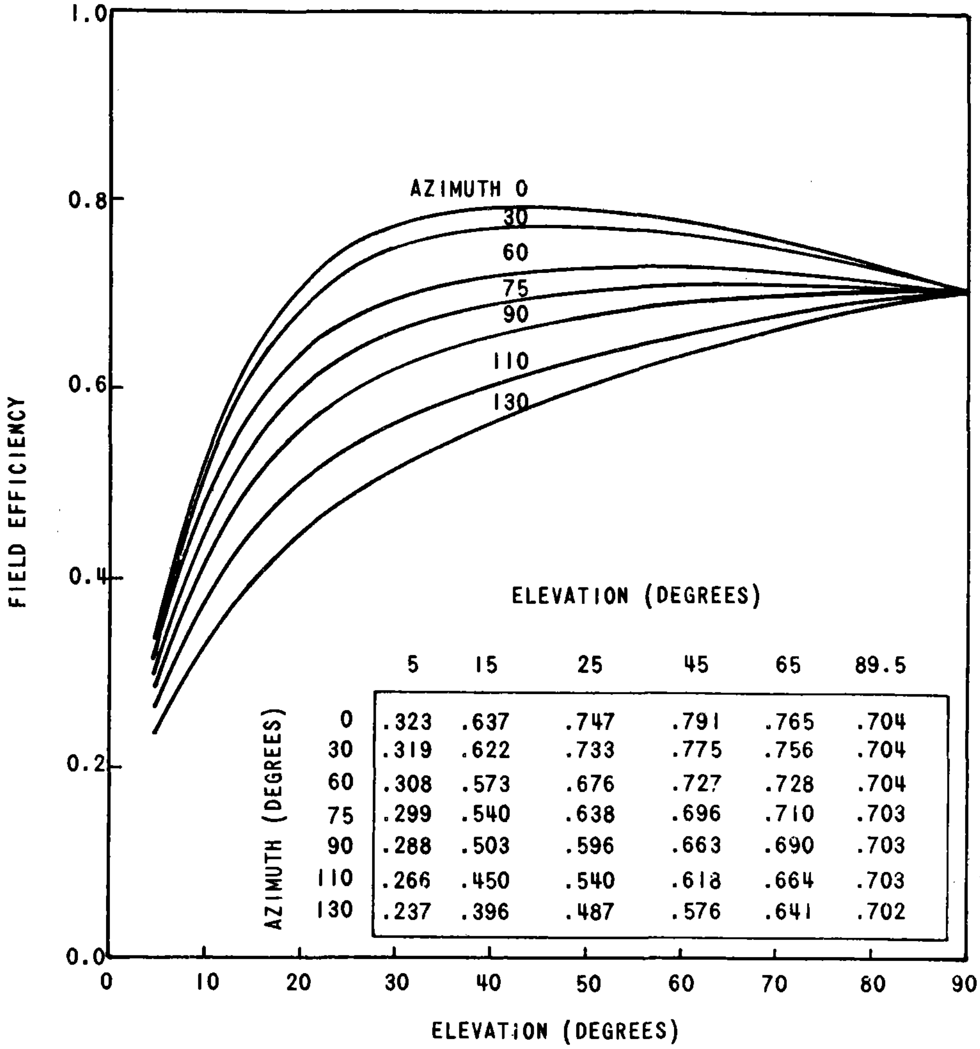
FIGURE 5.1-5

were placed along the northern edge of the field. However, the departure is necessary to reduce the peak incident flux on the north side of the receiver and redistribute more power to the west and east receiver panels, which results in less than 1 per cent loss in annual field performance.

Figure 5.1-6 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 attenuation, 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 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 slantrange, 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 subsystem will redirect 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 receiver centerline (i.e., no circumferential shift), but alternate between four vertical aim points on the receiver surface as illustrated in Figure 5.1-7. The vertical separation between aim points is a function of the heliostat's slantrange, and is tailored to meet the incident flux requirements of the receiver specified in Section 3.4. By spreading the beams vertically, incident power is evenly distributed without significantly increasing the total spillage loss.

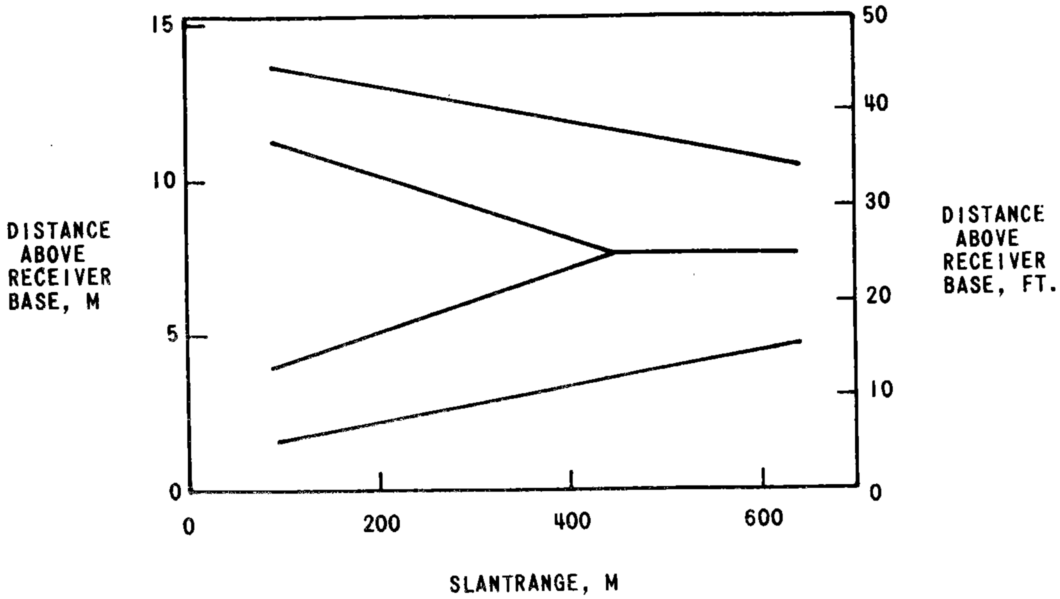


ELEVATION (DEGREES)

AZIMUTH (DEGREES)	5	15	25	45	65	89.5
0	.323	.637	.747	.791	.765	.704
30	.319	.622	.733	.775	.756	.704
60	.308	.573	.676	.727	.728	.704
75	.299	.540	.638	.696	.710	.703
90	.288	.503	.596	.663	.690	.703
110	.266	.450	.540	.618	.664	.703
130	.237	.396	.487	.576	.641	.702

COLLECTOR
FIELD EFFICIENCIES

FIGURE 5.1-6



COLLECTOR FOUR POINT AIM STRATEGY

FIGURE 5.1-7

A simple algorithm is presented there to generate the aim point coordinates (X, Y, and Z) based on a heliostat's polar field coordinates (R and THETA) and identification number (NH). Heliostats have been assigned unique identification numbers from 1 to 2,255 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 curves of the aim strategy diagram in Figure 5.1-7. Then the heliostat slantrange (S) is determined and used to compute the coordinates (X, Y, and Z) of the aim point in metres from the base of the tower.

The FORTRAN statements below can be used to perform the aim point calculations.

```
NA = 1 + MOD [(NH-1), 4]
 S = [(R - 4.724) ** 2 + 14,400] **0.5
 X = 4.724 * ASIN (THETA/57.2958)
 Y = 4.724 * ACOS (THETA/57.2958)
IF (NA.EQ.1) Z = 130.6 - 0.0057 * S
IF (NA.EQ.2) Z = 117.6 + 0.0057 * S
IF (NA.EQ.3) Z = AMAXI [124.1, (128.67 - 0.0102 * S)]
IF (NA.EQ.4) Z = [124.1, (119.53 + 0.0102 * S)]
```

The function MOD, used in the equations above, is a FORTRAN-supplied function which produces the remainder resulting from division of the first argument by the second. Functions ASIN and ACOS return the sine and cosine of their arguments, respectively.

(3) Operating Characteristics. The baseline heliostat and its control electronics are identical to the second generation heliostat configuration developed in the DOE Heliostat Development Program. The following data describe the operating characteristics expected for that design.

(a) In normal operating mode, each heliostat will track the sun, redirecting sunlight to an aim point on the receiver surface. In standby mode, heliostats will 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 will be 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 accross the normally unirradiated portion of the south side of the receiver. Similarly, heliostats in the west half of the field will be assigned a standby position northeast of the tower.

Heliostats may assume a directed position for cleaning, maintenance, or stowage on command from the Heliostat Array Controller or from local manual command at the Heliostat Controller.

Control software will provide time sequenced commands to the heliostats to execute predefined procedures such as start-up, shutdown, and emergency defocussing. In normal start-up, groups of heliostats will be 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 will be moved from standby to the receiver surface as needed. Evening shutdown will follow 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 will be directed to standby and will wait for operator command to return to target or to stow position.

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

(b) Each heliostat has two electric motors requiring a 110 volt ac power supply, and is expected to consume 32 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 A, 0.07 A, and 20 A, respectively. The Heliostat Array Controller has an identical backup system in hot standby which also requires 20 A.

The total installed power rating of equipment in the Collector System (based on 2,255 Heliostats, 71 Field Controllers, and two Heliostat Array Controllers) is 1,064 kW, and is broken down as follows.

	Total Installed Power
Heliostat Motors	1,006 kW
Heliostat Controllers	53 kW
Heliostat Field Controllers	0.5 kW
Heliostat Array Controllers	4.0 kW

Only a portion of the heliostats will be positioned at a time. The average operating power required by the collector system is 63.4 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 Master Control System (MCS) 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 71 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 grimbal 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 stow position.

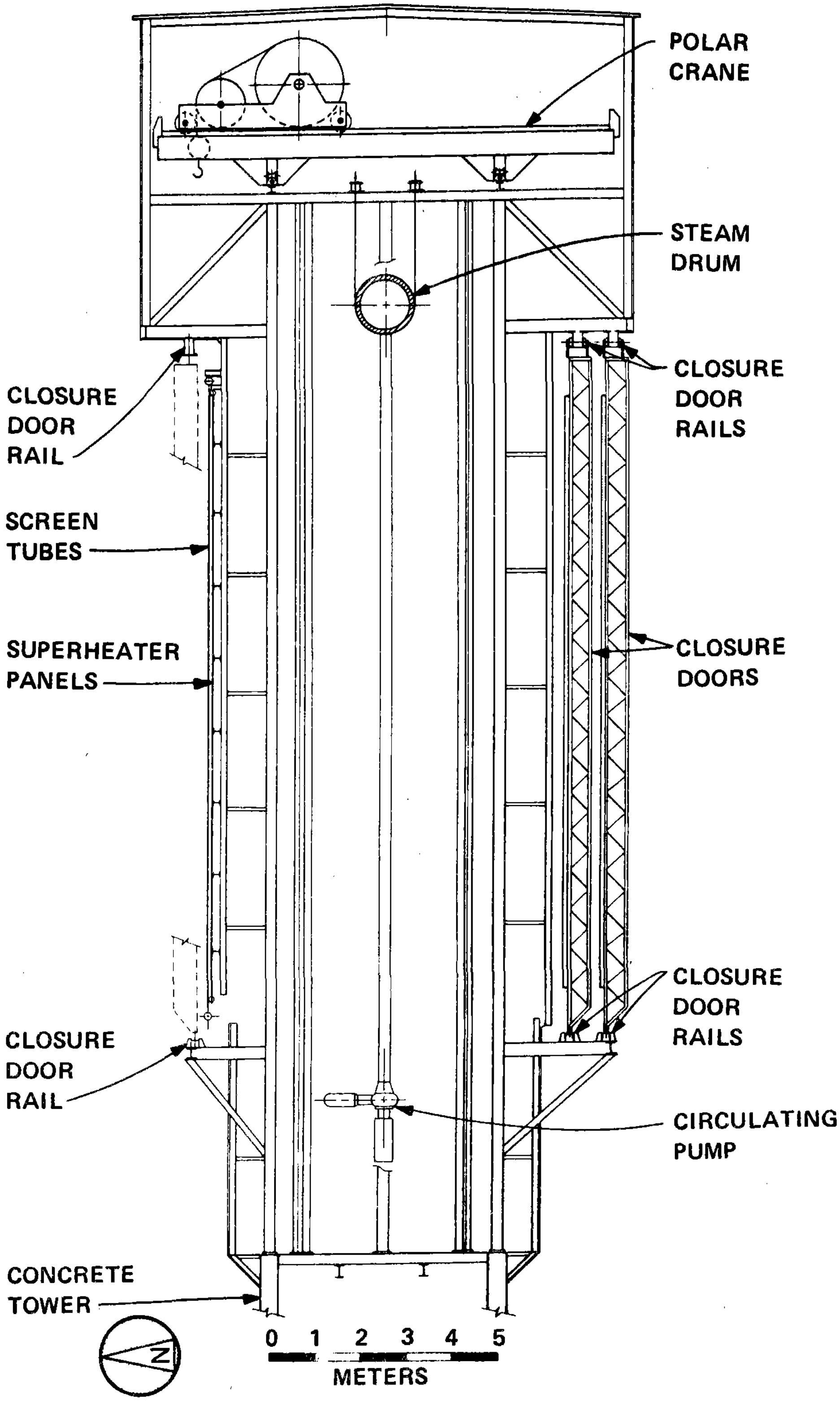
(d) The operating and survival limits of the collector system will be identical to those defined for the second generation heliostats designed in the DOE Heliostat Development Program.

5.1.4 Receiver Data

(1) Design characteristics are as follows.

(a) External receiver with closure doors (Figure 5.1-8), modular design steam generator with pump circulation.

- Diameter 9.5 m (31.2 ft).
- Height 15.24 m (50 ft).
- Center receiver 124 m (407 ft) above center of heliostats.
- Active surface 4.189 rad (240 degrees).



SOLAR RECEIVER
WITH CLOSURE DOORS

FIGURE 5.1-8

(b) Absorber tubes and panels are as follows.

- Materials, sizes, numbers, see Table 5.1-2.
- Number of tubes spacing, flow, see Table 5.1-3.

(c) Receiver valves, see Table 5.1-4.

(d) Weight of external receiver with closure doors.

- Boiler and mountings--73,000 kg (160,000 lb).
- Circulating pump and motor--5,000 kg (11,000 lb).
- Economizer--11,000 kg (25,000 lb).
- Superheater and piping--74,000 kg (164,000 lb).
- Controls--18,000 kg (40,000 lb).
- Insulation and lagging--136,000 kg (300,000 lb).
- Structural steel, platforms, and crane--277,000 kg (610,000 lb).
- Casing and siding--73,000 kg (160,000 lb).
- Closure door (with insulation)--63,000 kg (140,000 lb).
- Receiver fluid--15,000 kg (33,000 lb).
- Total--775,000 kg (1,643,000 lb).

(e) Receiver is designed to Section 1 of ASME Boiler Code.

(f) Receiver is designed for operational wind loads of 40 m/s (90 mph) and will survive gusts of 47 m/s (105 mph) as well as the seismic load of UBC Zone 1.

(g) Receiver surface coating: Pyromark with absorptivity of 95 per cent.

(h) Thermal performance, see Figure 5.1-9.

- Receiver heat losses, 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 5.1-10.

(i) Maximum receiver steam outlet pressure is 14.86 MPa (2,155 psi). Receiver design pressure is 16.55 MPa (2,450 psi).

Steam output at design point (equinox noon) is 111,260 kg (245,287 lb).

TABLE 5.1-2. GENERAL DESIGN DATA FOR SOLAR RECEIVER PANELS

Membrane (Superheater)	
Tube and Membrane Material	800H
Tube Outside Diameter cm (in.)	1.905 (0.750)
Tube Wall Thickness cm (in.)	0.254 (0.100)
Active Tube Length m (ft)	15.24 (50)
Total Tube Length m (ft)	15.85 (52)
Number of Tubes Per Panel	43
Panel Width m (ft)	1.24 (4.06)
Tube Spacing cm (in.)	2.858 (1.125)
Membrane Thickness cm (in.)	0.476 (0.187)
Inlet Header OD cm (in.)	11.43 (4.5)
Outlet Header OD cm (in.)	11.43 (4.5)
Header Matererial	800H
Design Pressure MA (PSIA)	16.9 (2,450)
Screen Tubes (Multi-Lead Internal Ribs)	
Tube Material	SA-213-T2
Tube Outside Diameter cm (in.)	3.493 (1.375); 3.810 (1.550); 4.128 (1.625)
Tube Wall Thickness cm (in.)	0.376 (0.148)
Tube Spacing cm (in.)	11.43 (4.50; 8.573 (3.375)
Number of Tubes PerPanel	15, 11
Active Tube Length m (ft)	15.24 (50)
Total Tue Length (ft)	16.15 (53)
Inlet Header OD cm (in.)	16.828 (6.625)
Outlet Header OD cm (in.)	16.828 (6.625)
Header Material	SA-210C
Membrane (Economizer)	
Tube and Membrane Material	SA-210-A1
Tube Outside Diameter cm (in.)	2.540 (1.000)
Tube Wall Thickness cm (in.)	0.343 (0.135)

TABLE 5.1-2 (Continued). GENERAL DESIGN DATA FOR SOLAR RECEIVER PANELS

Membrane Economizer (Continued)	
Active Tube Length m (ft)	15.24 (50)
Total Tube Length m (ft)	15.85 (52)
Number of Tubes Per Panel	32
Panel Width m (ft)	1.24 (4.06)
Tube Spacing cm (in.)	3.810 (1.500)
Membrane Thickness cm (in.)	0.635 (0.250
Inlet Header OD cm (in.)	16.828 (6.625)
Outlet Header OD cm (in.)	16.828 (6.625)
Header Material	SA-106-C
Design Pressure MPa (PSIA)	17.25 (2,500)

TABLE 5.1-3. PANEL DATA (EXTERNAL RECEIVER)

			Screen Tube (Boiler)						Membrane Tube				
Panel	Width (ft)	No.	Space (in.)	OD (in.)	ID (in.)	Flow (lb/h)	Type	No.	Space (in.)	OD (in.)	ID (in.)	Flow (lb/h)	Efficiency (per cent)
1	4.06	15	3.375	1.375	1.035	80180.	SH 1	43	1.125	0.750	0.530	54775.	88.99
3	4.06	15	3.375	1.375	1.035	80180.	SH 1	43	1.125	0.750	0.530	54775.	89.01
5	4.06	15	3.375	1.625	1.285	80180.	SH 3	43	1.125	0.750	0.530	60812.	86.94
7	4.06	15	3.375	1.625	1.285	80180.	SH 3	43	1.125	0.750	0.530	60812.	86.66
9	4.06	11	4.500	1.500	1.160	58799.	SH 2	43	1.125	0.750	0.530	60812.	86.85
11	4.06	11	4.500	1.375	1.035	58799.	SH 2	43	1.125	0.750	0.530	60812.	84.48
13	4.06	0	--	--	--	--	ECON	32	1.500	1.000	0.703	54775.	85.23
15	4.06	0	--	--	--	--	ECON	32	1.500	1.000	0.703	54775.	56.91

NOTES: (1) SH 1 - Primary superheater; SH 2 - Intermediate Superheater; SH 3 - Secondary Superheater
ECON - Economizer

(2) Panels with even number located on the west side of receiver are identical to those with next lower odd number on the east side.

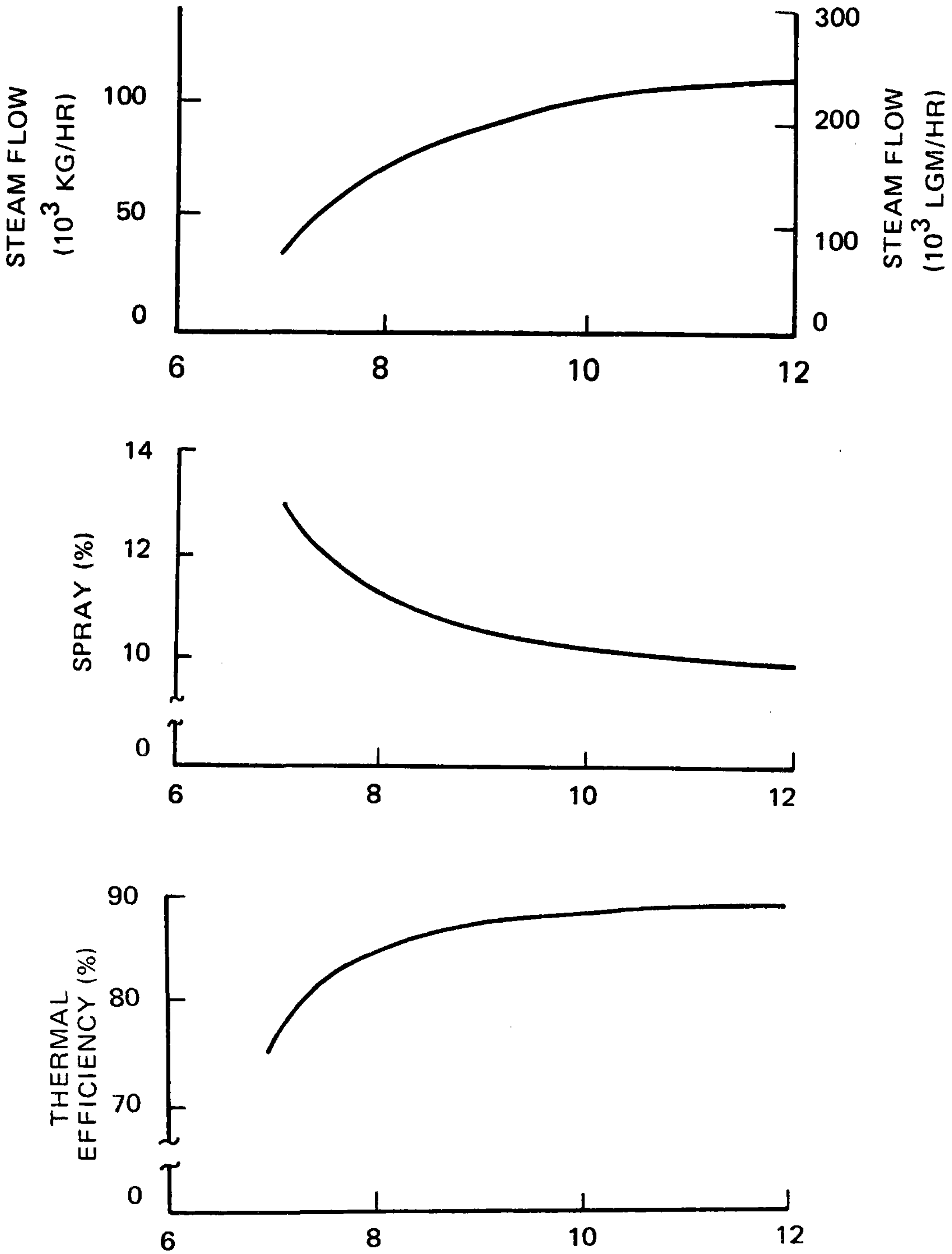
TABLE 5.1-4. LIST OF RECEIVER VALVES

No.	Service	Type	Operator*	Size	Quantity
1	Feedwater Regulator	Globe	Control	6	1
2	Feedwater Stop	Gate	Motor	6	1
3	Feedwater Check	Nonreturn		6	1
4	Economizer Drain	Globe	Motor	1	1
5	Economizer Press Test	Globe	Manual	1	2
6	Economizer Vent	Globe		1	2
7	Drum Atmospheric Vent	Globe	Motor	1	2
8	Drum Safety Valve	Safety	Spring	3	1
9	Drum Press Test	Globe		1	2
10	Drum Press	Globe		1	2
11	Drum Nitrogen	Globe	Motor	1	1
12	Steam Sampling	Globe		1	2
13	Continuous Blowdown	Globe	Motor	1	2
14	Chemical Feed	Globe		1	2
15	Water Sampling	Globe		1	2
16	Remote Level Trnasmittr	Globe		1/2	4
17	Water Gage Glass	Globe		1/2	2
18	Water Gage Drain	Globe		1/2	2
19	Drum Level Dump Shut-Off	Gate	Motor	2	1
20	Drum Level Dump	Globe	Control	2	1
21	Pump Auxiliary	Globe		1	20
22	Sparger Check	Nonreturn	Motor	1-1/2	3

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

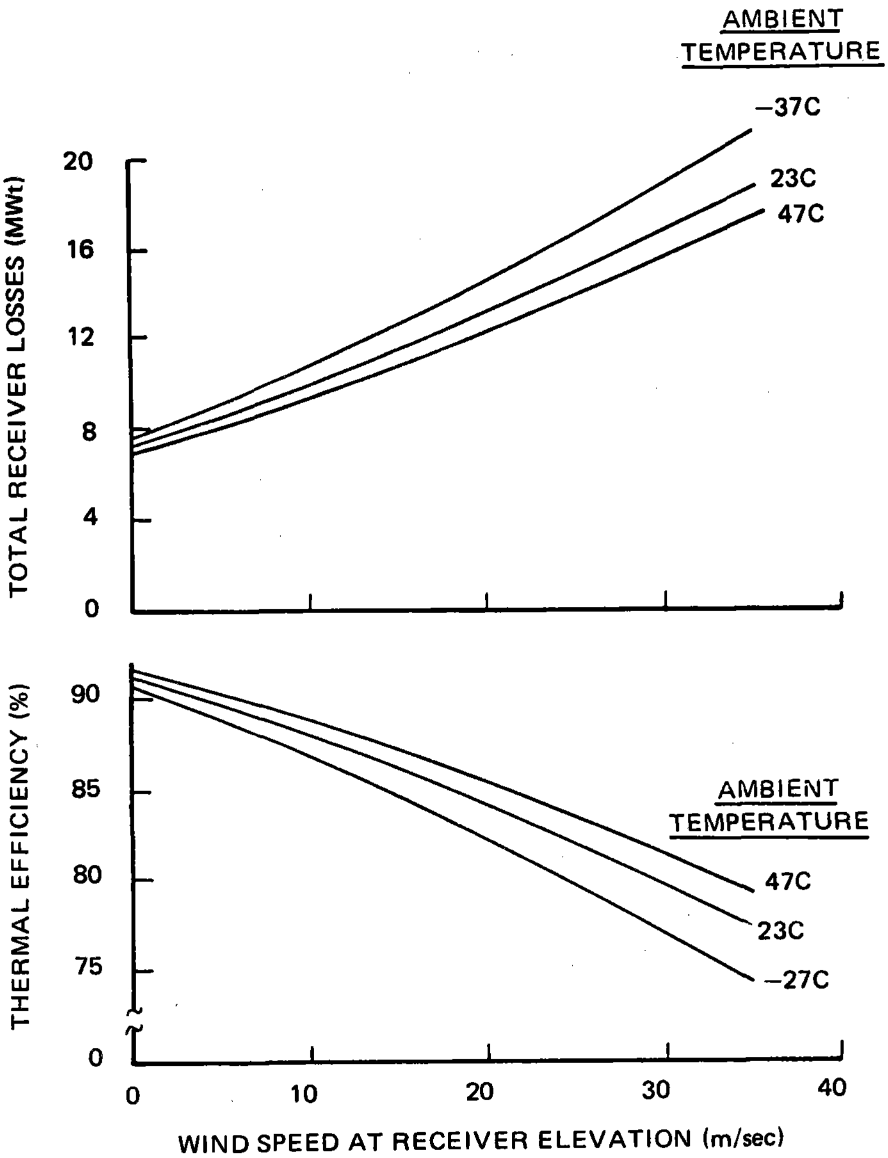
No.	Service	Type	Operator*	Size	Quantity
23	Sparger	Globe	Control	1-1/2	1
24	Receiver Blowdown	Globe	Motor (1)	1	3
25	Economizer Crculation	Nonreturn	Motor	1-1/2	1
26	Attemperator Block	Gate	Motor	1-1/2	1
27	Attemperatur Spray	Globe	Control	1-1/2	4
28	Attemperator Check	Nonreturn		1-1/2	4
29	PSH Panel	Butterfly	Control	3	4
30	ISH Panel	Butterfly	Control	3	4
31	SSH Panel	Butterfly	control	3	4
32	Superheater Vents	Globe	Motor	1	6
33	SH Vent Shut-Off	Globe	Motor	2	1
34	SH Nitrogen	Globe	Motor	1	2
35	SH Drain	Globe	Motor	1	6
36	SH Drain Shut-Off	Globe	Motor	1-1/2	1
37	SH Trap	Trap		1	6
38	MS Press Test	Globe		1	2
39	MS Safety Valve	Safety	Spring	2-1/2	1
40	MS Electromagnetic Shuf-Off	Gate	Motor	3	1
41	MS Electromatic	Relief	Electric	2-1/2	1
42	MS Stop Valve	Gate	Motor	10	1
43	Warm-Up Shut-Off Valve	Gate	Motor	3	1
44	Warm-Up Valve	Globe	Control	3	1

*Manual unless otherwise indicated.



THERMAL PERFORMANCE OF SOLAR RECEIVER DURING EQUINOX DAY

FIGURE 5.1-9



THERMAL EFFICIENCY AND LOSSES WITH VARIOUS WIND SPEED AND AMBIENT TEMPERATURE

FIGURE 5.1-10

(2) Operating characteristics are as follows.

(a) Receiver incident power density, see Table 5.1-5.

(b) Receiver absorbed power, see Table 5.1-5 and Figure 5.1-11.

(c) Flux map at design point, see Figure 5.1-12.

(d) Recevier losses, see Table 5.1-5.

(e) Tube material temperatures, see Figure 5.1-13.

Working stresses are below Code allowable with at least 13 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.

(f) Start-up Procedures--morning start-up (receiver cold). The primary consideration for start-up in the morning is to prewarm the receiver with feedwater and main steam from the fossil boiler to allow complete solar insolation at sunrise. The initial conditions of the receiver are near ambient temperature with a nitrogen blanket at slightly above atmospheric pressure. The warm-up procedure brings the receiver to main steam line pressure and saturation temperature by sunrise.

A maximum of 34,000 kg/h (75,000 lb/h) of feedwater at 186 C (367 F) and 17,500 kg (38,700 kg) of steam at 538 C (1,000 F) are used to supply about 13 MWh (44 MBtu) of energy for warm-up of the receiver metal and fluid plus overcome losses to the surroundings.

The expected trends during cold start-up of energy required, steam consumption, receiver pressurization, and temperature are shown on Figure 5.1-14.

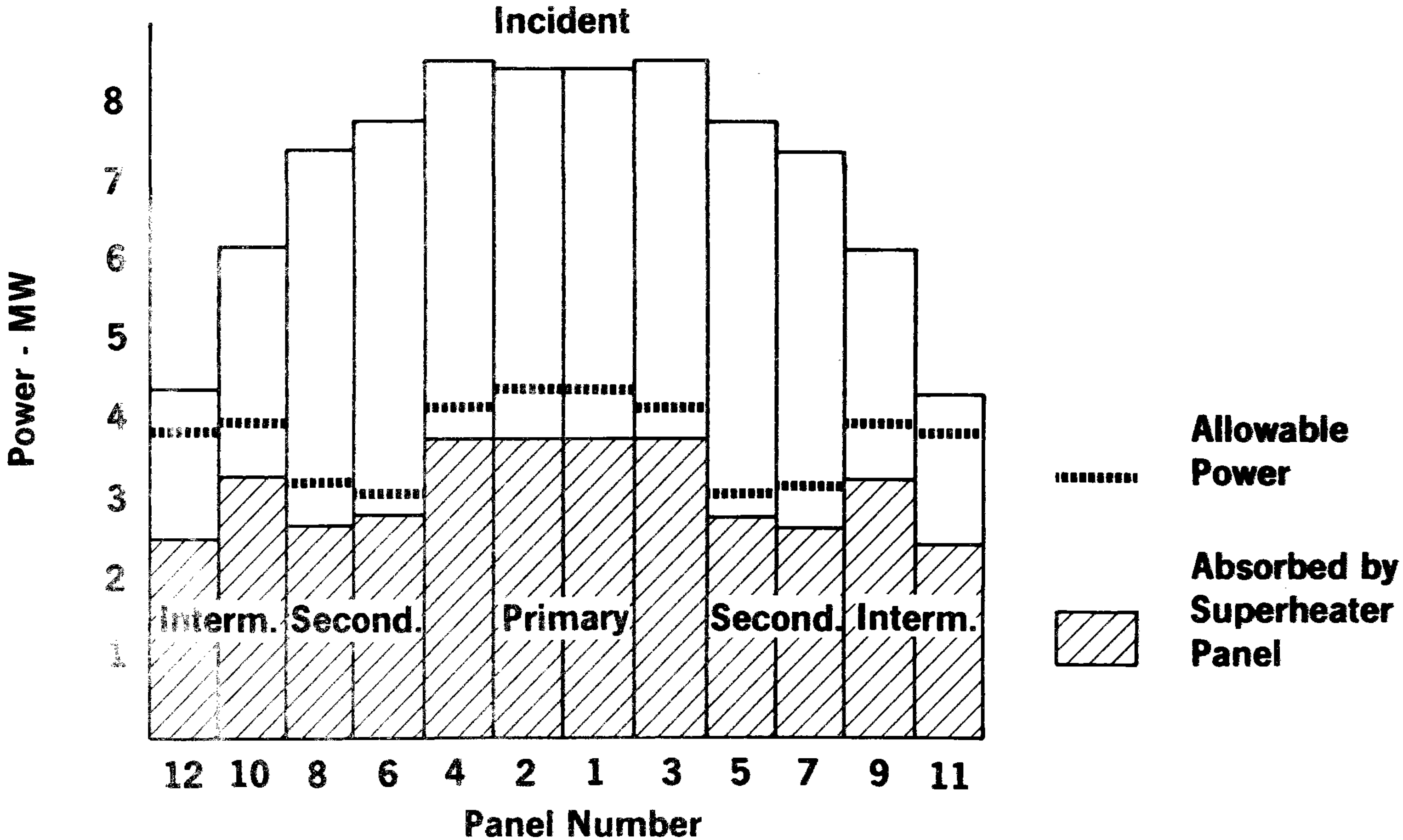
First, the boiler circulation system is heated from ambient to 116 C (240 F) saturation temperature with feedwater. At 100 C (212 F), the superheater is heated by admitting steam and removing condensate through drain traps.

TABLE 5.1-5. RECEIVER ABSORPTION DATA

Panel No.	Incident Power Density (KW/m^2)	Incident Power (MW)	Absorbed (MW)	Losses (MW)
1 & 2	439	8.28	7.53	0.75
3 & 4	415	7.83	7.12	0.71
5 & 6	392	7.40	6.57	0.83
7 & 8	356	6.72	5.95	0.77
9 & 10	290	5.47	4.85	0.62
11 & 12	198	3.73	3.19	0.54
13 & 14*	80	1.50	1.27	0.23
15 & 16*	15	0.29	0.17	0.12
Total		82.45	73.30	9.15
Efficiency			0.889	

*Economizer Panels.

POWER DISTRIBUTION TO SUPERHEATER PANELS



POWER DISTRIBUTION TO SUPERHEATER PANELS

FIGURE 5.1-11

SREG NES-071580

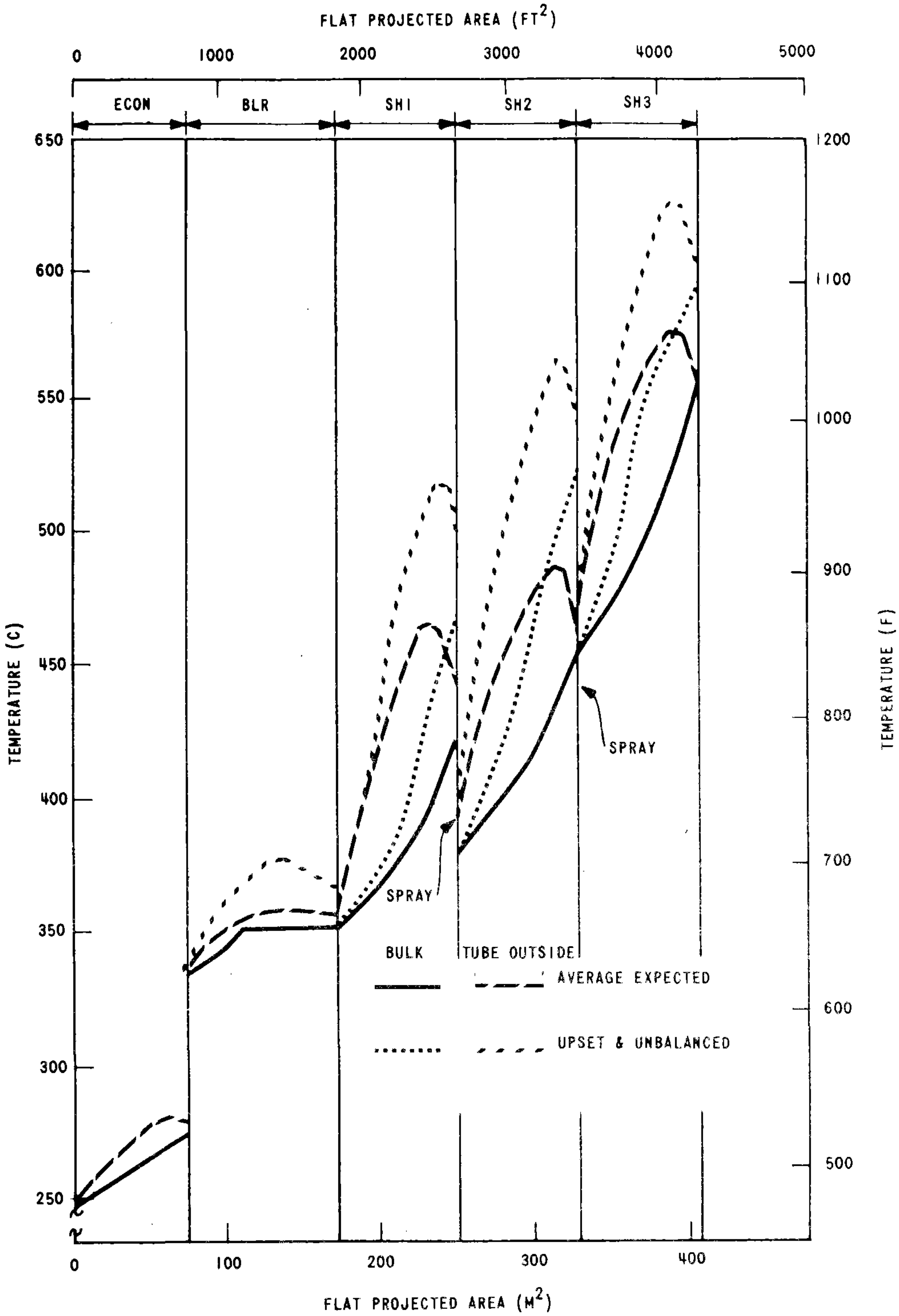
THE TIME POINT UNDER TEST IS: DAY = 80, HOUR = 12
TOTAL POWER WAS 83.381 MEGAWATTS
82.638 MW HIT THE CYLINDER
.744 MW MISSED THE CYLINDER
INSOLATION = 0.95 KW/SQM

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
14.48	128	135	123	121	97	70	32	4	1	0	1	0	0	1	0	1	4	32	70	97	121	123	135	128
12.95	412	353	357	333	294	207	77	14	1	0	0	0	0	0	0	1	14	77	207	294	333	357	353	412
11.43	473	412	390	388	330	204	86	19	3	0	0	0	0	0	0	3	19	86	204	330	388	390	412	473
9.91	594	578	542	449	373	254	102	14	6	0	0	0	0	0	0	6	14	102	254	373	449	542	578	594
8.38	592	584	520	499	356	254	110	26	6	1	0	0	0	0	1	6	26	110	254	356	499	520	584	592
6.86	626	593	522	470	383	233	104	27	3	1	0	0	0	0	1	3	27	104	233	383	470	522	593	626
5.33	595	539	503	473	359	250	109	18	6	1	0	0	0	0	1	6	18	109	250	359	473	503	539	595
3.81	459	470	450	392	337	219	93	18	4	1	0	0	0	0	1	4	18	93	219	337	392	450	470	459
2.29	400	375	391	330	275	219	65	11	1	0	0	0	0	0	0	1	11	65	219	275	330	391	375	400
0.76	113	117	130	116	99	71	20	4	0	0	0	0	0	0	0	0	4	20	71	99	116	130	117	113

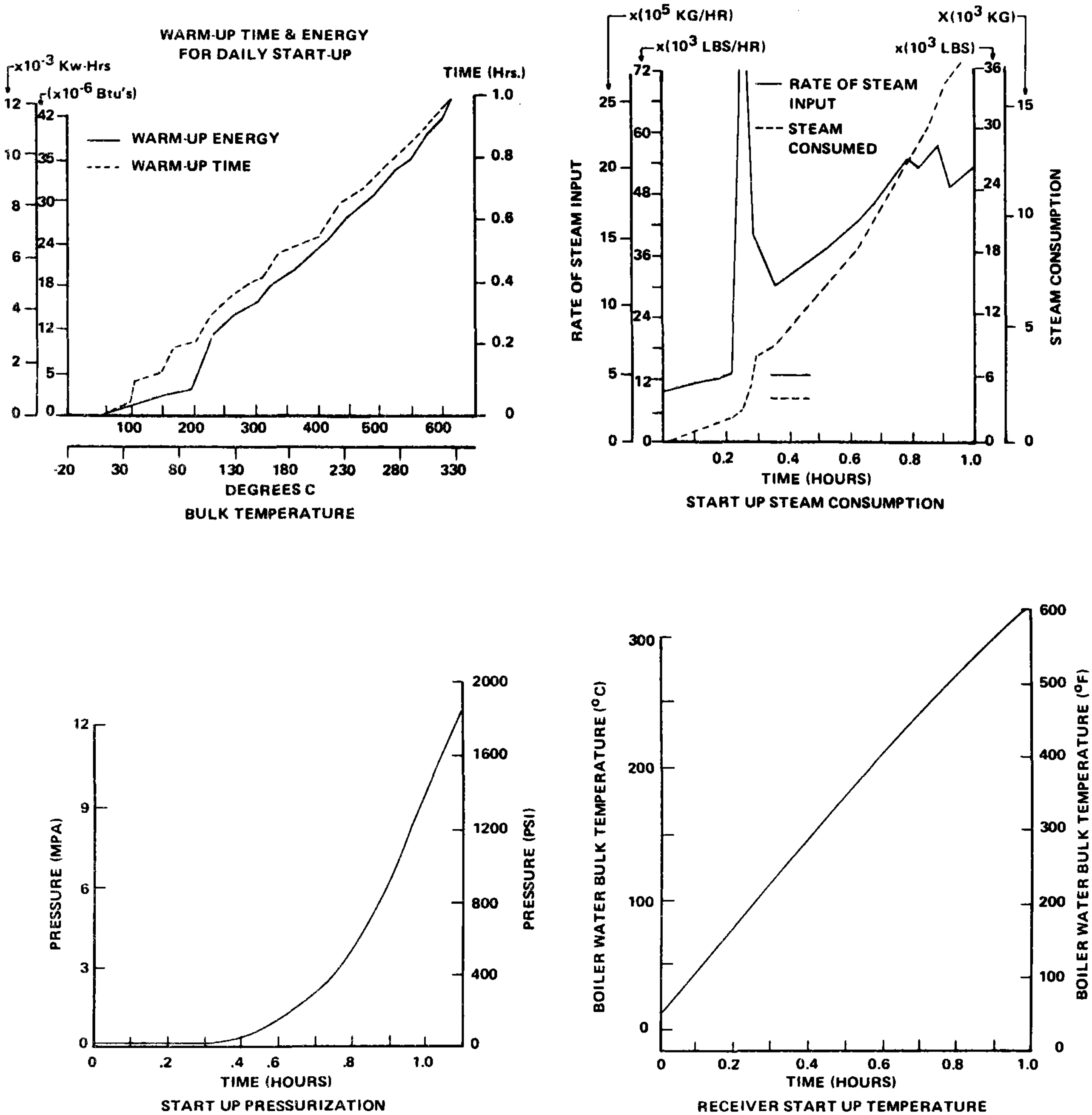
FLUX MAP FOR RECEIVER

FIGURE 5.1-12



FLUID AND METAL TEMPERATURE PROFILE OF BOILER

FIGURE 5.1-13



RECEIVER WARM-UP DATA
AT START-UP

FIGURE 5.1-14

Then the circulation system and the superheater are warmed up to 538 C (620 F) together.

This accomplishes a cost savings in energy by reducing radiation and convection losses to the surroundings.

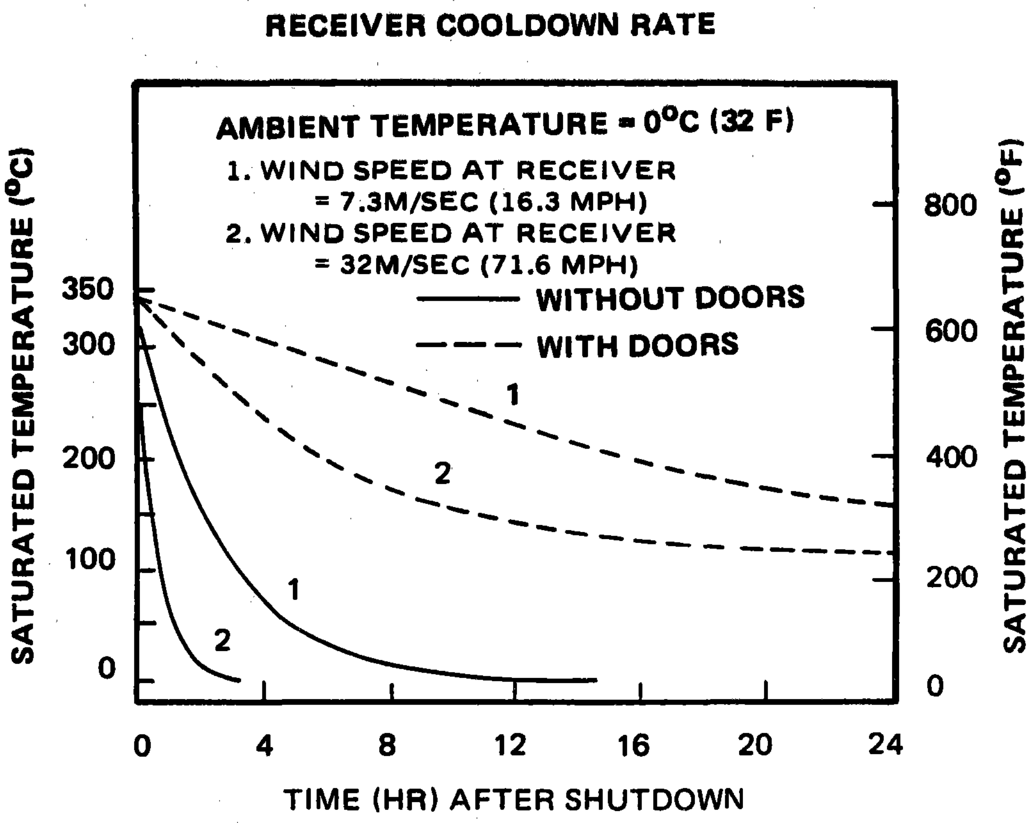
Additional start-up equipment required for a solar receiver are: a steam sparger inductor to warm up the boiler water and circulation system, drum level dump valve, superheater condensate traps and a warm-up valve to control rate of pressurization.

(g) Start-Up Procedures--Morning Start-Up (Receiver Warm). The receiver can be started up each morning with less energy requirements and in a shorter time period if enclosure doors are utilized. The receiver thermal energy is banked over-night by shutting the doors to reduce losses. The initial conditions for morning start-up may vary from 0.172 MPa (25 psia) and 115.6 C (240 F) to 1.72 MPa (250 psia) and 205 C (400 F) depending on ambient conditions.

The fossil boiler supplies 8.8 MWh (30 x 10^6 Btu) energy using about 13,600 kg (30,000 lb) main steam to warm up the solar receiver to saturation temperature and pressurize corresponding to steam line pressure existing at sunrise. The enclosure door is opened just prior to sunrise and the receiver will be at conditions to accept solar insolation.

(h) Mid-Day Start-Up--for start-up after sunrise, selective heliostat focusing will be required to duplicate the morning solar power input to the receiver. Other procedures will be the same as either the cold or warm morning start-up procedures.

(i) Receiver Cooldown--receiver cooldown curves with and without closure doors are shown on Figure 5.1-15.



RECEIVER COOLDOWN RATE

FIGURE 5.1-15

5.1.5 Receiver Loop Data

(1) Equipment Design Characteristics.

Equipment	Description
Condensate return pump	One full capacity centrifugal pump, 175 gpm at 200 feet head. The pump will be designed for pumping saturated liquid at 100 C (212 F), with casing design conditions of 445 kPa (50 psi) at 121 C (250 F). The pump will be electric motor driven driven with a motor horsepower of approximately 10 hp.
Main steam drain pumps	Two full capacity centrifugal pumps to serve the two main steam pipe yard area drains. The pumps will each be rated 50 gpm at 200 feet head. The pumps will be designed for pumping saturated liquid at 100 C (212 F), with casing design conditions of 445 kPa (50 psi) and 121 C (250 F). The pumps will each be driven with electric motors with approximate horsepower ratings of 5 hp.
Solar receiver blowdown tank	One tank to serve the solar receiver drains and the main steam pipe drain near the receiver. The tank will be of carbon steel construction, with an internal stainless steel wear plate at the inlet connection. The tank will vent to atmosphere, and will drain to the condensate return pump. The tank will be 1.2 metres (48 inches) in diameter and 2.1 metres (84 inches) tall.
Main steam drain tanks	Two tanks to serve the two main steam pipe yard area drains. The tanks will be of carbon steel construction, with an internal stainless steel wear plate at the inlet connection. The tanks will vent to atmosphere, and will drain to the main steam drain pumps. The tanks will be 0.9 metres (36 inches) in diameter and 2.1 metres (84 inches) tall.
Condensate filtering equipment	Filtering equipment to remove chemical solids from water returned from the solar receiver to the existing deaerator or condenser. The equipment will include redundant, full capacity, regeneration type filters. The filter

Equipment	Description
Condensate filtering equipment (continued)	pressure vessels will be designed for operation at 790 kPa (100 psi) and 121 C (250 F). The filtering equipment will include bypass, isolation, and drain valves and piping as required to facilitate operation.
Chemical feed equipment	Equipment for the addition of chemicals to the receiver feedwater makeup to control receiver water chemistry. The equipment will include a chemical solution tank suitable for batch mixing, a chemical solution tank mixer, and a chemical feed pump. The chemical feed pump will be a diaphragm type pump rated to deliver approximately 1 gph at 20.86 MPa (3,025 psi) from the solution tank to the feedwater piping.

(2) Piping Design Characteristics. The design characteristics for receiver loop piping and associated valves will be as indicated in Table 5.1-6 Pipeline Listing. 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 Buttwelding End Valves.
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.
SW	Socket-weld type valve end connections.
BW	Butt-weld type valve and connections.

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B & V NO.

TABLE 5.1-6
PIPELINE LISTING
RECEIVER LOOP SYSTEM

	PRESSURES AND TEMPERATURES		TEST PRESSURE		VALVES		INSULA-TION	SPECIAL
	OPERATING	DESIGN	psi	PIPE	2" & SMALLER	$2\frac{1}{2}$" & LARGER	CLASS	FEATURES
MAIN STEAM PIPING	2140 PSI 1011 F	2155 PSIA 1020 F	3210	ASTM A335 GRADE P22 10" PIPING: 8.250" ID 1.472" MIN WALL 2" AND SMALLER PIPING: SCH XXS	CL 2500 2-1/4 CR, SW	CL 2500 2-1/4 CR, BW	6"	FULLY RADIOGRAPH. SHOT BLAST CLEANING.
FEEDWATER PIPING	2750 PSI 477 F	3100 PSIA 500 F	4628	ASTM A106 GRADE B 6" PIPING: SCH XXS 2" AND SMALLER PIPING: SCH 160	CL 2500 CS, SW	CL 2500 CS, BW	2-1/2"	SHOT BLAST CLEANING
CONDENSATE PIPING	82 PSI 212 F	115 PSIA 250 F	150	ASTM A106 GRADE B 4" PIPING: SCH 40 2" AND SMALLER PIPING: SCH 80	CL 600 CS, SW	CL 150 CS, BW	2-1/2"	SHOT BLAST CLEANING.

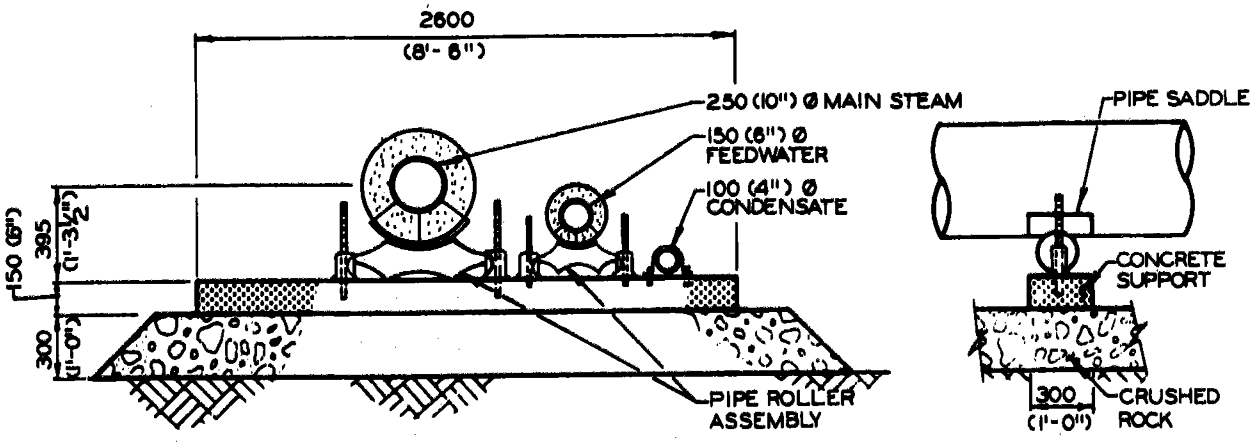
The piping lengths indicated below include piping within the receiver support tower, and the expansion loops required to allow for thermal growth of the piping between ambient and operating temperatures.

Piping System	Length
Main steam	1,612 metres (5,289 feet)
Feedwater	1,337 metres (4,387 feet)
Condensate	1,337 metres (4,387 feet)

The piping support method is illustrated on Figure 5.1-16.

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

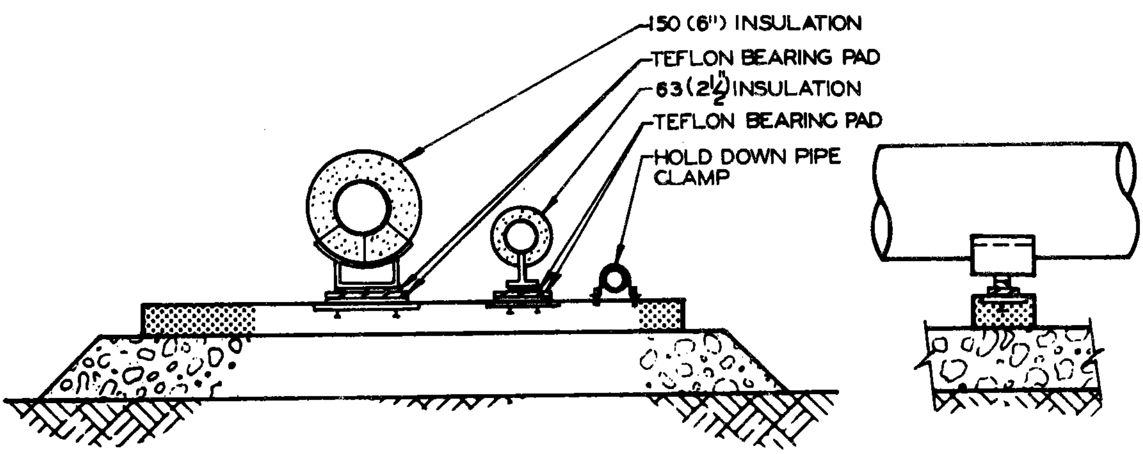
Main Steam Piping	Operating Conditions
Inlet pressure at overpressure operation	14.86 MPa (2,155 psia)
Outlet pressure at overpressure operation	13.76 MPa (1,995 psia)
Pressure drop	1.1 MPa (160 psi)
Inlet temperature	544 C (1,011 F)
Outlet temperature	538 C (1,000 F)
Flow rate	111,300 kg/h (245,287 lb/h)
Piping thermal loss at normal operating temperature	1,766,526 Btu/h
Feedwater Piping	
Inlet pressure at normal operation	19.07 MPa (2,765 psia)
Outlet pressure at normal operation	17.38 MPa (2,520 psia)
Pressure drop at normal operation	1.7 MPa (245 psi)
Water temperature	247 C (477 F)
Flow rate at normal operation	111,300 kg/h (245,287 lb/h)
Piping thermal loss at normal operation	636,554 Btu/h
Condensate Piping	
Inlet pressure for return flow to deaerator	668 kPa (96.9 psia)
Outlet pressure for return flow to deaerator	393 kPa (57 psia)
Pressure drop at normal operation	275 kPa (39.9 psi)
Water temperature	100 C (212 F)
Flow rate for receiver warming operation	34,000 kg/h (75,000 lb/h)



AXIAL EXPANSION

0 1000 2000

NOTE: DIMENSIONS ARE GIVEN IN MILLIMETERS (FT-IN)



AXIAL-TRANSVERSE EXPANSION

PIPE SUPPORTS

FIGURE 5.1-16

The normal shutdown of the solar facility will resutl in a reduction of the main steam pipe temperature. The expected rate in temperature decline from the normal operating temperature of 538 C (1,000 F) is indicated in Figure 5.1-17 as a function of the shutdown time.

5.1.6 Master Control System Data

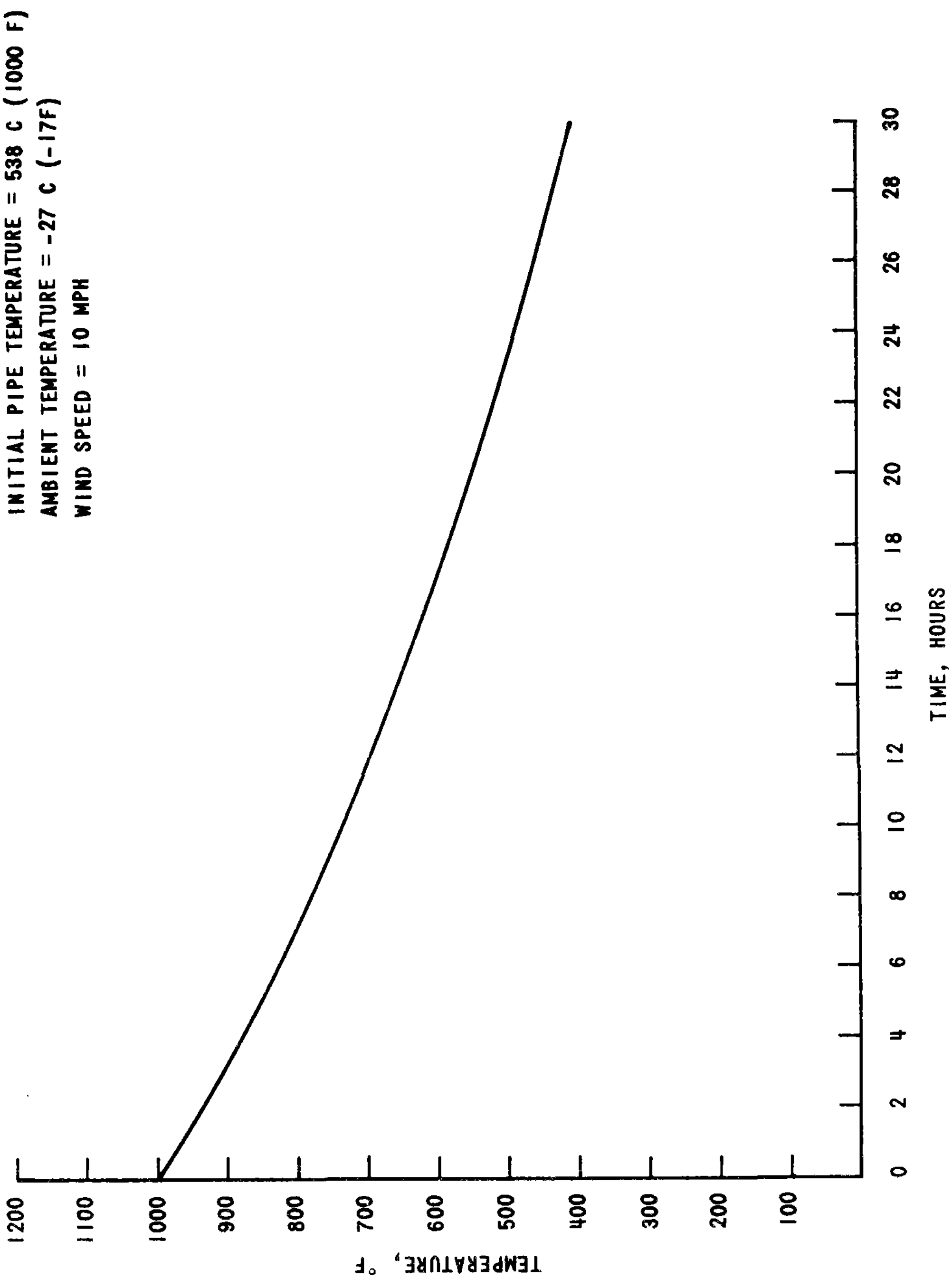
The Master Control System (MCS) consists of a control computer, computer peripheral equipment, control and display consoles, interface equipment to the other process systems, and all software required for a fully operational system.

The MCS will be comprised of the following major hardware components.

(1) Control Panel--a 3-metre (10 feet) wide, 2-metre (7 feet) high, 1.2-metre (4 feet) deep standup bench front panel which contains all operator displays and controls. The panel will include a 1.2-metre by 1.2-metre (4-foot by 4-foot) graphic display panel which indicates, at a glance, the operational status of each heliostat.

(2) Control Computer--a minicomputer with 256 K words of high speed random access working memory. The central processing unit has a 32-bit parallel bus and arithmetic unit memory management system which includes the following.

(a) 1,024 memory mapping registers.
(b) Auto memory allocation hardware.
(c) Memory protect on 256-word basis.
(d) Multi-port memory interface.
(e) 640-nanosecond effective cycle time.
(f) 15 general purpose registers.
(g) Bit, byte, word, double word and file manipulation.
(h) Fixed and floating point arithmetic hardware.
(i) 174 microprogrammed instructions.
(j) Context switching file with 240 registers.
(k) 11 interrupt levels, expandable to 16.
(l) Control console.



MAIN STEAM PIPE COOLDOWN TIME

FIGURE 5.1-17

(m) Memory parity.

(n) Power Fail/Auto Start.

(3) Mass Memory--five megaword moving head disk to be used as auxilliary memory for the control computer.

(4) Programming Terminal--a console with cathode ray tube and keyboard for interrogating and modifying the computer software.

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

(6) Interactive Cathode Ray Tubes and Keyboard--eight color intelligent CRT terminals with 64 alphaneumeric characters and 64 microprogrammed graphic characters. The CRT uses a EIA RS-232-C compatible interface at serial rates up to 9,600 BAUD. Each CRT is accompanied by an alphaneumeric keyboard and function push buttons for interactive display selection and modification.

(7) Printers--120 characters per second printing speed, 132-column print, complete with pedestal and enclosure.

(8) Emergency Shutdown System--a hardwired relay cabinet with power supply.

(9) Computer Input/Output System--the input/output system uses remote multiplexing stations in the receiver tower and a digital data highway for communication between the control computer and the receiver and receiver loop systems. Asynchronous serial binary (EIA RS-232C) ports are provided with the control computer for communications to the collector system.

5.1.7 <u>Fossil Energy System Data</u>

(1) Design Characteristics. The Fossil Energy System will not require any modifications to be compatible with the solar repowering systems. Interface design characteristics will be consistent with the receiver loop piping characteristics presented in Section 5.1.5.

(2) Operating Characteristics. A summary of the design point operating characteristics for operation with and without solar repowering is shown on Table 5.1-7. This summary includes the unit

TABLE 5.1-7. DESIGN POINT PERFORMANCE CHARACTERISTICS

	Fossil Only Operation	Fossil and Solar Operation
Unit Generation		
Gross turbine output, kWe	155,220	155,220
Auxiliary power, kWe	10,041	10,251
Net plant output, kWe	145,179	144,969
Turbine Heat Input		
Fossil, MBtu/h	1,242.38	993.90
Solar, MBtu/h	0	248.48
Total, MBtu/h	1,242.38	1,242.38
Plant Heat input		
Fossil, MBtu/h	1,485.04	1,188.16
Solar, MBtu/h	0	279.51
Total, MBtu/h	1,485.04	1,467.67
System Heat Rates		
Gross turbine heat rate, Btu/kWh	8,004	8,004
Equivalent fossil gross turbine heat rate, Btu/kWh	8,004	6,403
Equivalent fossil net plant heat rate, Btu/kWh	10,229	8,196

generation, turbine heat input, plant heat input, and the system heat rates.

The turbine cycle of the Fossil Energy System will not be affected by the solar repowering project since the solar steam will be at the same pressure and temperature as the superheated steam from the fossil boiler at the interface of the Receiver Loop System and the existing fossil main steam piping.

The fossil steam generator provides all of the hot reheat steam and only part of the superheated steam to the turbine generator during combined fossil-solar operation. This results in a slight change in the expected reheat steam temperatures during combined fossil-solar operation as shown on Figure 5.1-18. The worst case condition is at minimum turndown on the fossil steam generator (30 per cent flow) and maximum solar steam flow (25 per cent of maximum fossil steam flow). This condition would be infrequent and would still result in reheat steam temperature greater than 482 C (900 F), which will not significantly affect the performance of the turbine generator.

A plot of the boiler efficiency versus the fossil boiler power output during combined fossil-solar operation is shown on Figure 5.1-19.

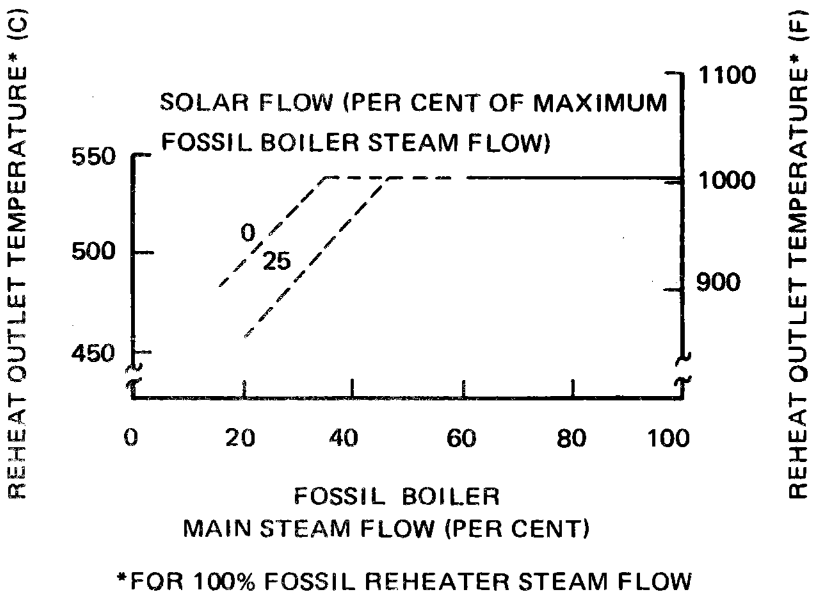
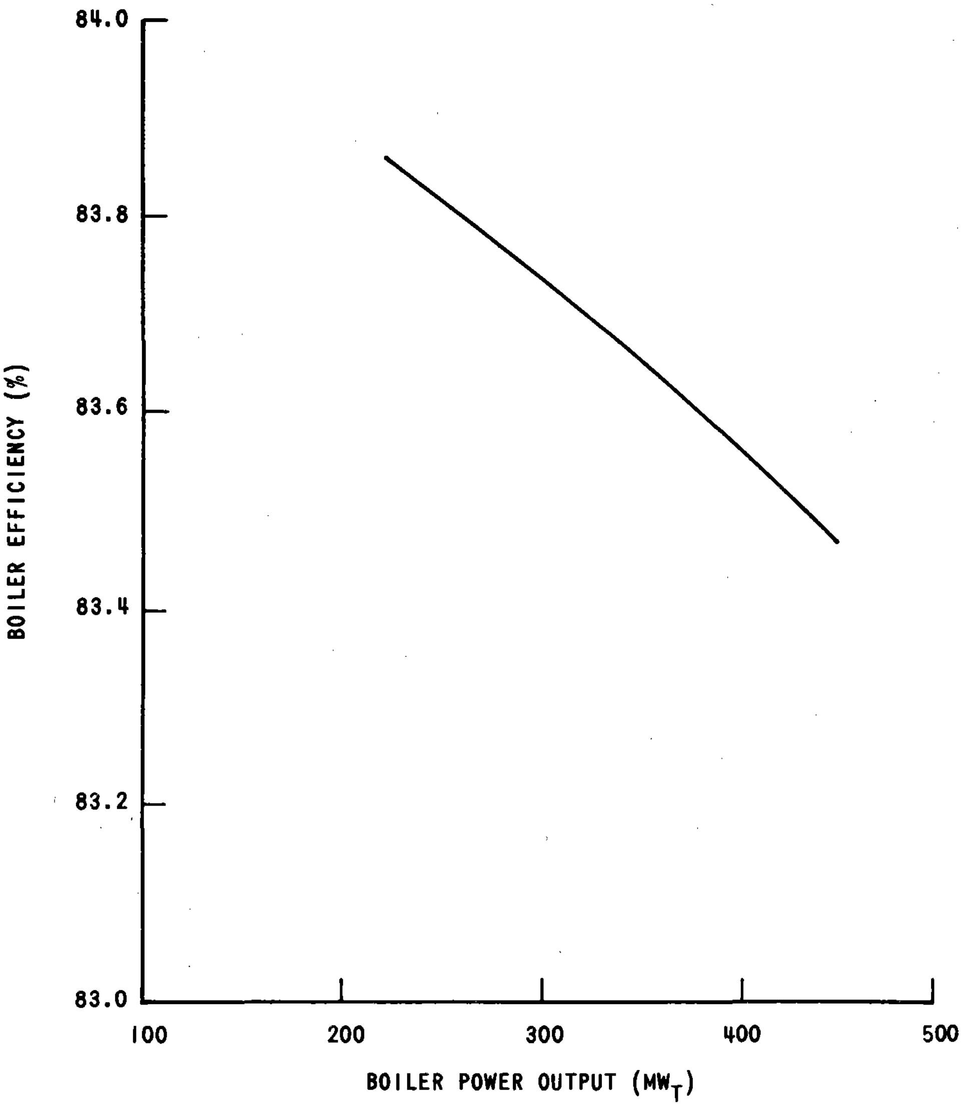

REHEAT OUTLET TEMPERATURE* (C)
SOLAR FLOW (PER CENT OF MAXIMUM
FOSSIL BOILER STEAM FLOW)
550
500
450
0
25
1100
1000
900
0
20
40
60
80
100
REHEAT OUTLET TEMPERATURE* (F)
FOSSIL BOILER
MAIN STEAM FLOW (PER CENT)
*FOR 100% FOSSIL REHEATER STEAM FLOW

FIGURE 5.1-18



BOILER EFFICIENCY VERSUS
FOSSIL BOILER POWER OUTPUT

FIGURE 5.1-19

5.2 EXISTING POWER PLANT DESCRIPTION

The existing power plant description and performance characteristics are as follows.

5.2.1 Major Equipment Data

The technical data for Unit 1 as extracted from the original manufacturer's equipment lists are as follows.

(1) Turbine Generator.

Manufacturer	Westinghouse
Type	Two cylinder, tandem compound, double flow impulse-reaction, condensing reheat - 23 inches last stage baldes TC2F23LSB
Generator	200,000 kVA, 0.80 power factor, three pase, 60 hertz, 60 psi hydrogen pressure, 14,400 V
Exciter	Separately driven, 1,000 kW, 375 V dc, air cooled motor generator
Capability*	
Rated steam conditions	
Throttle steam pressure	1,800 psi
Throttle steam temperature	1,000 F
Reheat steam temperature	1,000 F
Generator output	143,800 kW
Turbine cycle heat rate	8,036 Btu/kW-h
Overpressure steam conditions	
Throttle steam pressure	1,980 psi
Throttle steam temperature	1,000 F
Reheat steam temperature	1,000 F
Generator output	155,200 kW
Turbine cycle heat rate	8,004 Btu/kW-h

*With all five feedwater heaters in service.

(2) Steam Generator.

Manufacturer	Babcock & Wilcox
Type of unit	Radiant reheat, pressure furnace
Continuous rating, lb steam/h	1,000,000
Maximum rating, lb steam/h	1,150,000
Design pressure, psi	2,325
Superheater outlet pressure, psi	2,070
High pressure steam temperature, F	1,005
Reheat steam temperature, F	1,005

(3) Piping Systems.

	Main Steam	Hot Reheat	Cold Reheat	Boiler Feedwater
Number of lines	1	2	2	1
Outside diameter	14 in.	16 in.	14 in.	12-3/4 in.
Min. wall thickness (sched.)	2 in.	100	80	1-7/16 in.
Material	2-1/4 chrome 1 per cent moly	2-1/4 chrome 1 per cent moly	carbon steel	5 per cent chrome
Specification	ASTM A335 P22	ASTM A335 P22	ASTM A106 Grade B	ASTM A335 P5

(4) Condenser.

Manufacturer	Westinghouse
Type	Horizontal, two pass deaerating surface condenser
Surface area	120,000 sq ft
Tube material	Inhibited admiralty
Cooling water	119,000 gpm
Air ejector	
Number of units	1
Type	Steam jet - twin element - two stage
Priming ejector	
Type	Steam

(5) Boiler Feed Pumps.

Manufacturer	Pacific pumps
Type	Centrifugal 10 stage
Number of pumps	3
Capacity (each)	650,000 lb/h
Total dynamic head	2,535 psi
Speed	3,600 rpm
Motor	3,000 hp, 4,160 V

(6) Feedwater Heaters.

(a) LP Heater No. 1.

Manufacturer	Lummus	
Number	1	
Type	U-Tube	
Heating surface, effective	4,900	
Tube material	Inhibited Admiralty	
Design steam pressure, psi	150	
	Steam	Feedwater
Capacity, lb/h	54,598	857,176
Inlet temperature, F	178.1	102.5
Outlet temperaure, F	112.5	173.1

(b) LP Heater No. 2.

Manufacturer	Lummus	
Number	1	
Type	U-Tube	
Heating surface, effective	3,070	
Tube material	Inhibited Admiralty	
Design steam pressure, psi	150	
	Steam	Feedwater
Capacity, lb/h	47,512	857,176
Inlet temperature, F	321	173.1
Outlet temperature, F	183.1	228.5

(c) HP Heater No. 4.

Manufacturer	Lummus	
Number	1	
Type	Multilok U-Tube	
Heating surface, effective	5,940	
Tube material	70-30 Cupro Nickel	
Design steam pressure, psi	300	
	Steam	Feedwater
Capacity, lb/h	87,059	1,047,280
Inlet temperature, F	792	293.5
Outlet temperature, F	303.5	395.6

(d) HP Heater No. 5.

Manufacturer	Lummus	
Number	1	
Type	Multilok U-Tube	
Heating surface, effective	4,970	
Tube material	70-30 Cupro Nickel	
Design steam pressure, psi	750	
	Steam	Feedwater
Capacity, lb/h	97,615	1,047,230
Inlet temperature, F	694	395.6
Outlet temperature, F	405.6	478.8

(7) Deaerator.

Manufacturer	Cochrane
Number of units	1
Type	Jet tray - direct contact
Maximum output, lb/h	1,300,000
Water storage capacity, gal	18,000
Operating guarantee	0 to .005 oxygen cc/litre
Vent condenser	External tube and shell

(8) Cooling Tower.

Manufacturer	Marley
Type	Induced draft cross flow
Material	Douglas fir pretreated with boliden salts
Number of units	2
Water capacity	61,000 gpm
Design inlet water temperature	103.5 F
Design outlet water temperatuer	88 F
Design ambient wet bulb	76 F
Fans per tower	7
Fan wheel	22 feet diameter, 12 cast aluminum alloy blades
Fan speed	154 rpm
Fan motors	75 hp

(9) Condensate Pumps.

Manufacturer	Westinghouse Electric
Type	Vertical pit type
Number of pump	3
Pumping temperature, F	130
Total dynamic head, ft water	450
Capacity, gpm	1,300
Speed, rpm	1,170
Motor	250 hp 4,160 V Dripproof, vertical

(10) Forced Draft Fans.

Manufacturer	American Blower
Type	No. 726 Sirocco (double inlet)
Number of fans	2
Design temperature, F	125
Design static pressure, in. water	40.5
Capacity, cfm	195,000
Type control	Inlet and outlet dampers
Motor	1,750 hp, 4,160 V weather protected

A piping diagram of the boiler feedwater system is found on Figure 5.2-1. Included in this figure are the pipe sizes and routing, valves, drains, pumps, feedwater heaters, and deaerator of the fossil boiler feedwater system. The high pressure steam piping of the Fossil Energy System is shown on Figure 5.2-2. Illustrated on this diagram are the pipe sizes and location, valves, drains and interfaces with the steam generator and turbine generator.

Elevation drawings for NES-Unit 1 are shown on Figures 5.2-3 through 5.2-6. These elevation drawings show the arrangement of Unit 1 from the north, east, south, and west direction, respectively.

5.2.2 Existing Power Plant Performance Data

The predicted heat balances for various loads are shown on Figures 5.2-7 through 5.2-9. The predicted performance at minimum boiler turndown or 50 MW is shown on Figure 5.2-7. The heat balance for rated pressure conditions at 144 MW is shown on Figure 5.2-8. Figure 5.2-9 illustrates the design point performance for overpressure conditions at full load (155 MW). A plot of the turbine heat rate (Btu/kWh) versus generator output (MW) for rated and overpressure conditions is shown on Figure 5.2-10.

The design characteristics for feedwater regulators is shown on Figure 5.2-11. This figure plots the feedwater pressure versus feedwater flow and shows the available pressure at the feedwater interface with the Receiver Loop System.

A summary of the fossil steam generator performance is presented on Table 5.2-1.

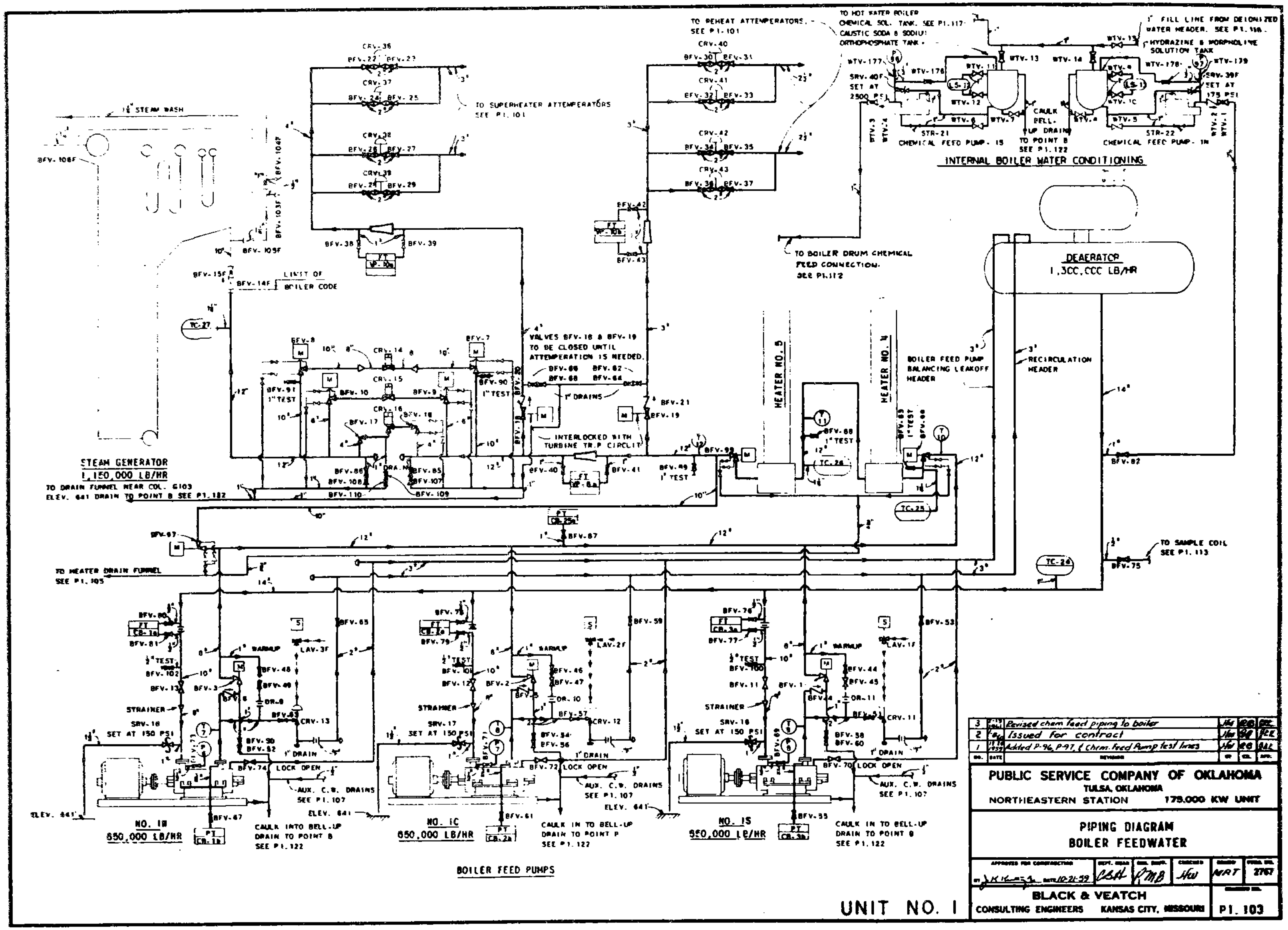

STEAM GENERATOR
1,150,000 LB/HR
DEAERATOR
1,300,000 LB/HR
HEATER NO. 5
HEATER NO. 4
INTERNAL BOILER WATER CONDITIONING
CHEMICAL FEED PUMP - 1S
CHEMICAL FEED PUMP - 1N
BOILER FEED PUMP BALANCING LEAKOFF HEADER
RECIRCULATION HEADER
VALVES BFV-18 & BFV-19 TO BE CLOSED UNTIL ATTEMPERATION IS NEEDED.
INTERLOCKED WITH TURBINE TRIP CIRCUIT
TO BOILER DRUM CHEMICAL FEED CONNECTION. SEE P1.112
TO SUPERHEATER ATTEMPERATORS SEE P1.101
TO REHEAT ATTEMPERATORS. SEE P1-101
TO HEATER DRAIN FUNNEL SEE P1.105
TO SAMPLE COIL SEE P1.113
NO. 1N
650,000 LB/HR
NO. 1C
650,000 LB/HR
NO. 1S
650,000 LB/HR
BOILER FEED PUMPS
UNIT NO. 1
PUBLIC SERVICE COMPANY OF OKLAHOMA
TULSA, OKLAHOMA
NORTHEASTERN STATION
175,000 KW UNIT
PIPING DIAGRAM
BOILER FEEDWATER
BLACK & VEATCH
CONSULTING ENGINEERS
KANSAS CITY, MISSOURI
P1. 103

FIGURE 5.2-1

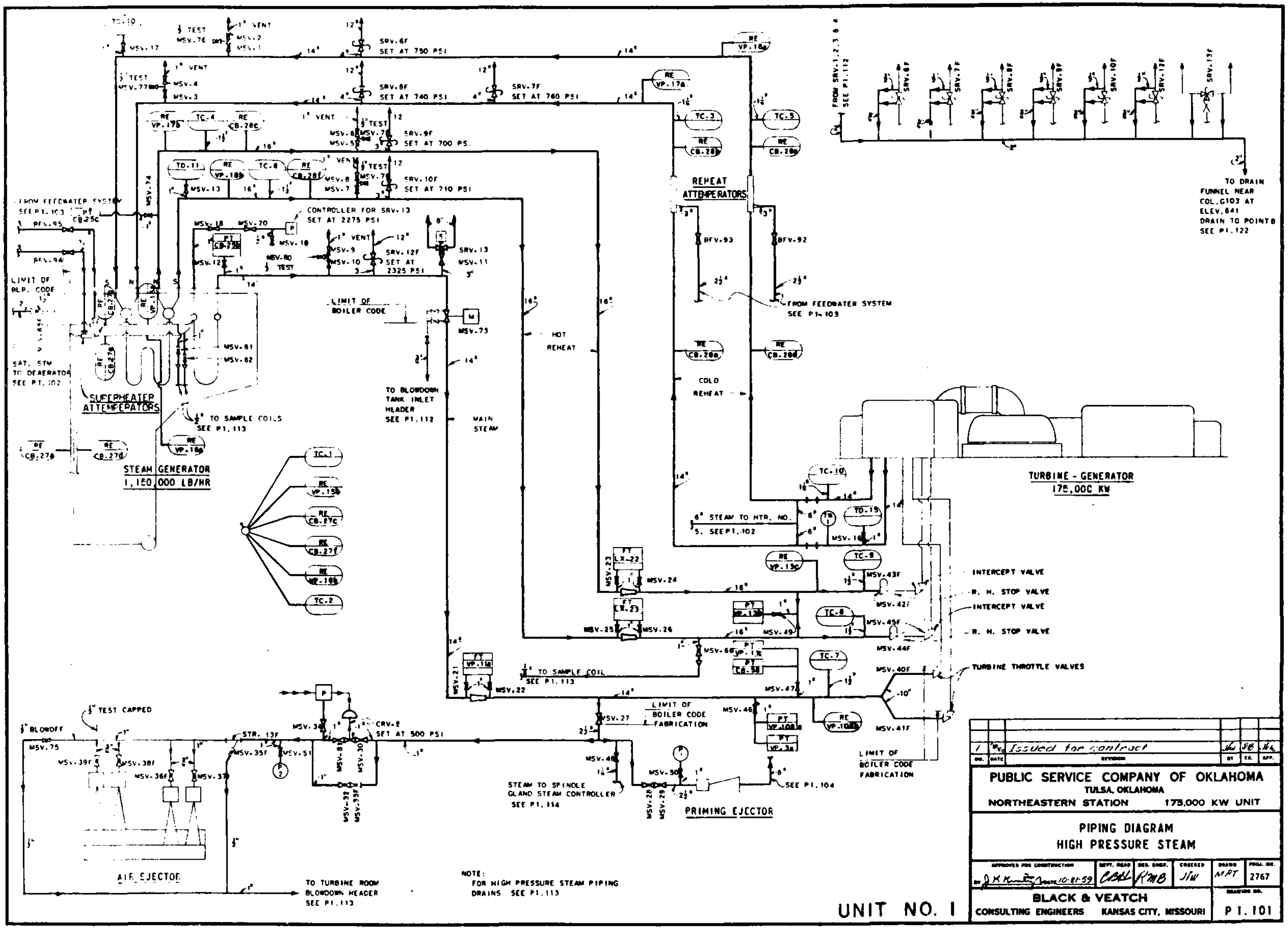
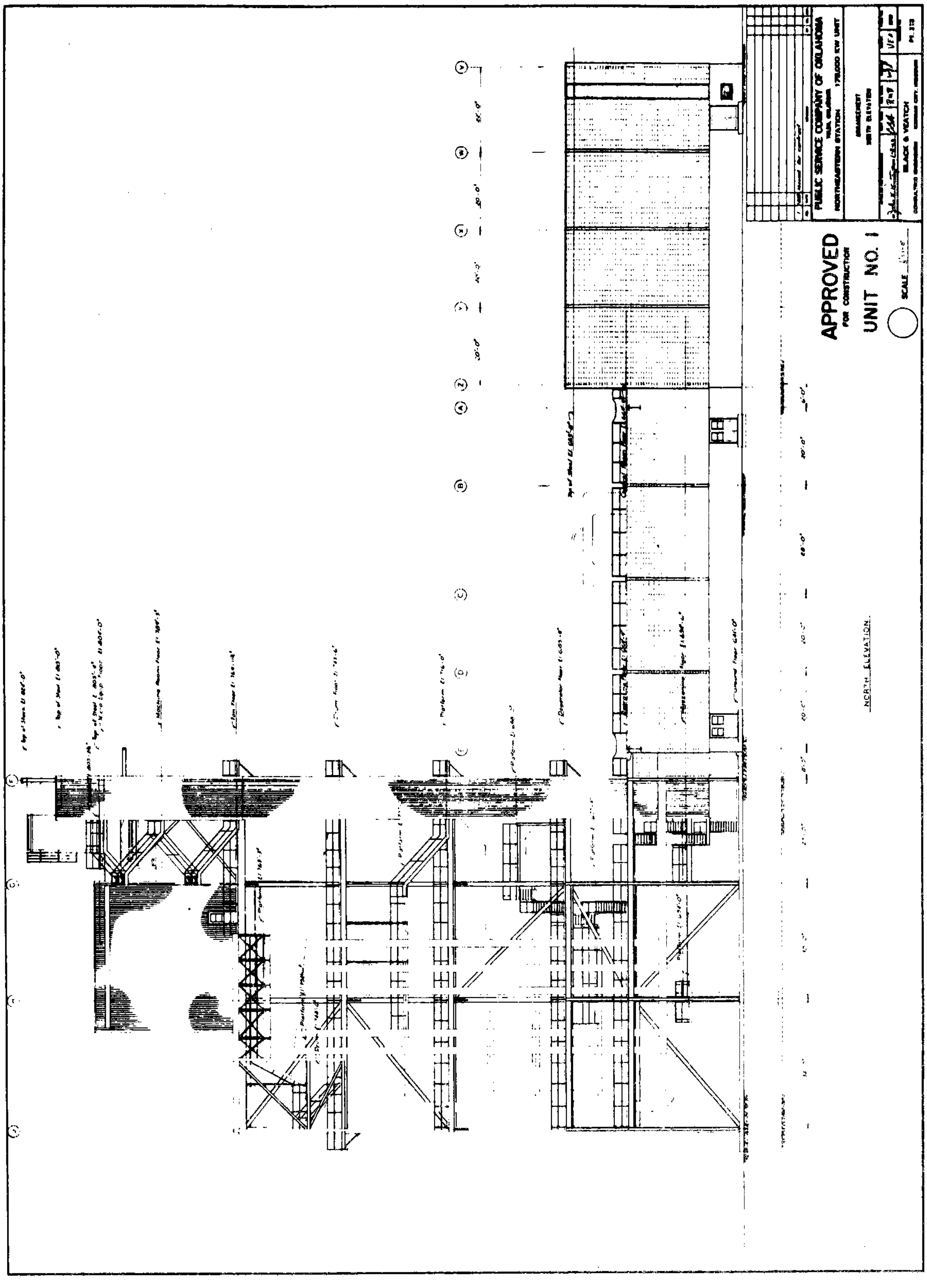
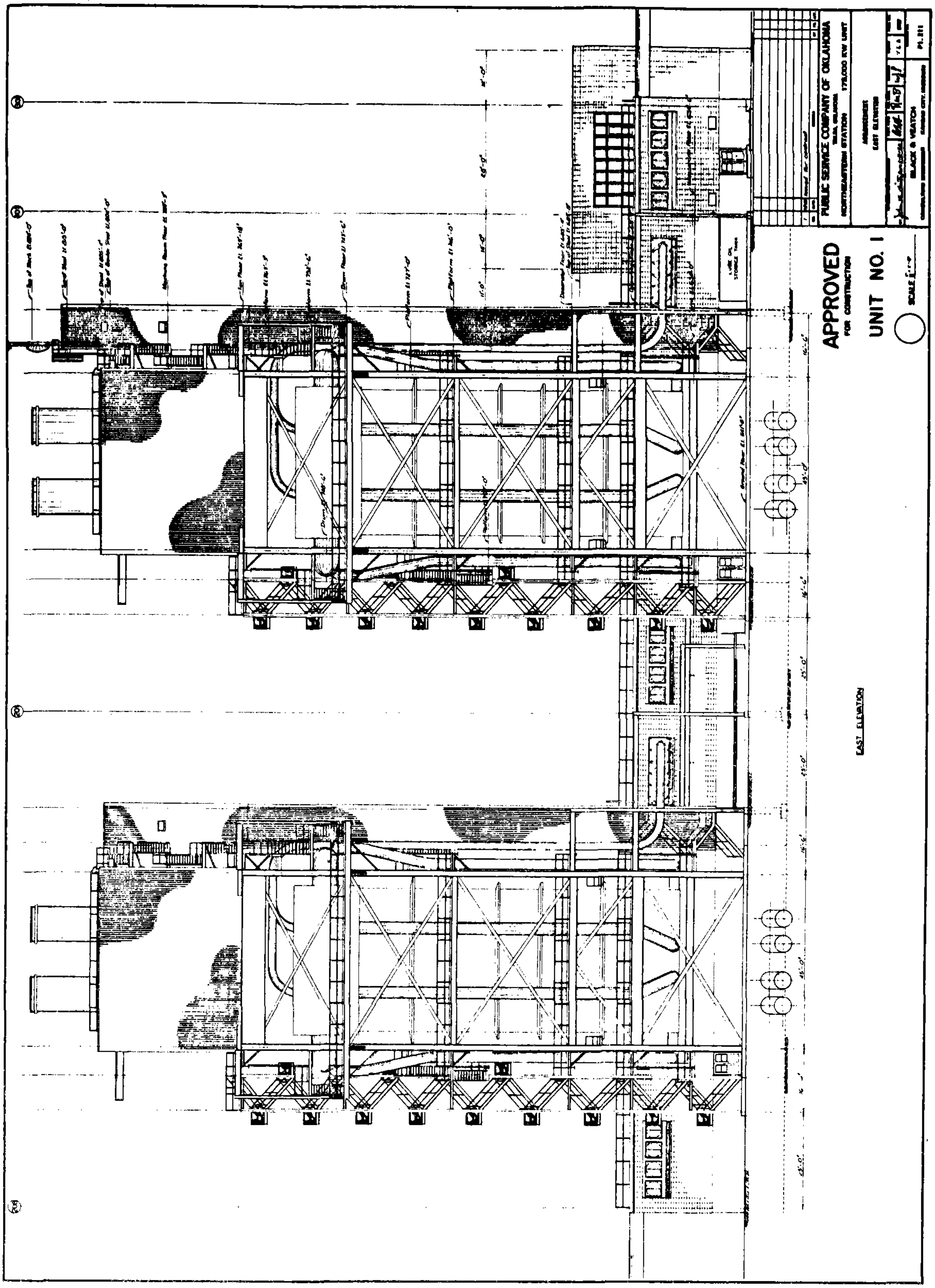

STEAM GENERATOR
1,150,000 LB/HR
SUPERHEATER ATTEMPERATORS
REHEAT ATTEMPERATORS
TURBINE - GENERATOR
175,000 KW
HOT REHEAT
COLD REHEAT
MAIN STEAM
INTERCEPT VALVE
R. H. STOP VALVE
INTERCEPT VALVE
R. H. STOP VALVE
TURBINE THROTTLE VALVES
AIR EJECTOR
PRIMING EJECTOR
LIMIT OF BOILER CODE
TO DRAIN FUNNEL NEAR COL. G103 AT ELEV. 641 DRAIN TO POINT B SEE P1.122
FROM FEEDWATER SYSTEM SEE P1.103
TO BLOWDOWN TANK INLET HEADER SEE P1.112
STEAM TO SPINDLE GLAND STEAM CONTROLLER SEE P1.114
TO TURBINE ROOM BLOWDOWN HEADER SEE P1.113
NOTE: FOR HIGH PRESSURE STEAM PIPING DRAINS SEE P1.113
SRV-6F SET AT 750 PSI
SRV-8F SET AT 740 PSI
SRV-7F SET AT 760 PSI
SRV-9F SET AT 700 PSI
SRV-10F SET AT 710 PSI
SRV-12F SET AT 2325 PSI
CONTROLLER FOR SRV-13 SET AT 2275 PSI
CRV-2 SET AT 500 PSI
UNIT NO. 1
Issued for contract
PUBLIC SERVICE COMPANY OF OKLAHOMA
TULSA, OKLAHOMA
NORTHEASTERN STATION 175,000 KW UNIT
PIPING DIAGRAM
HIGH PRESSURE STEAM
10-21-59
2767
BLACK & VEATCH
CONSULTING ENGINEERS KANSAS CITY, MISSOURI
P1.101

FIGURE 5.2-2



APPROVED
FOR CONSTRUCTION
UNIT NO. 1
NORTH ELEVATION
PUBLIC SERVICE COMPANY OF OKLAHOMA
BLACK & VEATCH

FIGURE 5.2-3



PUBLIC SERVICE COMPANY OF OKLAHOMA
APPROVED
UNIT NO. I
EAST ELEVATION
BLACK & VEATCH

FIGURE 5.2-4

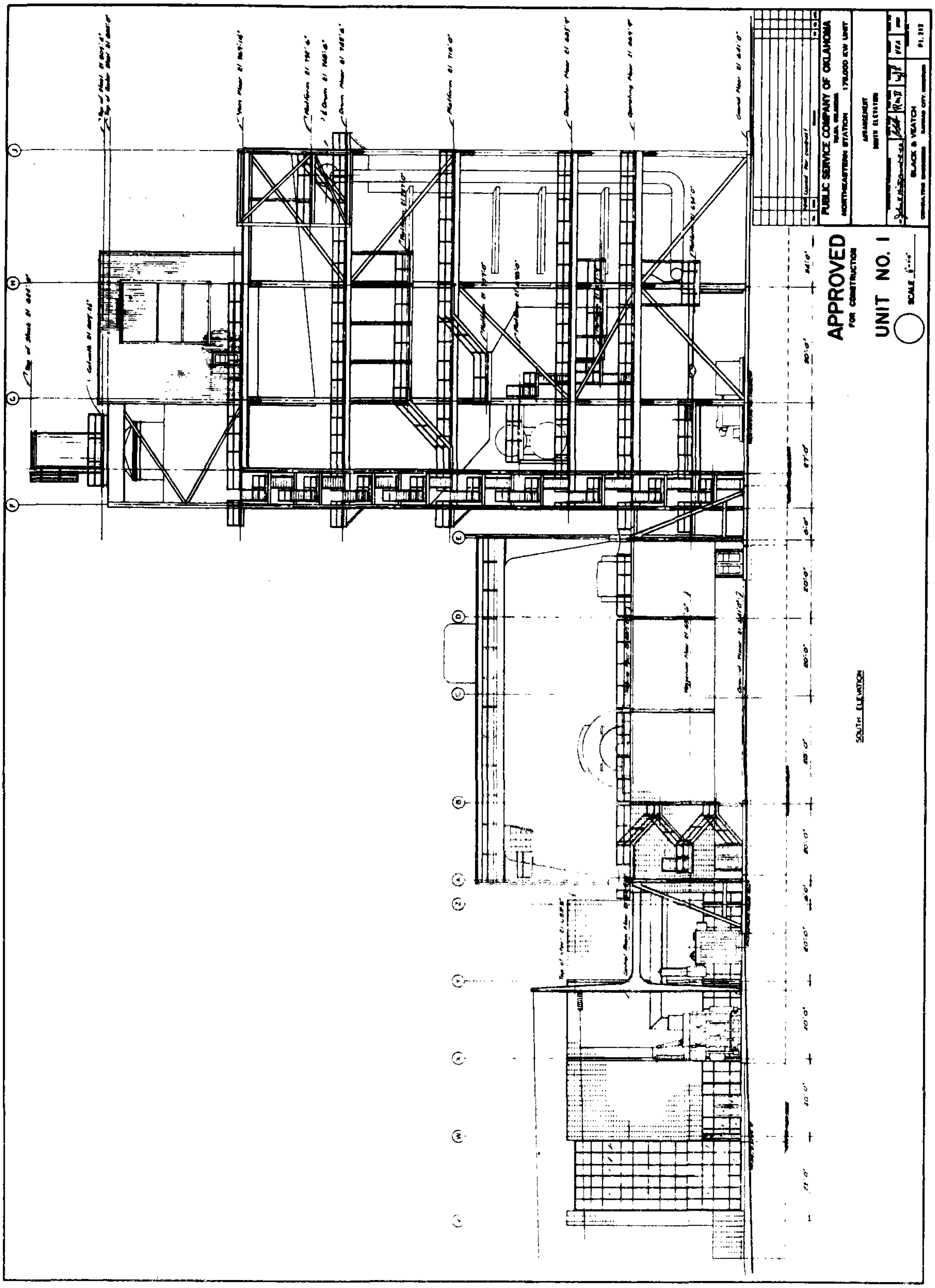
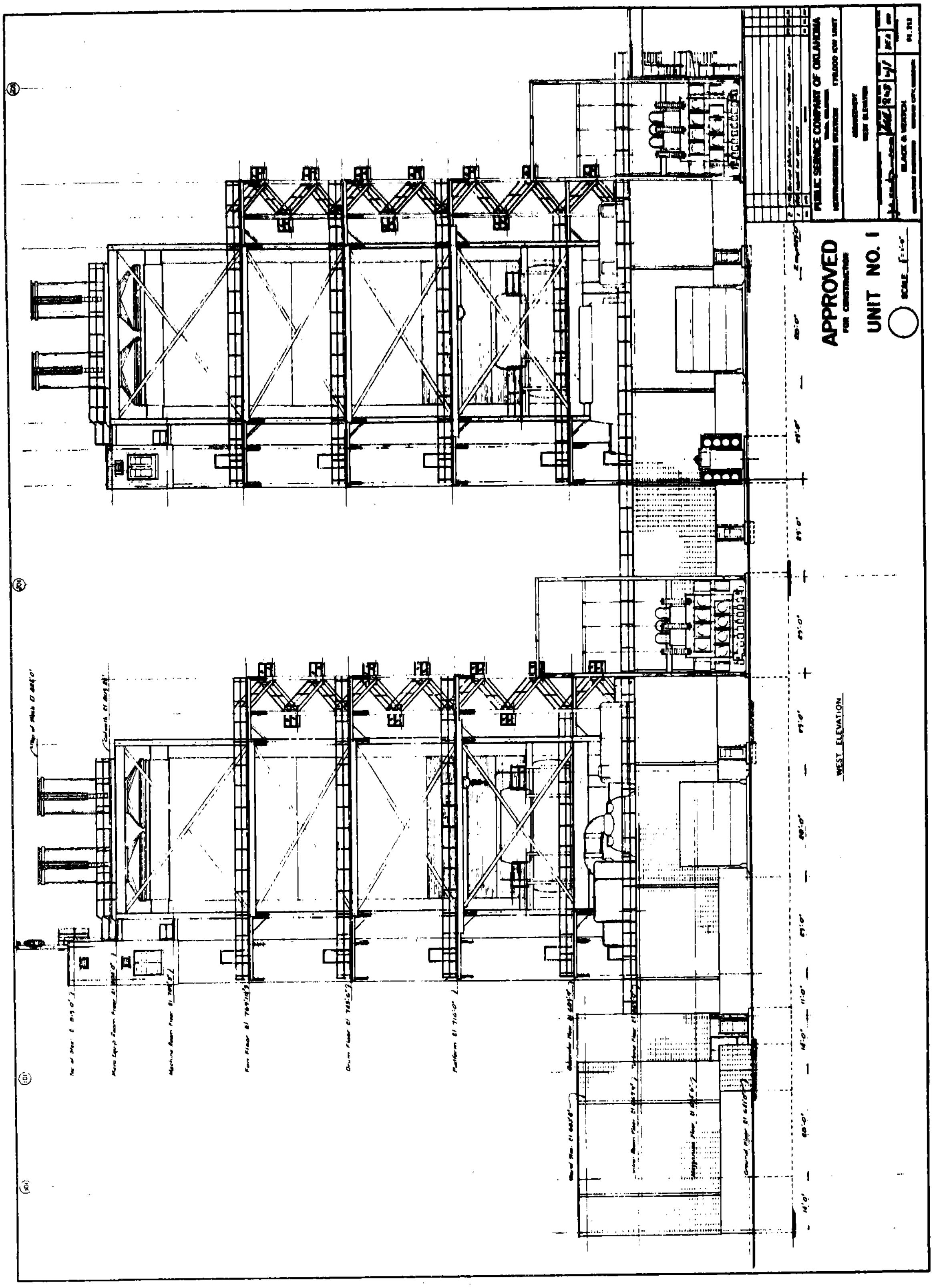
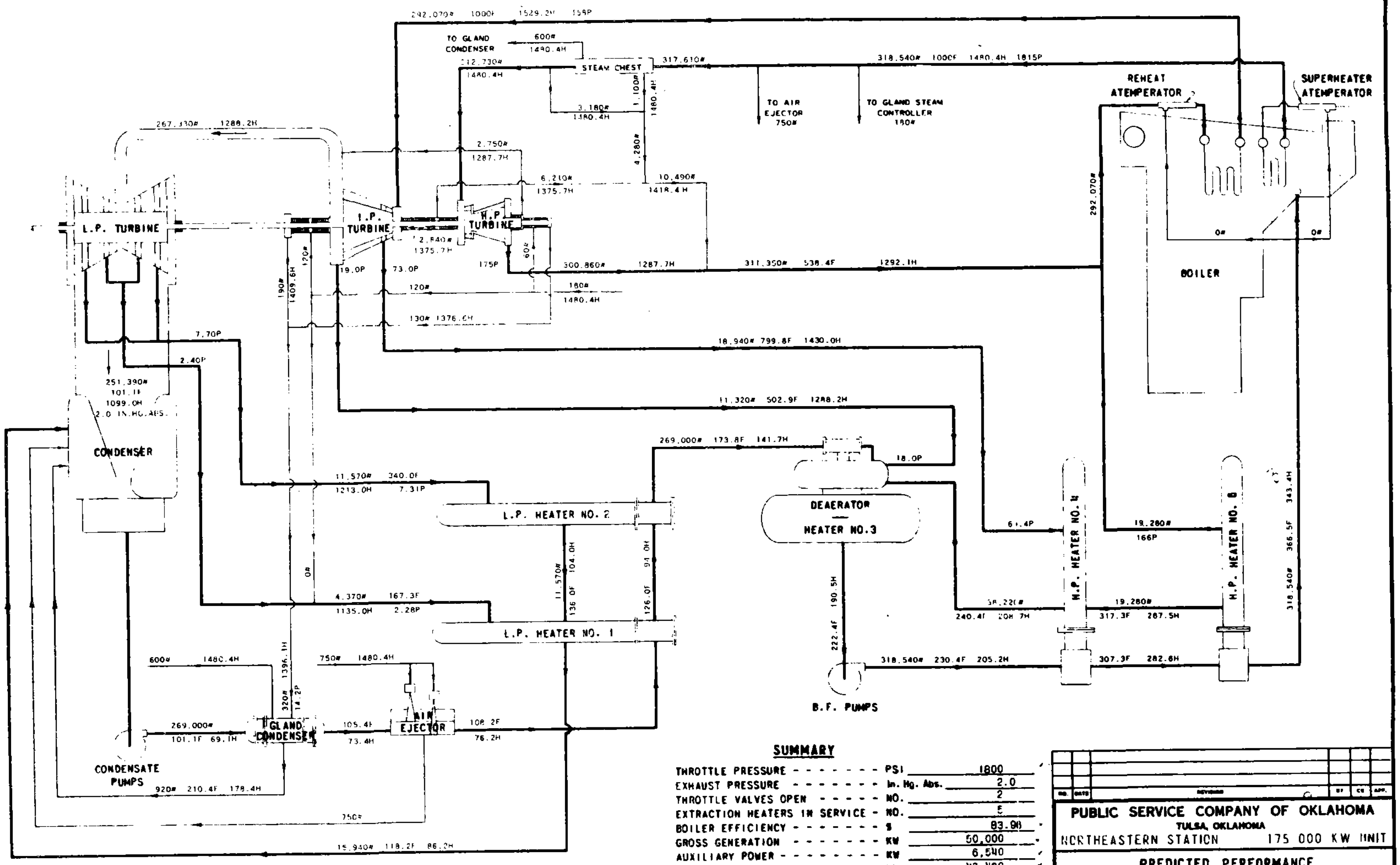

PUBLIC SERVICE COMPANY OF OKLAHOMA
APPROVED
FOR CONSTRUCTION
UNIT NO. 1
SOUTH ELEVATION
BLACK & VEATCH

FIGURE 5.2-5



PUBLIC SERVICE COMPANY OF OKLAHOMA
APPROVED
UNIT NO. I
WEST ELEVATION

FIGURE 5.2-6



SUMMARY

THROTTLE PRESSURE	PSI	1800
EXHAUST PRESSURE	In. Hg. Abs.	2.0
THROTTLE VALVES OPEN	NO.	2
EXTRACTION HEATERS IN SERVICE	NO.	5
BOILER EFFICIENCY	%	83.98
GROSS GENERATION	KW	50,000
AUXILIARY POWER	KW	6,540
NET GENERATION (SENDOUT)	KW	43,460
*TURBINE-CYCLE HEAT RATE	BTU/KWH	8,621
**PLANT-CYCLE HEAT RATE	BTU/KWH	11,813

SYMBOLS

- # - Pounds per hour
- F - Degrees Fahrenheit
- H - Enthalpy, Btu/#
- P - Pressure, psia

* Turbine-Cycle heat rate is defined as the number of BTU supplied to the turbine cycle by the boiler for each kilowatt-hour of output measured at the generator terminals.

** Plant-Cycle heat rate is defined as the number of BTU supplied to the boiler for each kilowatt-hour sendout measured at the main transformer high voltage bushings.

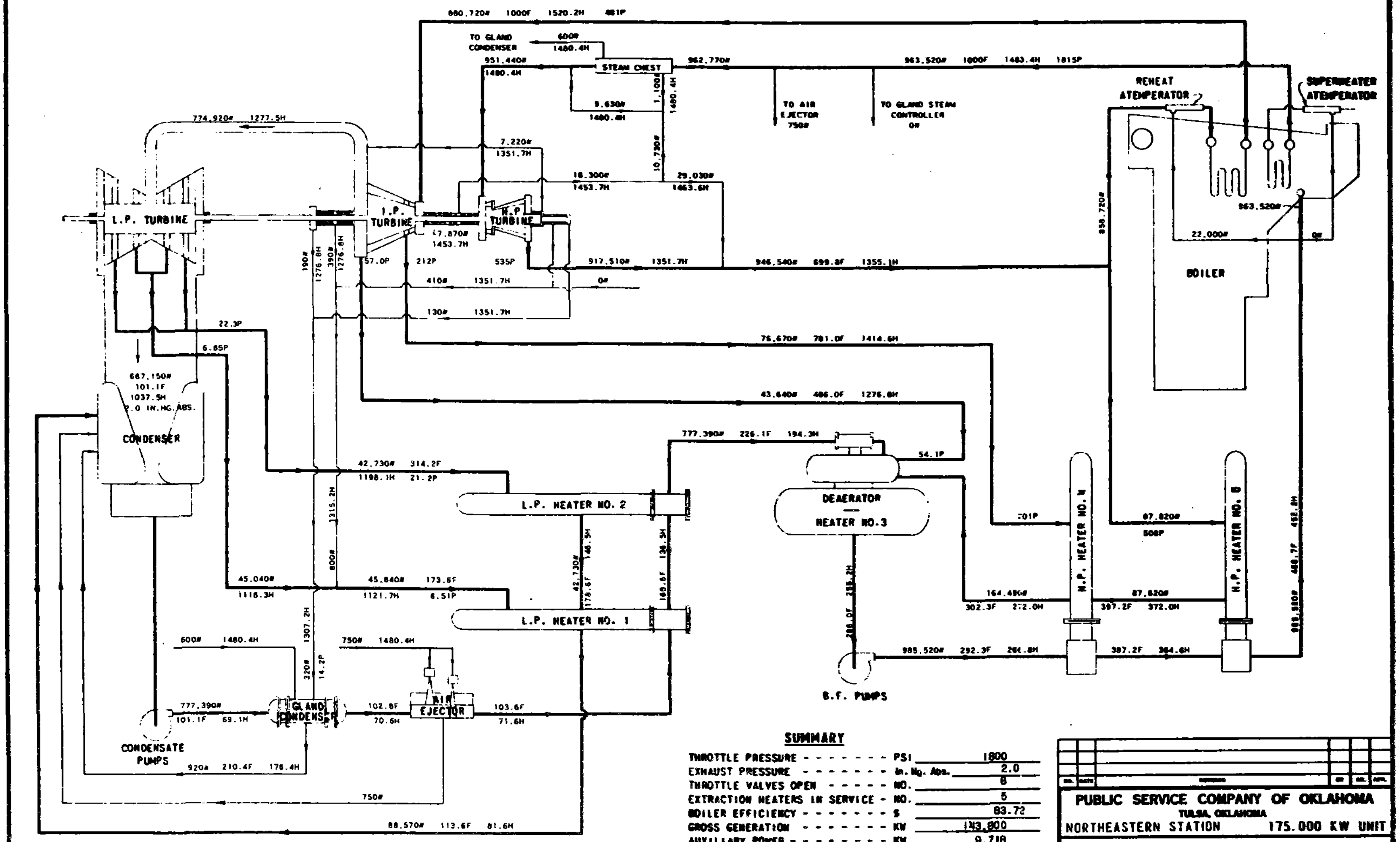
PUBLIC SERVICE COMPANY OF OKLAHOMA
TULSA, OKLAHOMA
NORTHEASTERN STATION 175 000 KW UNIT

PREDICTED PERFORMANCE
AT
50,000 KW

BLACK & VEATCH
CONSULTING ENGINEERS KANSAS CITY, MISSOURI
2767
H2767-120160-1

SYSTEM REQUIREMENTS SPECIFICATION
EXISTING POWER PLANT DESCRIPTION
FILE NO. 8734.23.0100
SECTION 5.2

FIGURE 5.2-7



SUMMARY

THROTTLE PRESSURE - - - - - - - -	PSI	1800
EXHAUST PRESSURE - - - - - - - -	In. Hg. Abs.	2.0
THROTTLE VALVES OPEN - - - - - -	NO.	6
EXTRACTION HEATERS IN SERVICE -	NO.	5
BOILER EFFICIENCY - - - - - - - -	%	83.72
GROSS GENERATION - - - - - - - -	KW	143,800
AUXILIARY POWER - - - - - - - -	KW	9,718
NET GENERATION (SENDOUT)- - - -	KW	134,082
*TURBINE-CYCLE HEAT RATE - - - -	BTU/KWH	8,036
**PLANT-CYCLE HEAT RATE - - - - -	BTU/KWH	10,294

* Turbine-Cycle heat rate is defined as the number of BTU supplied to the turbine cycle by the boiler for each kilowatt-hour of output measured at the generator terminals.

** Plant-Cycle heat rate is defined as the number of BTU supplied to the boiler for each kilowatt-hour sendout measured at the main transformer high voltage bushings.

SYMBOLS

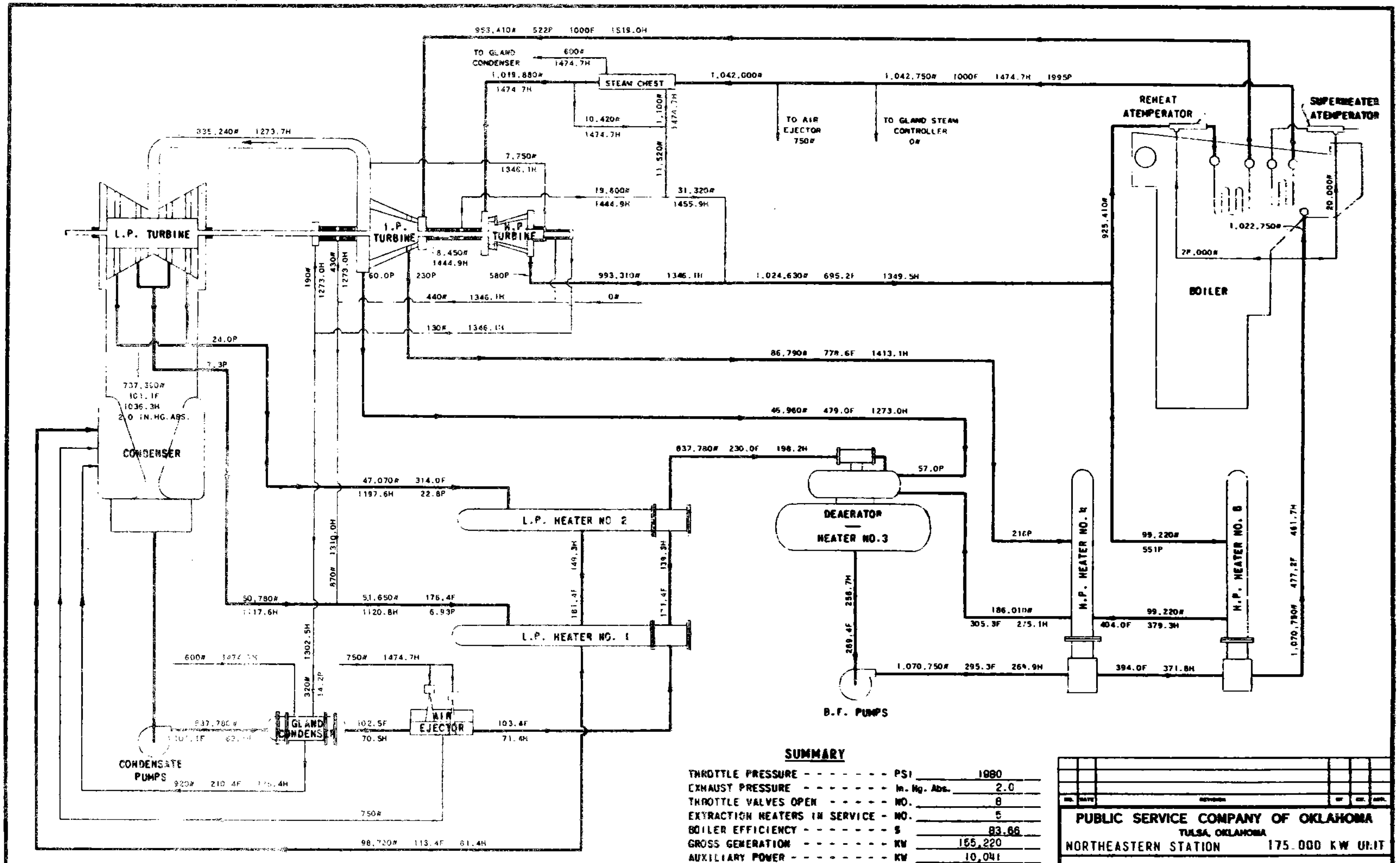
- # -- Pounds per hour
- F -- Degrees fahrenheit
- H - Enthalpy, Btu/#
- P - Pressure, psia

PUBLIC SERVICE COMPANY OF OKLAHOMA
TULSA, OKLAHOMA
NORTHEASTERN STATION 175.000 KW UNIT

PREDICTED PERFORMANCE
AT
143,800 KW

BLACK & VEATCH
CONSULTING ENGINEERS KANSAS CITY, MISSOURI
2767
N2767-120160-6

FIGURE 5.2-8



SUMMARY

THROTTLE PRESSURE	PSI	1980
EXHAUST PRESSURE	In. Hg. Abs.	2.0
THROTTLE VALVES OPEN	NO.	8
EXTRACTION HEATERS IN SERVICE	NO.	5
BOILER EFFICIENCY	%	83.66
GROSS GENERATION	KW	155,220
AUXILIARY POWER	KW	10,041
NET GENERATION (SENDOUT)	KW	145,179
*TURBINE-CYCLE HEAT RATE	BTU/KWH	8,004
**PLANT-CYCLE HEAT RATE	BTU/KWH	10,229

* Turbine-Cycle heat rate is defined as the number of BTU supplied to the turbine cycle by the boiler for each kilowatt-hour of output measured at the generator terminals.

** Plant-Cycle heat rate is defined as the number of BTU supplied to the boiler for each kilowatt-hour sendout measured at the main transformer high voltage bushings.

SYMBOLS

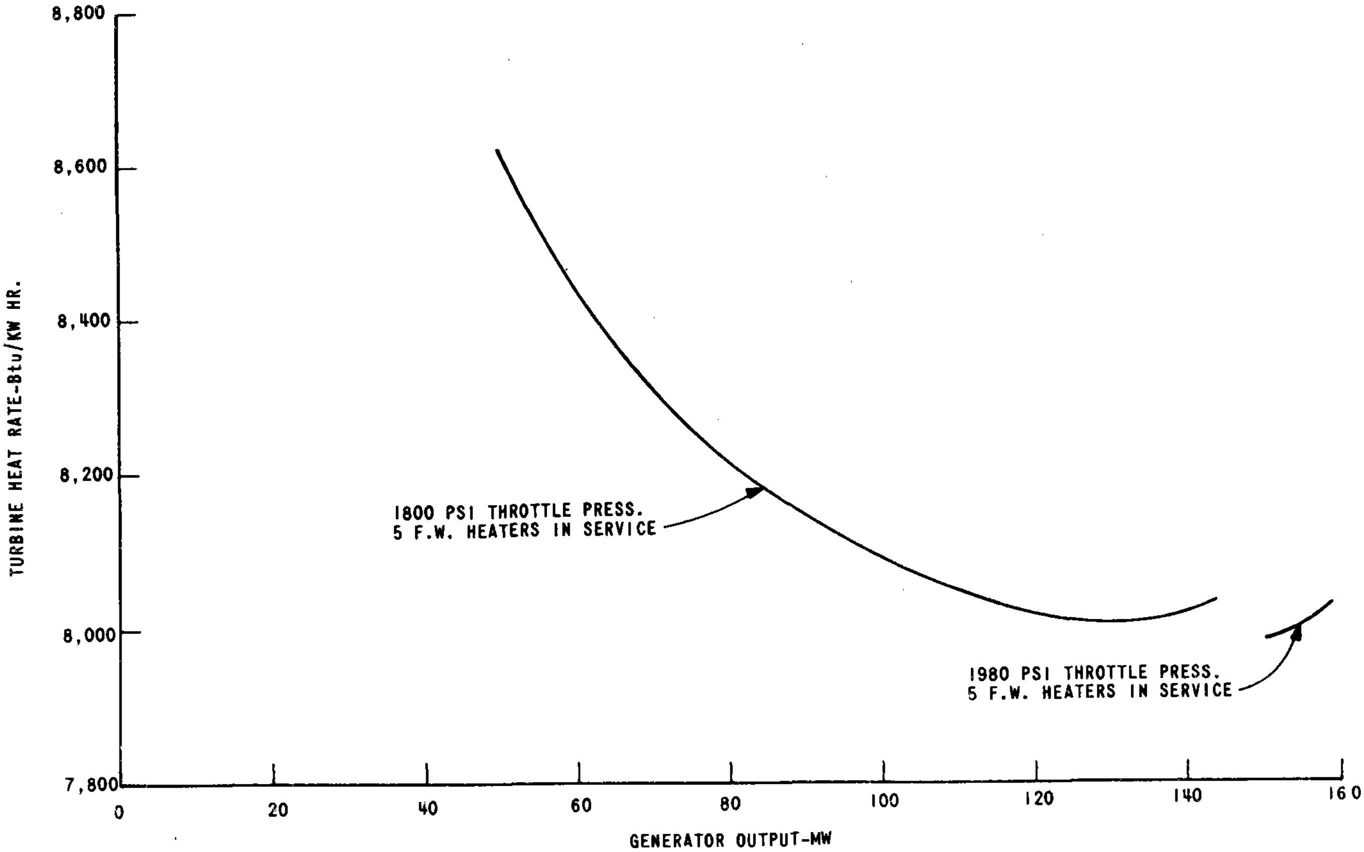
- # - Pounds per hour
- F - Degrees Fahrenheit
- H - Enthalpy, Btu/#
- P - Pressure, psia

PUBLIC SERVICE COMPANY OF OKLAHOMA
TULSA, OKLAHOMA
NORTHEASTERN STATION 175,000 KW UNIT

PREDICTED PERFORMANCE
AT
155,220 KW

BLACK & VEATCH
CONSULTING ENGINEERS KANSAS CITY, MISSOURI
2767
K2767-
1201EG-E

FIGURE 5.2-9

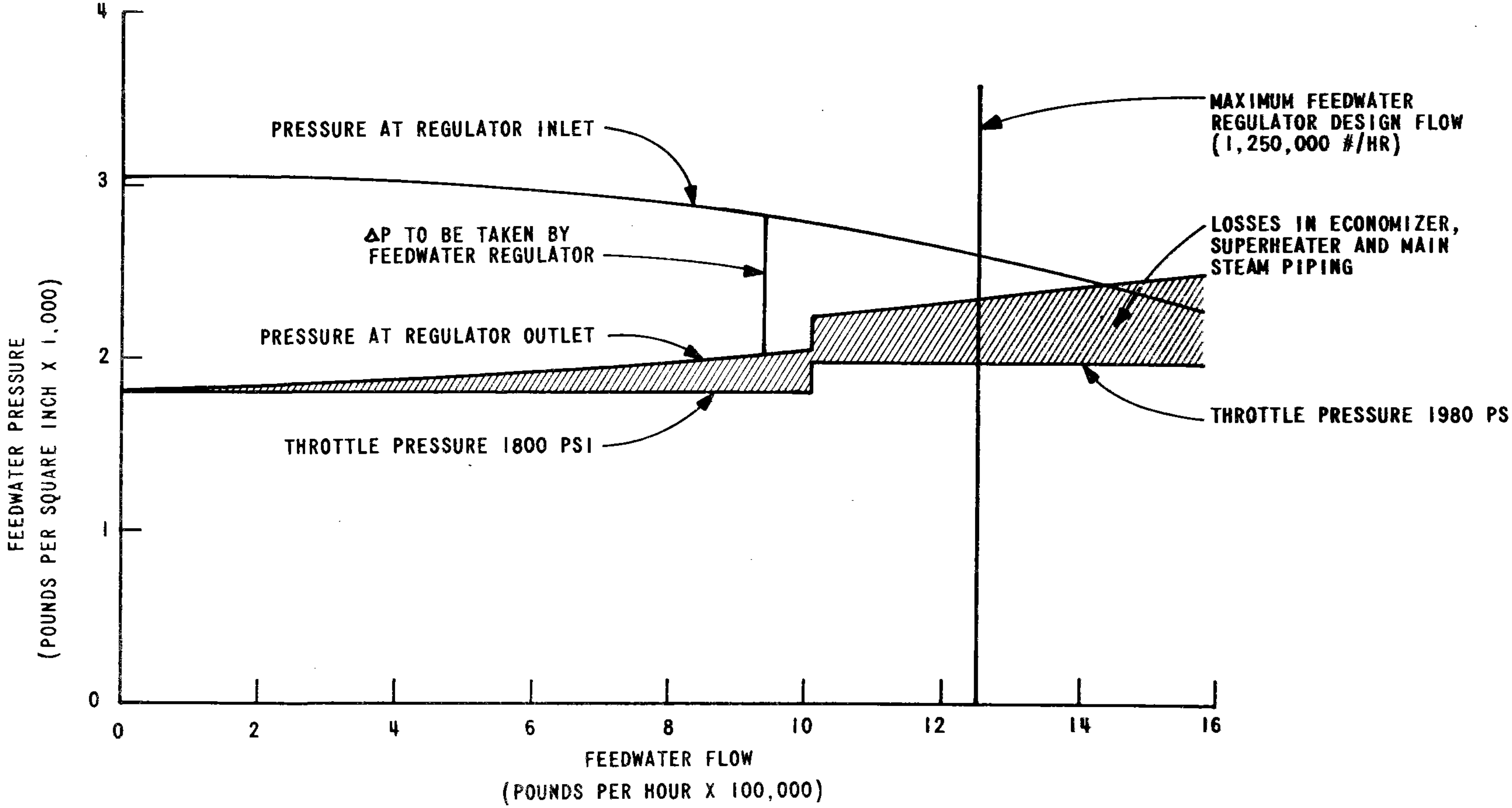


PUBLIC SERVICE COMPANY OF OKLAHOMA
NORTHEASTERN STATION
175,000 KW UNIT UNIT NO. 1

TURBINE HEAT RATE VERSUS
GENERATOR OUTPUT

FIGURE 5.2-10

SREG NES-071580



PUBLIC SERVICE COMPANY OF OKLAHOMA
NORTHEASTERN STATION
BOILER 1 TURBINE 1

DESIGN CHARACTERISTICS FOR FEEDWATER REGULATORS

FIGURE 5.2-

SYSTEM REQUIREMENTS SPECIFICATION

EXISTING POWER PLANT DESCRIPTION

FILE NO. 8734.23.0100

SECTION 5.2

TABLE 5.2-1. STEAM GENERATOR PERFORMANCE DATA (BASED ON NATURAL GAS FUEL AT 1,025 BTU/CU FT)

	60 Per Cent Capacity	Rated Capacity	Maximum Capability
Steam output, lb/h	600,000	1,000,000	1,150,000
Reheat steam flow, lb/h	530,000	891,000	1,150,000
Excess air leaving air heater, per cent	25	7	7
No. burners in use	15	15	15
Fuel, cu ft/h	900,000	1,416,000	1,818,000
Flue gas leaving air heater, lb/h	874,000	1,184,000	1,525,000
Air leaving air heater, lb/h	834,000	1,123,000	1,443,000
Steam pressure at SH outlet, psi	1,850	1,850	2,070
Pressure drop, drum to SH outlet, psi	37	102	102
Pressure drop through economizer, psi	19	53	70
Steam pressure entering reheater, psi	300	486	515
Steam pressure leaving reheater, psi	287	458	485
Steam temperature leaving superheater, F	1,005	1,005	1,005
Steam temperature entering reheater, F	601	661	695
Steam temperature leaving reheater, F	1,005	1,005	1,005
Flue gas temperature leaving economizer, F	630	715	720
Flue gas temperature leaving air heater, F	290	330	340
Air temperature entering air heater, F	100	100	100
Water temperature entering economizer, F	419	466	310
Water temperature entering boiler, F	497	526	463

TABLE 5.2-1 (Continued). STEAM GENERATOR PERFORMANCE DATA (BASED ON NATURAL GAS FUEL AT 1,025 BTU/CU FT)

	60 Per Cent Capacity	Rated Capacity	Maximum Capability
Boiler and superheater draft loss, in. water	1.6	3.0	4.9
Economizer draft loss, in. water	1.0	1.8	2.9
Air heater draft loss, in. water	2.0	3.6	5.8
Damper and flue draft loss, in. water	0.1	0.3	0.5
Burner and wind box air resistance, in. water	1.8	3.5	5.7
Duct resistance, in. water	0.3	0.5	0.8
Air heater resistance, in. water	1.8	3.3	5.3
Net resistance and draft loss, in. water	8.6	16.0	25.9
Dry gas, per cent heat loss	3.90	4.01	4.18
Hydrogen and water in fuel, per cent heat loss	10.32	10.48	10.53
Moisture in air, per cent heat loss	0.11	0.11	0.12
Unburned combustible, per cent heat loss	0.00	0.00	0.00
Radiation, per cent heat loss	0.31	0.23	0.20
Unaccounted, per cent heat loss	1.50	1.50	1.50
Total heat loss, per cent	16.14	16.33	16.53
Efficiency of unit, per cent	83.86	83.67	83.47

5.3 PLANT COST DATA

Presented herein is the project cost estimate for the Solar Repowering of Northeastern Station, Unit 1. 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 in Table 5.3-2. A detailed description of the owner's cost estimate is shown on Figure 5.3-1.

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

(1) Land and Land rights at $3,000/acre.

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

(3) Costs of obtaining all necessary licenses and permits including preparation of environmental impact statements (included as part of the engineering costs).

(4) Owner'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.

(5) Plant consumable supplies and start-up costs (included as part of the operation and maintenance costs).

(6) Property taxes and insurance costs on the land and plant during construction based upon insurance at .73 per cent of asset value and taxes at 1.58 per cent of asset value.

(7) Cost of money, AFUDC (Allowance for Used Funds During Construction) based upon a rate of 10.5 per cent compounded semi-annually.

5.3.2 Construction Cost Estimate

The construction cost estimate is summarized on Table 5.3-3. The detailed breakdown of the construction cost estimate by account number

TABLE 5.3-1. PROJECT COST ESTIMATE SUMMARY

Owner's Cost Estimate	$22,038,000
Construction Cost Estimate	55,099,000
Annual Operations and Maintenance Cost Estimate	$ 243,720

TABLE 5.3-2. OWNER'S COST ESTIMATE SUMMARY

Land and Land Rights	$ 528,000
Consulting Services	84,000
Owner's Managerial, Engineering, Etc. (Included in Construction Cost Estimate)	--
Property Taxes and Insurance on Land and Plant During Construction	3,453,000
Cost of Money (AFUDC)	17,973,000
Total Owner's Cost Estimate	$22,038,000

BLACK & VEATCH CONSULTING ENGINEERS

Owner D.O.E. – P.S.O.
Plant North Eastern Station Unit 1
Project No. 8734 File No. 8734.23.0100
Title Owner's Cost Estimate

Computed By W.E.S.
Date 6-5-1980
Checked By [illegible]
Date 6-9-1980
Page ____ of ____

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
(1) Land & Land Rights	176 Ac	3,000	528,000				—	528,000
(2) Consulting Services:								
Topographic Survey	1 LS	5,000	5,000				15,000	20,000
Geotechnical Investigation	1 LS	7,500	7,500				7,500	15,000
Const. Control Testing	1 LS	8,500	8,500				40,500	49,000
(3) Owner's Managerial								
Engr., Financing, Etc.	1 LS	Included in Const. Cost						—
(4) Property Taxes & Insurance on Land & Plant During Construction:								
Taxes	1 LS	2,361,000	2,361,000	—		—	—	2,361,000
Insurance	1 LS	1,092,000	1,092,000	—		—	—	1,092,000
(5) Cost of Money (AFUDC)	1 LS	17,973,000	17,973,000	—		—	—	17,973,000
Total Owner's Cost Excluding Home Office Costs Included in Construction Estimate.			21,975,000				63,000	22,038,000

Owner's Cost Estimate

FIGURE 5.3-1

GN 171B

TABLE 5.3-3. CONSTRUCTON COST SUMMARY

Account Number	Element Description	Cost Expressed In January, 1980 Dollars ($ X 1,000) Level 3	Level 2	Level 1	Level 0
5000	Total Facility*				55,099
5100	Site Improvements			309	
5200	Site Facilities			1,690	
5300	Collector System			29,106	
5310	Heliostats		28,770		
5320	Other Costs		336		
5400	Receiver System			14,192	
5410	Tower		2,574		
5420	Receiver		11,618		
5450	Receiver Loop System			3,854	
5451	Pipe Supports System	279			
5452	Feedwater Piping System	796			
5453	Main Steam Piping System	2,029			
5454	Condensate Piping System	750			
5500	Master Control System			5,817	
5600	Fossil Energy System			131	

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

showing material and labor costs is presented on Tables 5.3-4a through 5.3-4p. The supporting data for each account follows the appropriate table.

5.3.2.1 Basis of Estimation. The construction cost estimate summarized in Table 5.3-3 is based upon the following.

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

(2) Costs are for a facility to be located at the Public Service Company of Oklahoma's Northeastern Station Unit 1 near Oologah, Oklahoma.

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

(4) Transportation costs to the facility site for materials and components are included in the material costs.

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

(6) Costs are summarized in January, 1980 dollars. Costs are given in the supporting base sheets are also January, 1980 dollars and indicate material and labor cost breakdowns.

(7) 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.

(8) Labor costs are based on recently experienced man-hours to complete similar tasks on other B&V projects, multiplied by the appropriate wage rate. The wage rates used for the estimate are based on a wage rate survey of the Tulsa, Oklahoma area. The labor costs for heliostat installation (Account 5310-E-Machinery & Equipment) are not shown separately, but are included in the $\$260/M^2$ total heliostat costs supplied by DOE.

TABLE 5.3-4a

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. – P.S.O.

LOCATION NORTHEASTERN STATION – UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5000 SUMMARY

CONT. NO.

MADE BY W.E.J

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	203286	2,565,091	237,230	41,906,210	44,709,000
L	Temporary Construction Facilities					290,000
M	Construction Services, Supplies & Expense					410,000
N	Field Staff, Subsistence & Expense					660,000
P	Craft Benefits, Payroll Burdens & Insurance					820,000
Q	Equipment Rental					258,000
	TOTAL FIELD COSTS					2,438,000
R	Engineering					
	Design & Engineering					3,860,000
	Home Office Costs					710,000
	R & D					
S	Major Equipment Procurement					173,000
T	Construction Management					815,000
	TOTAL OFFICE COSTS					5,558,000
	TOTAL FIELD & OFFICE COSTS					7,996,000
U	Labor Productivity					—
V	Contingency					2,392,000
W	Fee					
	TOTAL CONSTRUCTION COST					55,097,000

DATE 6-3-81 REVISION NO. ______ REVISION DATE ______

SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
PLANT COST DATA	SECTION 5.3

TABLE 5.3-46 CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.

LOCATION NORTHEASTERN STATION - UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5100 SITE IMPROVEMENTS

CONT. NO.

MADE BY W. E. S.

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	2,978	48,219	–	73,162	121,381
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	2,978	48,219	–	73,162	121,381
L	Temporary Construction Facilities					6,090
M	Construction Services, Supplies & Expense					8,610
N	Field Staff, Subsistence & Expense					13,860
P	Craft Benefits, Payroll Burdens & Insurance					17,220
Q	Equipment Rental					5,418
	TOTAL FIELD COSTS					51,198
R	Engineering					95,970
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					3,633
T	Construction Management					17,115
	TOTAL OFFICE COSTS					116,718
	TOTAL FIELD & OFFICE COSTS					167,916
U	Labor Productivity					
V	Contingency					19,152
W	Fee					
	TOTAL CONSTRUCTION COST					308,499

DATE 5-29-80 REVISION NO. ________ REVISION DATE ________

	SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
	PLANT COST DATA	SECTION 5.3

TABLE 5.3-4C CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.

LOCATION NORTHEASTERN STATION - UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5200 SITE FACILITIES

CONT. NO.

MADE BY W.E.S.

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	3	158	–	–	158
B	Concrete	25	289	–	106	395
C	Structural Steel					
D	Buildings	1,600	20,250	–	13,500	33,750
E	Machinery & Equipment	4,009	47,128	–	35,828	82,956
F	Piping					
G	Electrical	12,342	149,463	–	402,870	552,533
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	17,979	217,488	–	452,304	669,792
L	Temporary Construction Facilities					33,350
M	Construction Services, Supplies & Expense					47,150
N	Field Staff, Subsistence & Expense					75,900
P	Craft Benefits, Payroll Burdens & Insurance					94,300
Q	Equipment Rental					29,670
	TOTAL FIELD COSTS					280,370
R	Engineering					525550
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					19,895
T	Construction Management					93,725
	TOTAL OFFICE COSTS					639,170
	TOTAL FIELD & OFFICE COSTS					919,540
U	Labor Productivity					
V	Contingency					100,548
W	Fee					
	TOTAL CONSTRUCTION COST					1,689,880

DATE 5-29-80 REVISION NO. REVISION DATE PAGE NO. 5.3 9.

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. - PSO
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COST ESTIMATE

Computed By W.E.S.
Date 5-13-1980
Checked By BLL
Date 5-20-1980
Page 1 of 24

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
ACCOUNT NO. 5100								
SITE IMPROVEMENTS								
A - EXCAVATION & CIVIL								
A1 SITE GRADING (REMOVE DAM & FILL-IN FARM POND								
700 HP CRAWLER DOZER	1 WK	4,675	4,675	40	40	33.45	1,338	6,013
A2 DRAINAGE DITCHES & ROADS SUB-GRADE	2 WK	1,825	3,650	40	80	13.86	1,109	4,759
A3 TRENCHING FOR CULVERTS	30 CY	1.35	41	.089	3	14.65	39	80
A4 CULVERTS	200 LF	12.00	2,400	.175	35	16.80	588	2,988
A5 MAIN ACCESS ROAD BASE	6,027 SY	1.70	10,246	.019	115	25.20	2,886	13,132
A6 MAIN ACCESS ROAD (ASPHALT)	4,018 SY	2.40	9,643	.048	193	18.13	3,497	13,140
A7 PARKING LOT	534 SY	4.10	2,189	.067	36	43.33	1,550	3,739
A8 SECONDARY ACCESS ROAD								
OILED GRAVEL	9,044 SY	.71	6,421	.020	181	80.67	14,592	21,013
A9 6' CHAIN LINK w/ 3 STRANDS B-WIRE REMOVE & REINSTALL FENCE	3,404 LF	—	—	.320	1,089	8.31	9,052	9,052
A10 6' CHAINLINK w/3 STANDS B-WIRE INSTALL NEW FENCE	5,231 LF	6.48	33,897	.193	1,012	11.82	11,960	45,857
A11 REMOVE BARBED WIRE FENCE	5,231 LF	—	—	.037	194	8.31	1,608	1,608
A. CIVIL TOTAL			73,162		2978		48,219	121,381

5.3-26

GN 171B

5.3-9a

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D. O. E. – PSO
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COST ESTIMATE

Computed By W. E. J.
Date 5 – 16 – 19 80
Checked By [illegible]
Date 5 – [illegible] – 19 [illegible]
Page 2 of 24

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
ACCOUNT NO. 5200								
SITE FACILITIES A – EXCAVATION & CIVIL								
A1 EXCAVATION & BACKFILL FOR								
TOWER & SWITCHGEAR GROUND	15 CY	–	–	.210	3	50.00	158	158
A. EXCAVATION & CIVIL TOTAL			–		3		158	158
								5.3-27

GN 171B

5.3-96

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. - PSO
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COST ESTIMATE

Computed By W.E.S.
Date 5-14-1980
Checked By G.L.
Date 5-20-1980
Page 3 of 24

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
ACCOUNT NO. 5200								
SITE FACILITIES B- CONCRETE								
B1 TRANSFORMER PAD	1.4 CY	75.71	106	17.857	25	11.56	289	395
B. CONCRETE TOTAL			106		25		289	395
								5.3-28

P-GN 171B

5.3-9C

BLACK & VEATCH
CONSULTING ENGINEERS

Owner: D.O.E. - PSO
Plant: NORTHEASTERN STATION Unit: 1
Project No. 8734 File No. 8734.23.0100
Title: CONSTRUCTION COST ESTIMATE

Computed By: W.E.S.
Date: 5-15-1980
Checked By:
Date: 5 19
Page 4 of 24

ITEM	QUANTITY	MATERIAL		LABOR				TOTAL COST
		UNIT COST	TOTAL MAT'L COST	HRS. PER UNIT	TOTAL HRS.	COST PER HOUR	TOTAL LABOR COST	
ACCOUNT NO. 5200								
SITE FACILITIES								
D - BUILDINGS								
D1 PREFABRICATED METAL								
BUILDING (25'x30')	750 SF	18.00	13,500	2.133	1,600	12.66	20,250	33,750
								5.3-29

GN 171B

5.3-4d

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. - PSO
Plant Northeastern Sta Unit 1
Project No. 8734 File No. 8734.23.0100
Title Construction Costs

Computed By GLL
Date 5-20-1980
Checked By W.G.S.
Date 5-22-1980

ITEM	QUANTITY	MATERIAL		LABOR				TOTAL COST
Account 5200		UNIT COST	TOTAL MAT'L COST	HRS. PER UNIT	TOTAL HRS.	COST PER HOUR	TOTAL LABOR COST	
SITE FACILITIES								
E- Machinery & Equipment								
E1 Heat Exchanger air to H_2O 60 KW pump w/90KW startup	LS	-	4000		510	11.76	6000	10,000
E2 CONDENSATE SYSTEM FILTERS Feedwater Recirculation 6-25gpm	LS	-	24,000		3061	11.76	36,000	60,000
E3 Nitrogen Sys Two 12 cylinder banks manifolds & piping ASTM B88 Type K	LS		5,644		150	11.76	1,764	7,408
E4 Service Air System Piping incl hose bibs	364 LF	2.25	819		130	11.76	1529	2,348
E5 Service Water System Piping incl hose bibs 1" ASTM B88 Type K	364 LF	3	1100		155	11.76	1800	2,900
E6 Fire Extinguishers	3 EA	88	265		3	11.76	35	300
E. MACHINERY & EQUIPMENT TOTAL			35,828		4009		47,128	82,956

P-GN 171B

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. - PSO
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COST ESTIMATE

Computed By W.E.S.
Date 5-15-1980
Checked By J.L.L.
Date 5-20-1980
Page 6 of 24

ITEM ACCOUNT No. 5200	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
SITE FACILITIES								
G - ELECTRICAL								
G1 990 KW - 4160 V DIESEL								
GENERATOR & ASSOC. EQUIP.	1 EA	182,932	182,932	360	360	12.32	4,435	187,367
G2 4160 V SWITCHGEAR	1 EA	76,000	76,000	109.111	109	12.12	1,322	77,322
G3 CIRCUIT P01 5KV CABLE	30 LF	3.14	94	.171	5	12.12	62	156
G4 CIRCUIT P02 5KV CABLE	60 LF	3.14	188	.171	10	12.12	124	312
G5 3" RIGID STEEL CONDUIT								
FOR CIRCUITS P01 & P02	90 LF	4.00	360	.750	68	12.12	818	1,178
G6 INCOMING POWER CIRCUITS								
500 MCM CABLE	24,060 LF	3.73	89,744	.067	1,612	12.12	19,538	109,282
G7 4" RIGID STEEL CONDUIT								
FOR INCOMING POWER CIRCUITS	8,020 LF	6.00	48,120	1.250	10,025	12.12	121,503	169,623
G8 PAD MOUNTED TRANSFORMER	1 EA	4,293	4,293	44.444	44	12.12	539	4,832
G9 TOWER & SWITCHGEAR GROUNDING	1 LS	1,139	1,139	109	109	12.12	1,322	2,461
G. ELECTRICAL TOTAL			402,870		12,342		149,663	552,533

GN 171B

5.3-4F

	SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
	PLANT COST DATA	SECTION 5.3

TABLE 5.3-4d

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.

LOCATION NORTHEASTERN STATION - UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5300 COLLECTOR SYSTEM

CONT. NO. ____

MADE BY W. E. J.

APPROVED ____

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	54	2,720	–	–	2,720
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	–	–	–	28,879,741	28,879,741
F	Piping					
G	Electrical	854	10,350	–	10,500	20,850
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	908	13,070	–	28,890,241	28,903,311
L	Temporary Construction Facilities					6,670
M	Construction Services, Supplies & Expense					9,430
N	Field Staff, Subsistence & Expense					15,180
P	Craft Benefits, Payroll Burdens & Insurance					18,860
Q	Equipment Rental					5,934
	TOTAL FIELD COSTS					56,074
R	Engineering					105,110
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					3,979
T	Construction Management					18,745
	TOTAL OFFICE COSTS					127,834
	TOTAL FIELD & OFFICE COSTS					183,908
U	Labor Productivity					
V	Contingency					19,152
W	Fee					
	TOTAL CONSTRUCTION COST					29,106,371

DATE 5-29-80 REVISION NO. ____ REVISION DATE ____

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D. O. E. – P.S.O.
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COST ESTIMATE

Computed By W. E. S.
Date 6-5- 1980
Checked By [illegible]
Date 6-? 1980

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
ACCOUNT NO. 5300 COLLECTOR SYSTEM								
A – EXCAVATION & CIVIL			–		54		2,720	2,720
E – MACHINERY & EQUIPMENT			28,879,741		–		–	28,879,741
G – ELECTRICAL			10,500		854		10,350	20,850
TOTAL ACCOUNT 5300			28,890,241		908		13,070	28,903,311

R-GN-171B

SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
PLANT COST DATA	SECTION 5.3

TABLE 5.3-4e

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.

LOCATION NORTHEASTERN STATION - UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5310 HELIOSTATS

CONT. NO.

MADE BY W.E.S.

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings	—	—	—	28,769,741	28,769,741
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	—	—	—	28,769,741	28,769,741
L	Temporary Construction Facilities					—
M	Construction Services, Supplies & Expense					—
N	Field Staff, Subsistence & Expense					—
P	Craft Benefits, Payroll Burdens & Insurance					—
Q	Equipment Rental					—
	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					
U	Labor Productivity					
V	Contingency					—
W	Fee					
	TOTAL CONSTRUCTION COST					28,769,741

DATE 6-7-80 REVISION NO. ______ REVISION DATE ______

TABLE 5.3-45

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.
LOCATION NORTHEASTERN STATION - UNIT 1
PROJECT 8734
DESCRIPTION ACCOUNT 5320 OTHER COSTS
CONT. NO.
MADE BY W.E.S.
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	54	2,720	—	—	2,720
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment	—	—	—	110,000	110,000
F	Piping					
G	Electrical	854	10,350	—	10,500	20,850
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	908	13,070	—	120,500	133,570
L	Temporary Construction Facilities					6,670
M	Construction Services, Supplies & Expense					9,430
N	Field Staff, Subsistence & Expense					15,180
P	Craft Benefits, Payroll Burdens & Insurance					18,860
Q	Equipment Rental					5,934
	TOTAL FIELD COSTS					56,074
R	Engineering					105,110
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					3,979
T	Construction Management					18,745
	TOTAL OFFICE COSTS					127,834
	TOTAL FIELD & OFFICE COSTS					183,908
U	Labor Productivity					
V	Contingency					19,152
W	Fee					
	TOTAL CONSTRUCTION COST					336,630

DATE 6-7-80 REVISION NO. ______ REVISION DATE ______

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. – P.S.O.
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COST ESTIMATE

Computed By W. E. S.
Date 6-5-1980
Checked By CB
Date 6-6 1980
Page 8 of 24

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
ACCOUNT NO. 5310								
COLLECTOR SYSTEM HELIOSTATS								
E – MACHINERY & EQUIPMENT								
E1 HELIOSTATS	2,255 EA	@	49.07	m^2/EA	x $260.00	/m^2 =		28,769,741
E. MACHINERY & EQUIPMENT TOTAL			—	—	—		—	28,769,741

S.3.17R

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BLACK & VEATCH
CONSULTING ENGINEERS

Owner D. O. E. - PSO
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COST ESTIMATE

Computed By W. E. S.
Date 5-21-1980
Checked By [illegible]
Date 6-[illegible] 19[illegible]
Page 9 of 24

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
Account No. 5320								
Collector System Other Costs								
A- Excavation & Civil								
A1 Primary Distribution								
Direct Burial Cable								
Excavation & Backfill	259 CY	—	—	.210	54	50.00	2,720	2,720
A. Excavation & Civil Total			—		54		2,720	2,720
E- Machinery & Equipment								
E1 Heliostat Washing Vehicle	1 EA	30,000	30,000	—	—	—	—	30,000
E2 Heliostat Maint. Vehicle	1 EA	25,000	25,000	—	—	—	—	25,000
E3 Heliostat Leveling Equipment	1 LS	10,000	10,000	—	—	—	—	10,000
E4 Heliostat Lifting Vehicle	1 EA	30,000	30,000	—	—	—	—	30,000
E5 Field Controller & Laser Aiming System	1 LS	15,000	15,000	—	—	—	—	15,000
E. Machinery & Equipment Total			110,000	—	—	—	—	110,000
G- Electrical								
G1 5KV Direct Burial Cable	7000 LF	1.50	10,500	.122	854	12.12	10,350	20,850
G. Electrical Total			10,500		854		10,350	20,850

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	SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
	PLANT COST DATA	SECTION 5.3

TABLE 5.3-4g

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.

LOCATION NORTHEASTERN STATION - UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5400 * RECEIVER SYSTEM

CONT. NO.

MADE BY W.E.S.

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	222	13,942	–	8,160	22,102
B	Concrete	40,346	442,145	–	133,675	575,820
C	Structural Steel	9,698	133,792	36,358	1,244,368	1,414,518
D	Buildings	201	2,266	–	6,382	8,648
E	Machinery & Equipment	22,485	310,359	80,589	6,044,192	6,435,140
F	Piping					
G	Electrical	9,873	119,680	–	142,402	262,082
H	Instruments	1,190	16,666	4,683	572,772	594,121
J	Painting	22	250	–	84	334
K	Insulation	29,372	411,355	115,600	1,282,198	1,809,153
	DIRECT FIELD COSTS	113,409	1,450,455	237,230	9,434,233	11,121,918
L	Temporary Construction Facilities					50,750
M	Construction Services, Supplies & Expense					71,750
N	Field Staff, Subsistence & Expense					115,500
P	Craft Benefits, Payroll Burdens & Insurance					143,500
Q	Equipment Rental					45,150
	TOTAL FIELD COSTS					426,650
R	Engineering					799,750
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					30,275
T	Construction Management					142,625
	TOTAL OFFICE COSTS					972,650
	TOTAL FIELD & OFFICE COSTS					1,399,300
U	Labor Productivity					
V	Contingency					1,671,012
W	Fee					
	TOTAL CONSTRUCTION COST					14,192,230

DATE 5-29-80 REVISION NO. ______ REVISION DATE ______

* EXCLUDES ACCOUNT 5450 SHOWN SEPARATELY.

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D. O. E. - P. S. O.
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734. 23. 0100
Title CONSTRUCTION COSTS

Computed By W. E. S.
Date 6-8-1980
Checked By [illegible]
Date 6-9 1980

ITEM ACCOUNT NO. 5400	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
RECEIVER SYSTEM								
A - EXCAVATION & CIVIL			8,160		222		13,942	22,102
B - CONCRETE			133,675		40,346		442,145	575,820
C - STRUCTURAL STEEL			* 1,280,726		9,698		133,792	1,414,518
D - BUILDINGS			6,382		201		2,266	8,648
E - MACHINERY & EQUIPMENT			* 6,124,781		22,485		310,359	6,435,140
G - ELECTRICAL			142,402		9,873		119,680	262,082
H - INSTRUMENTS & CONTROLS			* 577,455		1,190		16,666	594,121
J - PAINTING			84		22		250	334
K - INSULATION & LAGGING			* 1,397,798		29,372		411,355	1,809,153
TOTAL ACCOUNT 5400			* 9,671,463		113,409		1,450,455	11,121,918

* MATERIAL $'S INCLUDE SUBCONTRACT $'S.

GN 171B

TABLE 5.3 - 4h

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.
LOCATION NORTHEASTERN STATION
PROJECT 8734

DESCRIPTION ACCOUNT 5410 TOWER

CONT. NO.
MADE BY W.E.S.
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	222	13,942	–	8,160	22,102
B	Concrete	40,346	442,145	–	133,675	575,820
C	Structural Steel	460	5,415	–	25,945	31,360
D	Buildings	201	2,266	–	6,382	8,648
E	Machinery & Equipment	1,995	23,400	–	97,600	121,000
F	Piping					
G	Electrical	9,873	119,680	–	142,402	262,082
H	Instruments					
J	Painting	22	250	–	84	334
K	Insulation					
	DIRECT FIELD COSTS	53,119	607,098	–	414,248	1,021,346
L	Temporary Construction Facilities					50,750
M	Construction Services, Supplies & Expense					71,750
N	Field Staff, Subsistence & Expense					115,500
P	Craft Benefits, Payroll Burdens & Insurance					143,500
Q	Equipment Rental					45,150
	TOTAL FIELD COSTS					426,650
R	Engineering					799,750
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					30,275
T	Construction Management					142,625
	TOTAL OFFICE COSTS					972,650
	TOTAL FIELD & OFFICE COSTS					1,399,300
U	Labor Productivity					
V	Contingency					153,216
W	Fee					
	TOTAL CONSTRUCTION COST					2,573,862

DATE 6-8-80 REVISION NO. ______ REVISION DATE ______

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. – P.S.O.
Plant NORTHEASTERN STATION Unit 1
Project No. 8784 File No. 8784.23.0100
Title CONSTRUCTION COSTS

Computed By W. G. S.
Date 5-16-1980
Checked By [illegible]
Date [illegible] 19 [illegible]

ITEM ACCOUNT NO. 5410	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
TOWER								
A – EXCAVATION & CIVIL								
A1 TOWER FDN. EXCAVATION	282 CY	–	–	.070	20	63.30	1,250	1,250
A2 TOWER FDN. BACKFILL	258 CY	–	–	.035	9	50.00	452	452
A3 ROCK ANCHORS	102 EA	80.00	8,160	1.896	193	63.30	12,240	20,400
A. EXCAV. & CIVIL TOTAL			8,160		222		13,942	22,102
B – CONCRETE								
B1 TOWER FDN. & SLAB	39 CY	85.21	3,323	23.359	911	10.89	9,917	13,240
B2 TOWER STRUCTURE	890 CY	144.45	128,560	43.710	38,902	10.96	426,365	554,925
B3 PLATFORM REINF. SLABS	16 CY	112.00	1,792	33.313	533	11.00	5,863	7,655
B. CONCRETE TOTAL			133,675		40,346		442,145	575,820
C – STRUCTURAL STEEL								
C1 PLATFORM SUPPORTS	3.25 TN	1100	3,575	24.000	78	11.20	874	4,449
C2 GRATING	177 SF	6.00	1,062	.200	35	11.76	416	1,478
C3 HANDRAIL	80 LF	12.00	960	.390	31	12.71	397	1,357
C4 CAGED LADDER	350 LF	55.00	19,250	.850	298	11.76	3,499	22,749
C5 STAIR WITH LANDING	18 LF	61.00	1,098	1.000	18	12.71	229	1,327
C. STRUCTURAL STEEL TOTAL			25,945		460		5,415	31,360

GN 171B

BLACK & VEATCH CONSULTING ENGINEERS

Owner D. O. E. – PSO
Plant NORTHEASTERN STATION Unit
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COSTS

Computed By W. E. S.
Date 5– –19 80
Checked By [illegible]
Date 6-6 19 80
Page 12 of 24

ITEM Account No. 5410	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
RECEIVER SYSTEM D- BUILDINGS								
D1 ROLL-UP STEEL DOOR	140 SF	17.86	2,500	.570	80	12.45	994	3,494
D2 HOLLOW METAL DOORS	2 EA	312.39	625	8.099	16	10.72	174	799
D3 METAL STUD WALL WITH INSUL.								
METAL PANELING	552 SF	5.90	3,257	.190	105	10.47	1,098	4,355
D. BUILDINGS TOTAL			6,382		201		2,266	8,648
E – MACHINERY & EQUIPMENT								
E1 ELEVATOR	1 EA	97,000	97,000	1961	1,961	11.73	23,000	120,000
E2 VENTILATION FANS W/DAMPERS	2 EA	300	600	17.00	34	11.76	400	1,000
E. MACHINERY & EQUIP. TOTAL			97,600		1,995		23,400	121,000

GN 17B

BLACK & VEATCH
CONSULTING ENGINEERS

Owner: D. O. E. – PNO
Plant: NORTHEASTERN STATION Unit: 1
Project No.: 8734 File No.: 8734.23.0100
Title: CONSTRUCTION COSTS

Computed By: W. E. S.
Date: 5- - 1980
Checked By: [illegible]
Date: [illegible] 19[illegible]

ITEM	QUANTITY	MATERIAL		LABOR				TOTAL COST
		UNIT COST	TOTAL MAT'L COST	HRS. PER UNIT	TOTAL HRS.	COST PER HOUR	TOTAL LABOR COST	
ACCOUNT NO. 5410								
RECEIVER SYSTEM								
G – ELECTRICAL								
G1 500 MCM CABLE –								
CIRCUIT NO 3	1,050 LF	3.73	3,917	.116	122	12.12	1,476	5,393
G2 #12 AWG CABLE								
MOV CIRCUITS	16,200 LF	1.06	17,172	.082	1,328	12.12	16,100	33,272
G3 4/0 AWG CABLE								
RECIRC. PUMP CIRCUIT	90 LF	1.65	149	.084	8	12.12	92	241
G4 #12 CABLE								
LIGHTING CIRCUITS	7,000 LF	.57	3,990	.082	574	12.12	6957	10,947
G5 480 V MOTOR CONTROL CENTER	1 EA	16,550	16,550	50.000	50	12.12	606	17,156
G6 480–120/208 TRANSFORMER	1 EA	1,000	1,000	55.000	55	12.12	667	1,667
G7 WALL MTD. LIGHTING & POWER PANEL	1 EA	613	613	40.000	40	12.12	485	1,098
G8 LIGHTING FIXTURES, DEVICE PLATES								
& ETC.	1 LS	800	800	99	99	12.12	1,200	2,000
G9 LIGHTNING PROTECTION	1 LS	9000	9000	495	495	12.12	6000	15,000
G10 FAA OBSTRUCTION LIGHTING	1 LS	59,500	59,500	2,103	2,103	12.12	25,500	85,000
G11 CABLE TRAY	360 LF	8.10	2,916	1.067	384	12.12	4656	7,572
G12 4" RIGID STEEL CONDUIT CIRCUIT NO 3	1,050 LF	6.00	6,300	.625	656	12.12	7,954	14,254
G13 1" RIGID STEEL CONDUIT MOV CIRCUITS	23,290 LF	.88	20,495	.170	3,959	12.12	47,987	68,482
G. ELECTRICAL TOTAL			142,462		9873		119,680	[illegible]

GN 171B

5.13-14c

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D. O. E. - PUO
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COSTS

Computed By W. E. S.
Date 5 - - 1980
Checked By [signature]
Date 6-6 1980
Page 14 of 24

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
ACCOUNT No. 5710								
RECEIVER SYSTEM J - PAINTING								
J1 TOWER EQUIP. ROOM WALLS	836 SF	.10	84	.03	22	11.29	250	334
J. PAINTING TOTAL			84		22		250	334

GN 171B

5.3-14d

	SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
	PLANT COST DATA	SECTION 5.3

TABLE 5.3-4i

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.
NORTHEASTERN
LOCATION STATION - UNIT 1
PROJECT 8734

DESCRIPTION
ACCOUNT 5420
RECEIVER

CONT. NO.
MADE BY W.E.S.
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel	9,238	128,377	36,358	1,218,423	1,383,158
D	Buildings					
E	Machinery & Equipment	20,490	286,959	80,589	5,946,592	6,314,140
F	Piping					
G	Electrical					
H	Instruments	1,190	16,666	4,683	572,772	594,121
J	Painting					
K	Insulation	29,372	411,355	115,600	1,282,198	1,809,153
	DIRECT FIELD COSTS	60,290	843,357	237,230	9,019,985	10,100,572
L	Temporary Construction Facilities					—
M	Construction Services, Supplies & Expense					—
N	Field Staff, Subsistence & Expense					—
P	Craft Benefits, Payroll Burdens & Insurance					—
Q	Equipment Rental					—
	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					
U	Labor Productivity					
V	Contingency					1,517,796
W	Fee					
	TOTAL CONSTRUCTION COST					11,618,368

DATE 6-8-80 REVISION NO. ______ REVISION DATE ______ PAGE NO. 5.3-15

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. – P.S.O.
Plant NORTH EASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COSTS

Computed By W.E.S. Date 6-8-1980
Checked By [illegible] Date 6-9-1980
Page 15 of 24

ITEM ACCOUNT No. 5420	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
RECEIVER C- STRUCTURAL STEEL								
C1 RECEIVER STRUCTURAL STL	1 LS	1,254,781	*1,254,781	7,752	7,752	16.56	128,377	1,383,158
C. STRUCTURAL STEEL TOTAL			*1,254,981		7,752		128,377	1,383,158
E- MACHINERY & EQUIPMENT								
E1 BOILER, MOUNTINGS, & SIDING	1 LS	1,691,700	*1,691,700	13,291	13,291	14.01	186,141	1,877,841
E2 ECONOMIZER	1 EA	95,293	*95,293	665	665	14.01	9,313	104,606
E3 SUPERHEATER & PIPING	1 LS	3,741,679	*3,741,679	6,295	6,295	14.01	88,158	3,829,837
E4 CIRC. PUMP & MOTOR	1 EA	498,509	*498,509	239	239	14.01	3,347	501,856
E. MACHINERY & EQUIP. TOTAL			*6,027,181		20,490		286,959	6,314,140
H- INSTRUMENTS & CONTROLS								
H1 CONTROLS	1 LS	577,455	*577,455	1,190	1,190	14.01	16,666	594,121
H. INSTRUMENTS & CONTROLS TOTAL			*577,455		1,190		16,666	594,121
K- INSULATION								
K1 INSULATION & LAGGING	1 LS	1,397,798	*1,397,798	29,372	29,372	14.01	411,355	1,809,153
K. INSULATION TOTAL			*1,397,798		29,372		411,355	1,809,153
TOTAL ACCOUNT 5420			*9,257,215				843,357	10,100,572

*MATERIAL $'S INCLUDE SUBCONTRACT $'S.

GN 171B

5.13-15a

SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
PLANT COST DATA IN	SECTION 5.3

TABLE 5.3-4J

CONSTRUCTION COST ESTIMATE

CLIENT: D.O.E. - P.S.O.

LOCATION: NORTHEASTERN STATION - UNIT 1

PROJECT: 8734

DESCRIPTION: ACCOUNT 5450 RECEIVER LOOP SYSTEM

CONT. NO.

MADE BY: W. E. S.

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	106	5,847	–	6,182	12,029
B	Concrete	374	4,115	–	3,120	7,235
C	Structural Steel	1,687	18,897	–	72,610	91,507
D	Buildings					
E	Machinery & Equipment					
F	Piping	51,139	628,001	–	756,335	1,384,336
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation	1,476	18,645	–	15,288	33,933
	DIRECT FIELD COSTS	54,782	675,505	–	853,535	1,529,040
L	Temporary Construction Facilities					75,980
M	Construction Services, Supplies & Expense					107,420
N	Field Staff, Subsistence & Expense					172,920
P	Craft Benefits, Payroll Burdens & Insurance					214,840
Q	Equipment Rental					67,596
	TOTAL FIELD COSTS					638,756
R	Engineering					1,197,340
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					45,326
T	Construction Management					213,530
	TOTAL OFFICE COSTS					1,456,196
	TOTAL FIELD & OFFICE COSTS					2,094,952
U	Labor Productivity					
V	Contingency					229,824
W	Fee					
	TOTAL CONSTRUCTION COST					3,853,816

DATE 5-29-80 REVISION NO. ______ REVISION DATE ______ PAGE NO. 5.3-16

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D. O. E. - F. S. O.
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734. 23. 0100
Title CONSTRUCTION COSTS

Computed By W. E. S.
Date 6 - 8 - 1980
Checked By [illegible]
Date 6-9 1980
Page 17 of 24

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
Account No. 5450								
Receiver Loop System								
A - Excavation & Civil			6,182		106		5,847	12,029
B - Concrete			3,120		374		4,115	7,235
C - Structural Steel			72,610		1,687		18,897	91,507
F - Piping			756,335		51,137		628,001	1,384,336
K - Insulation			15,288		1,476		18,645	33,933
Total Account 5450			853,535		54,780		675,505	1,529,040

GN-17B

TABLE 5.3-4k

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. — P.S.O.

LOCATION NORTHEASTERN STATION — UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5451 PIPE SUPPORTS SYSTEM

CONT. NO. ______

MADE BY W.E.J.

APPROVED ______

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil	106	5,847	—	6,182	12,029
B	Concrete	374	4,115	—	3,120	7,235
C	Structural Steel	1,687	18,897	—	72,610	91,507
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	2,167	28,859	—	81,912	110,771
L	Temporary Construction Facilities					5,510
M	Construction Services, Supplies & Expense					7,790
N	Field Staff, Subsistence & Expense					12,540
P	Craft Benefits, Payroll Burdens & Insurance					15,580
Q	Equipment Rental					4,902
	TOTAL FIELD COSTS					46,322
R	Engineering					86,830
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					3,287
T	Construction Management					15,485
	TOTAL OFFICE COSTS					105,602
	TOTAL FIELD & OFFICE COSTS					151,924
U	Labor Productivity					
V	Contingency					16,758
W	Fee					
	TOTAL CONSTRUCTION COST					279,453

SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
PLANT COST DATA	SECTION 5.3

TABLE 5.3-4

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.

LOCATION NORTHEASTERN STATION UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5452 FEEDWATER PIPING SYSTEM

CONT. NO.

MADE BY W.E.S.

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping	14,715	180,700	–	128,400	309,100
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation	310	3,916	–	3,192	7,108
	DIRECT FIELD COSTS	15,025	184,616	–	131,592	316,208
L	Temporary Construction Facilities					15,660
M	Construction Services, Supplies & Expense					22,140
N	Field Staff, Subsistence & Expense					35,640
P	Craft Benefits, Payroll Burdens & Insurance					44,280
Q	Equipment Rental					13,932
	TOTAL FIELD COSTS					131,652
R	Engineering					246,780
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					9,342
T	Construction Management					44,010
	TOTAL OFFICE COSTS					300,132
	TOTAL FIELD & OFFICE COSTS					431,784
U	Labor Productivity					
V	Contingency					47,880
W	Fee					
	TOTAL CONSTRUCTION COST					795,872

DATE 6-8-80 REVISION NO. ____ REVISION DATE ____

	SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
	PLANT COST DATA	SECTION 5.3

TABLE 5.3-4m CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. – P.S.O.

LOCATION NORTHEASTERN STATION – UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5453 MAIN STEAM PIPING SYSTEM

CONT. NO.

MADE BY W.E.S.

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping	23,606	289,889	–	496,193	786,082
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation	848	10,710	–	8,820	19,530
	DIRECT FIELD COSTS	24,454	300,599	–	505,013	805,612
L	Temporary Construction Facilities					40,020
M	Construction Services, Supplies & Expense					56,580
N	Field Staff, Subsistence & Expense					91,080
P	Craft Benefits, Payroll Burdens & Insurance					113,160
Q	Equipment Rental					35,604
	TOTAL FIELD COSTS					336,444
R	Engineering					630,660
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					23,874
T	Construction Management					112,470
	TOTAL OFFICE COSTS					767,004
	TOTAL FIELD & OFFICE COSTS					1,103,448
U	Labor Productivity					
V	Contingency					119,700
W	Fee					
	TOTAL CONSTRUCTION COST					2,028,760

DATE 6-8-80 REVISION NO. ______ REVISION DATE ______ PAGE NO. 5.3-19

Table 5.3-4m

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.
LOCATION Northeastern Station - Unit 1
PROJECT 8734

DESCRIPTION Account 5454 Condensate Piping System

CONT. NO.
MADE BY W. E. S.
APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping	12,816	157,412	–	131,742	289,154
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation	318	4,019	–	3,276	7,295
	DIRECT FIELD COSTS	13,134	161,431	–	135,018	296,449
L	Temporary Construction Facilities					14,790
M	Construction Services, Supplies & Expense					20,910
N	Field Staff, Subsistence & Expense					33,660
P	Craft Benefits, Payroll Burdens & Insurance					41,820
Q	Equipment Rental					13,158
	TOTAL FIELD COSTS					124,338
R	Engineering					233,070
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					8,823
T	Construction Management					41,565
	TOTAL OFFICE COSTS					283,458
	TOTAL FIELD & OFFICE COSTS					407,796
U	Labor Productivity					
V	Contingency					45,486
W	Fee					
	TOTAL CONSTRUCTION COST					749,731

DATE 6-8-80 REVISION NO. ______ REVISION DATE ______

BLACK & VEATCH
CONSULTING ENGINEERS

Owner: D.O.E. – PSO
Plant: Northeastern Station Unit: 1
Project No.: 8734 File No.: 8734.23.0100
Title: Construction Costs

Computed By: W. E. S.
Date: 5-28-1980
Checked By: [illegible]
Date: [illegible] 19 [illegible]
Page 16 of 24

ITEM	QUANTITY	MATERIAL		LABOR				TOTAL COST
Account No. 5451		UNIT COST	TOTAL MAT'L COST	HRS. PER UNIT	TOTAL HRS.	COST PER HOUR	TOTAL LABOR COST	
Receiver Loop System A – Excavation & Civil								
A1 Pipe Supports Excavation	920 CY	—	—	.070	64	63.30	4,077	4,077
A2 1"ϕ Gravel	920 CY	6.72	6,182	.014	13	25.94	334	6,516
A3 Drilled Piers (21"ϕ)	72 EA	—	—	.399	29	50.00	1,436	1,436
A. Excavation & Civil Total			6,182		106		5,847	12,029
B – Concrete								
B1 Pipe Supports (Horizontal)	138 EA	14.13	1,950	2.145	296	11.07	3,278	5,228
B2 Truss Foundations	72 EA	16.25	1,170	1.083	78	10.73	837	2,007
B. Concrete Total			3,120		374		4,115	7,235
C – Structural Steel								
C1 Pipe Support Steel	55.8 TN	1,014.87	56,630	24.00	1,339	11.20	14,999	71,629
C2 Pipe Rollers	174 EA	91.84	15,980	2.100	348	11.20	3,898	19,878
C. Structural Steel Total			72,610		1,687		18,697	91,507

GN 171B

5.3-20a

BLACK & VEATCH
CONSULTING ENGINEERS

Owner: D.O.E - PSO
Plant: Northeastern Sta Unit: 1
Project No. 8734 File No. 8734.23.0100
Title: Construction Costs

Computed By: GLL
Date: 5-20-1980
Checked By: W.E.S.
Date: 5-22-1980
Page 18 of 24

ITEM Account 5453	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
Receiver Loop System F- Piping Main Steam Piping Sys								
F1 Pipe ASTM 335 GR P22-3"φ OD 11.195" IN 8.251"	5039 LF	72	362,800	4.478	22,565	12.28	277,100	639,900
F2 10" Globe Valve ASTM A217 GRWC9 2-1/4 CR	1 EA	36,207	36,207	16	16	12.28	196	36,403
F3 2" Globe Valve ASTM A182 GRF22 2-1/4 CR	3 EA	1,687.75	5,063	4	12	12.28	147	5,210
F4 1" Globe Valve ASTM A182 GRF22 2-1/4 CR	10 EA	332.25	3,323	2	20	12.28	246	3,569
F5 Drain Tanks - Main Steam	2 EA	35,000	70,000	285	570	12.28	7,000	77,000
F6 Drain Pumps - M.S. 50 gpm @ 100' H	2 EA	6000	12,000		Incl			12,[illegible]
F7 Misc. Piping ASTM A335 GRP22 2 1/4 CR	100 LF	68	6800	4.235	423	12.28	5200	12,000
Account 5453 Total			496,193		23,606		289,889	786,082
Account 5452 Feedwater Piping Sys								
F1 6" Pipe ASTM 106B Sch XXS	4387 LF	29	127,200	3.34	14,650	12.28	179,900	307,100
F2 Chemical Feed Equipment	1 LS	1,200	1,200	65.147	65	12.28	800	2,000
Account 5452 Total			128,400		14,715		180,700	309,100
Account 5454 Condensate Piping Sys								
F1 3" Pipe ASTM A106 GRB Sch 40	4500 LF	11	49,500	2.61	11,726	12.28	144,000	193,500
F2 Solar Receiver Blowdown Tank	1 EA	62,000	62,000	407	407	12.28	5,000	67,000
F3 Condensate Ret Pump 175 gpm 100' H	1 EA	7000	7000	163	163	12.28	2,000	9000

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BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. -PSO
Plant Northeastern Sta. Unit 1
Project No. 8734 File No. 8734.23.0100
Title Construction Costs

Computed By GLL
Date 5-20-1980
Checked By W.E.S.
Date 5-22-1980

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
F4 4" Globe Valves	3 EA	2,241	6,723	6	18	12.28	221	6,944
ASTM A216 GR WCB CS-150								
F5 Misc Piping	150 LF	4.67	700	3.09	464	12.28	5700	6400
2" Pipe - CS								
ASTM A106B								
F6 Misc Valves	10 EA	581.94	5,819	4.00	40	12.28	491	6,310
2" Gate Valves								
CS								
ACCOUNT 5454 TOTAL			131,742		12,816		157,412	289,154

NOTE: ACCOUNT 5452 ALSO INCLUDES 1 - 6" MOTOR OPERATED GATE VALVE (A216, GRADE WCB, CLASS 2500, C/S) WHICH WAS ADDED AFTER THE ESTIMATE WAS COMPLETED. ITS INSTALLED COST OF $8,200 IS INCLUDED IN THE CONTINGENCY.

P-GN 171B

BLACK & VEATCH CONSULTING ENGINEERS

Owner D.O.E. - PSO
Plant Northeastern Sta Unit 1
Project No. 8734 File No. 8734.23.0100
Title Construction Costs Insulation

Computed By GLL Date 5-23 1980
Checked By [initials] Date 6-9 1980
Page 20 of 24

ITEM Account 5450	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
K - Insulation								
Account 5453 Total								
K1 Thermal insul	2520 SF	3.50	8820	.34	848	12.63	10,710	19,530
& jacketing - 6"								
5039' ASTM A335 Gr P22								
Main Steam Piping								
Account 5452 Total								
K2 Insulation -	912 SF	3.50	3192	.34	310	12.63	3916	7108
2 1/2" - 4387 LF								
ASTM A106 B								
Feedwater Piping								
Account 5454 Total								
K3 Insulation -	936 LF	3.50	3276	.34	318	12.63	4019	7295
2 1/2" - 4500 LF								
ASTM A106								
Account 5450 K. Insulation Total			15,288		1,476		18,645	33,933

P-GN 171B

5.3-20d

	SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
	PLANT COST DATA	SECTION 5.3

TABLE 5.3-40

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.
LOCATION NORTHEASTERN STATION - UNIT 1
PROJECT 8734

DESCRIPTION ACCOUNT 5500 MASTER CONTROL SYSTEM

CONT. NO. ____
MADE BY W.G.S.
APPROVED ____

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping					
G	Electrical	2,635	31,928	—	147,548	179,476
H	Instruments	10,531	127,640	—	2,004,000	2,131,640
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	13,166	159,568	—	2,151,548	2,311,116
L	Temporary Construction Facilities					114,550
M	Construction Services, Supplies & Expense					161,950
N	Field Staff, Subsistence & Expense					260,700
P	Craft Benefits, Payroll Burdens & Insurance					323,900
Q	Equipment Rental					101,910
	TOTAL FIELD COSTS					963,010
R	Engineering					1,805,150
	Design & Engineering					
	Home Office Costs					
	R & D					
						68,335
S	Major Equipment Procurement					
						321,925
T	Construction Management					
	TOTAL OFFICE COSTS					2,195,410
	TOTAL FIELD & OFFICE COSTS					3,158,420
U	Labor Productivity					
						347,130
V	Contingency					
W	Fee					
	TOTAL CONSTRUCTION COST					5,816,666

DATE 5-29-80 REVISION NO. ____ REVISION DATE ____

BLACK & VEATCH
CONSULTING ENGINEERS

Owner: D. O. E. - PSO
Plant: NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734. 23. 0100
Title: CONSTRUCTION COSTS

Computed By: W. E. J.
Date ______ 19 ____
Checked By: CBB
Date: 6-9 1980

ITEM ACCOUNT NO. 5500	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
MASTER CONTROL SYSTEM G - ELECTRICAL								
G1 125 V DC BATTERY & FUSE	1 EA	21,000	21,000	15.00	15	12.12	182	21,182
G2 125 V DC PANEL	1 EA	6,580	6,580	18.00	18	12.12	218	6,798
G3 37.5 KVA REGULATING TRANSF.	1 EA	1,158	1,158	39.25	39	12.12	476	1,634
G4 125 V DC BATTERY CHARGER	2 EA	12,800	25,600	15.00	30	12.12	364	25,964
G5 120 V AC UNINTERRUPTIBLE								
POWER PANEL	1 EA	70,000	70,000	105.00	105	12.12	1,273	71,273
G6 #10 - 2 CONDUCTOR COPPER								
CABLE - UPS TO MULTIPLEXER								
IN TOWER	5,000 LF	.67	3,350	.027	135	12.12	1,636	4,986
G7 2" RIGID STEEL CONDUIT -								
UPS TO MULTIPLEXER IN TOWER	5,000 LF	1.90	9,500	.225	1,125	12.12	13,635	23,135
G8 #10 - 2 CONDUCTOR COPPER								
CABLE - UPS TO COMPUTER IN								
POWER PLANT	1,500 LF	.67	1,005	.027	41	12.12	491	1,496
G9 1" RIGID STEEL CONDUIT -								
UPS TO COMPUTER IN POWER								
PLANT	1,500 LF	.88	1,320	.170	255	12.12	3,091	4,411
G10 4/0 AWG CABLE - BATTERY								
CHARGERS STANDBY SOURCE								
IN POWER PLANT	2,000 LF	1.65	3,300	.084	168	12.12	2,036	5,336
G11 3" RIGID STEEL CONDUIT -								
BATTERY CHARGERS STANDBY								
SOURCE IN POWER PLANT	700 LF	4.00	2,800	.750	525	12.12	6,363	9,163
G12 350 MCM 1 CONDUCTOR COPPER								
CABLE - DC PANEL TO INVERTER	500 LF	2.67	1,335	.107	54	12.12	648	1,983

GN 171B

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. — PSO
Plant NORTHEASTERN STATION Unit 1
Project No. 8734 File No. 8734.23.0100
Title CONSTRUCTION COSTS

Computed By W.E.V.
Date 19
Checked By
Date 19
Page 22 of 24

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
ACCOUNT NO. 5500 CONT'D								
MASTER CONTROL SYSTEM								
G13 4" RIGID STEEL CONDUIT -								
DC PANEL TO INVERTER	100 LF	6.00	600	1.250	125	12.12	1,515	2,115
G. ELECTRICAL TOTAL			147,548		2635		31,928	179,476

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5.3-216

BLACK & VEATCH
CONSULTING ENGINEERS

Owner D.O.E. - PSO
Plant Northeastern Sta. Unit 1
Project No. 8734 File No. 8734.23.0100
Title Cable - Master Control System

Computed By GLL
Date 5-21-1980
Checked By [illegible]
Date 6-7 1980

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
Account 5500								
Master Control System								
H Instruments & Controls								
H1 - Cable 10 C	4000 LF	1.957	7800	.061	244	12.12	2,957	10,757
H2 - Cable 10 C	1000 LF	↓	2000	.061	61	12.12	739	2739
H3 - Cable 2C	20,000 LF	.472	9500	.014	280	12.12	3394	12,894
H4 - Cable 2C	75,000 LF	.472	35,500	.014	1050	12.12	12,726	48,226
H5 - Cable 10C	100 LF	1.957	200	.061	6	12.12	74	274
H6 - 2" Rigid Steel Conduit	10,000 LF	1.90	19,000	.225	2250	12.12	27,270	46,270
H7 12" Dia Core Drilling for 8" Slab	6 EA	—	—	6.6	40	12.12	480	480
H8 Control Panel and Computer Equipment	1 LS	—	1,930,000*	6,600	6,600	12.12	80,000	2,010,000
H. Instruments & Controls Total			2,004,000		10,531		127,640	2,131,640

* Includes $40,000 for Start-up Engineering by Controls Sub-contractor.

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5.3-21C

	SYSTEM REQUIREMENTS SPECIFICATION	FILE NO. 8734.23.0100
	PLANT COST DATA	SECTION 5.3

TABLE 5.3-4p

CONSTRUCTION COST ESTIMATE

CLIENT D.O.E. - P.S.O.

LOCATION NORTHEASTERN STATION - UNIT 1

PROJECT 8734

DESCRIPTION ACCOUNT 5600 FOSSIL ENERGY SYSTEM

CONT. NO.

MADE BY W. E. S.

APPROVED

A/C NO.	ITEM & DESCRIPTION	MAN HOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping	69	786	—	51,187	51,973
G	Electrical					
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS	69	786	—	51,187	51,973
L	Temporary Construction Facilities					2,610
M	Construction Services, Supplies & Expense					3,690
N	Field Staff, Subsistence & Expense					5,940
P	Craft Benefits, Payroll Burdens & Insurance					7,380
Q	Equipment Rental					2,322
	TOTAL FIELD COSTS					21,942
R	Engineering					41,130
	Design & Engineering					
	Home Office Costs					
	R & D					
S	Major Equipment Procurement					1,557
T	Construction Management					7,335
	TOTAL OFFICE COSTS					50,022
	TOTAL FIELD & OFFICE COSTS					71,964
U	Labor Productivity					
V	Contingency					7,182
W	Fee					
	TOTAL CONSTRUCTION COST					131,119

DATE 5-29-80 REVISION NO. ____ REVISION DATE ____

BLACK & VEATCH
CONSULTING ENGINEERS

Owner: D. O. E. - PSO
Plant: NORTHEASTERN STATION Unit: 1
Project No. 8734 File No. 8734.23.0100
Title: CONSTRUCTION COST

Computed By: W. E. S.
Date: 5-28-1980
Checked By: CAB
Date: 6-6 1980
Page 24 of 24

ITEM	QUANTITY	MATERIAL UNIT COST	MATERIAL TOTAL MAT'L COST	LABOR HRS. PER UNIT	LABOR TOTAL HRS.	LABOR COST PER HOUR	LABOR TOTAL LABOR COST	TOTAL COST
ACCOUNT No. 5600								
FOSSIL ENERGY SYSTEM F - PIPING								
F1 12" STOP-CHECK VALVE	1 EA	51,187	51,187	64	64	12.28	786	51,973
F. PIPING TOTAL			51,187		64		786	51,973

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5.3.22a

(9) 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-E-Machinery & Equipment (total installed heliostat costs figured at $260/M^2$).

(b) Account 5420 - Codes C, E, H, K - Babcock & Wilcox receiver contract is all-inclusive.

(10) Distributable and indirect costs are spread by account as a function of the direct field costs in all but two cases. The exceptions are Accounts 5310 - Heliostats and 5420 - Receiver, where pricing is all-inclusive due to contract or DOE input information. No additional distributable dollars are spent against these items.

(11) 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. Contingency allowance has not been included on the installed heliostat cost.

5.3.2.2 Methdology. 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 in Table 5.3-5. A detailed description of the operations and maintenance cost is shown on Table 5.3-6.

TABLE 5.3-5. OPERATIONS AND MAINTENANCE COST SUMMARY

OM100 Operations	$ 127,290
OM200 Maintenance Materials	55,130
OM300 Maintenance Labor	61,300
Annual Total Operations and Maintenance Cost Estimate	$ 243,720

TABLE 5.3-6. ANNUAL OPERATIONS AND MAINTENANCE COSTS[1]

	Cost $/yr
OM100 Operations	
OM110 Personnel	
Roving Control Room Operator(s) (.5 men)	9,130
Roving Plant Operator(s) (2 men)	32,560
Total	41,690
OM120 Operating Consumables	
Nitrogen (60,000 Scf/yr)[2]	81,000
Makeup Water (4,000,000 lbm/yr)[3]	600
Water Treatment Chemicals (phosphates, hydrazine)	4,000
Total	85,600
OM130 Fixed Charge Rate	____
OM100 Total	127,290
OM200 Maintenance Materials	
OM210 Spare Parts	
OM211 Site	
None	
OM212 Site Facilities	
No change from existing facilities	
OM213 Collector System[4]	
Reflective units	13,600
Drives	5,000
Motors	4,400
Control Electronics	2,500
Total	25,500
OM214 Receiver System	
Boiler Tubes	750
Superheater Tubes	1,500
Economizer Tubes	200
Valves	5,000

TABLE 5.3-6 (Continued). ANNUAL OPERATIONS AND MAINTENANCE COSTS[1]

	Cost $/yr
Pumps	4,000
Elevator and Crane	500
Aircraft Warning Lights	600
Gasket	500
Total	13,050
OM215 Receiver Loop System	
Controls and Sensors	500
Pumps	750
Valves	3,000
Total	4,250
OM216 Fossil Energy System	
(No change from existing facilities)	
OM217 Master Control System	
Computer Main Frame	2,000
Moving Head Disc	400
Printer	600
Total	3,000
OM218 Specialized Equipment	
Heliostat Washing Equipment	500
Maintenance Vehicle	400
Total	900
OM220 Materials for Repairs	1,000
(Materials presently in use at plant, e.g., welding rods, paint, lubricants, etc.)	
OM230 Other	
Heliostat Washing Solution (82,000 gal/yr)[5]	2,000
Heliostat Rinsing Solution (190,000 gal/yr)[5]	230

TABLE 5.3-6 (Continued). ANNUAL OPERATIONS AND MAINTENANCE COSTS[1]

	Cost $/yr
Pyromark Receiver Paint (15 gal/yr)	900
Maintenance Vehicle Fuel (800 gal/yr)	1,000
Heliostat Washing Vehicle Fuel (2,700 gal/yr)	3,300
Total	7,430
OM200 Total	55,130
OM300 Maintenance Labor	
OM310 Scheduled Maintenance Labor	
OM311 Site	
Mowing of Heliostat Field Area (180 man-hours/yr)[6]	1,350
OM312 Site Facilities	
Normal facility upkeep (painting, etc.)	5,000
OM313 Collector System	
Inspection (752 man-hours/yr)[7]	6,730
Cleaning (2,700 man-hours/yr)[8]	24,190
Total	30,920
OM314 Receiver System	
Annual Inspection of drums, tubes, etc. (160 man-hours/yr)	1,430
Valve Packing (120 man-hours/yr)	1,080
Pump Maintenance (32 man-hours/yr)	290
Absorptive Surface Painting (120 man-hours/yr)	1,270
Controls Recalibration (32 man-hours/yr)	290
Total	4,360
OM315 Receiver Loop System	
Loop Inspection (24 man-hours/yr)	220
Valve Packing and Inspection (32 man-hours/yr)	290

TABLE 5.3-6 (Continued). ANNUAL OPERATIONS AND MAINTENANCE COSTS[1]

	Cost $/yr
Pump Maintenance (16 man-hours/yr)	150
Controls Recalibration (8 man-hours/yr)	80
Total	740
OM316 Fossil Energy System	
No changes from existing system	
OM317 Master Control System	
Routine servicing (25 man-hours/yr)	230
OM320 Correctve Maintenance Labor	
OM321 Site	
Minimal	
OM322 Site Facilities	
Minimal	
OM323 Collector System	
Repairs (1,535 man-hours/yr)	13,780
OM324 Receiver System	
Repairs (250 man-hours/yr)	2,240
OM325 Receiver Loop System	
Repairs (100 man-hours/yr)	890
OM326 Fossil Energy System	
No change from existing system	
OM327 Master Control System	
Repairs (200 man-hours/yr)	1,790
OM300 Total	61,300
OM Total (Per Year)	243,720

[1]Materials, supplies and labor costs exclude G&A and Overhead.

[2]Nitrogen blanket applied when receiver pressure drops below 16 psia following shutdown, as in the case of extremely cold winter temperatures or extended cloud coverage. Volume of nitrogen per application is 1,200 scf; 50 applications per year are assumed.

TABLE 5.3-6 (Continued). ANNUAL OPERATIONS AND MAINTENANCE COSTS[1]

[3]Makeup is 1 per cent of total receiver steam flow.

[4]Estimates based upon engineering judgment and general discussions with Sandia Livermore personnel.

[5]Based on 12 washings per year, 3 gallons of washing solution and 7 gallons of rinsing solution (deionized water) per heliostat.

[6]Three mowings per year.

[7]Two inspections per year, 5 minutes per heliostat, two men.

[8]Three minutes per wash, 12 washes per year, two men.

5.4 ECONOMIC DATA

The basis for the economic evaluation is described as follows.

5.4.1 Economic Evaluation Assumptions

The economic evaluation involves determining the economic value of the repowered unit to PSO in the context of the PSO 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 by PSO for system generation additions during the period after 1985 for the system with and without the repowered unit.

(2) System simulation codes were to model the expansion plans and determine the annual productions (fuel and O&M) costs based on PSO projected fuel costs.

(3) Annual production costs are combined with PSO projected capital costs of the two expansion plans and, using PSO financial factors, a cumulator comparative cost was calculated.

(4) Steps 2 and 3 are repeated for DOE projected fuel and capital costs.

(5) Steps 2 and 3 are repeated for a variation in solar power level using PSO projected costs.

(6) Examination of comparative costs for the different expansions plans allows the calculation of the value to the PSO system of the repowered unit.

Table 5.4-1 shows the financial factors and the values of fuel and capital cost used by PSO for their projections. Operating and maintenance costs (O&M) (as shown in Section 5.3) for the repowered unit were developed jointly by Black & Veatch and PSO. Black & Veatch determined the components of the O&M cost while PSO provided the regional adjustments for labor and material rates.

TABLE 5.4-1. ECONOMIC EVALUATION PARAMETERS (PSO VALUES)

Financial Factors		Per Cent
Discount rate		13.0*
Investment tax credit		10.0
AFUDC rate		10.5
Property tax rate		2.0
General inflation rate		7.0
Combined state and federal income tax rate		50.0
Fuel Cost Projections		
Fuel	1980 Cost $/MBtu	Escalation Rate per cent
Natural gas	2.80	8
Coal	1.41	8
Lignite	0.99	8
Nuclear fuel	***	***
Unit Capital Cost Projections		
Unit Type	1980 Capital Cost $/kW	Escalation Rate per cent
Nuclear	861	7
Coal	589	7
Lignite	621	7
Combined cycle (oil)	N/A	N/A
Combustion turbine (oil)	N/A	N/A

*Capital structure of 57 per cent debt with a return of 11.5 per cent; return on equity 15.0 per cent.

**Compounded semiannually.

***Varies over first years (actual costs).

1987--$1.41.

1988--$1.29.

1989--$1.17 and escalated at 8 per cent.

5.4.2 Alternate Fuel Cost Assumptions

Table 5.4-2 shows the financial factors and fuel and capital cost values provided by DOE.*

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*Solar Repowering/Industrial Retrofit Technical Information Memo Number 6; January 18, 1980.

TABLE 5.4-2. ECONOMIC EVALUATION PARAMETERS (DOE VALUES)

Fuel Cost Projections	1980 $/MBtu	Escalation Rate-Per Cent
Oil	4.00	12
Natural Gas	2.50	11
Coal	1.25	10
Nuclear Fuel	0.85	9

Unit Capital Cost Projections	Capital Cost 1980 ($/kW)	Escalation Rate-Per Cent*
Unit type		
Nuclear	1,000	8.0
Coal	860	8.0
Combined cycle (oil)	360	8.0
Combustion turbine (oil)	190	8.0

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*Assumed equal to DOE supplied General Inflation Rate of 8.0 per cent per year.

5.5 SIMULATION MODELS

The following describes the mathematical and computer models that were used to obtain performance predictions and economic evaluations.

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

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

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 in 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).

5.5.2 Plant Performance Models

Predictions of annual system performance were made using the Black & Veatch computer code, Solar Thermal Electric Plant Performance Evaluator

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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 5.5-1. INSOLATION MODEL PARAMETERS

Date	A (Btuh/Sq Ft)	B (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

(STEPPE). Runs of STEPPE were utilized to estimate monthly and annual steam production by the solar system; these steam production data were subsequently used in PROCOST, a PSO economic dispatch computer code. STEPPE results were also used to establish annual average system efficiency and fuel displacement.

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 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 a function of input power and dry bulb temperature as provided by B&W.

(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. power generated; 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 Tulsa, Oklahoma. Dry bulb temperature was modeled artifically using normal monthly data for daily low, high, and average temperature.[1]

5.5.3 Economic Models

The economic evaluation of the solar repowered facility was performed by explicitly comparing the economic performance of the PSO system with and without the solar repowered unit.

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

The economic comparison was performed in several steps.

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

(2) PSO's system simulation code, a specially developed version of pre-cost, was used to develop the annual system production costs for the alternate expansion plans.

(3) The production costs were combined with the capital cost requirements of the two expansion plans to developed comparative discounted power costs. This method allows the explicit inclusion of capacity credits in the economic evaluation.

(4) Comparison of the power costs 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 recalculated based on values provided by DOE.

5.5.3.1 System Expansion Plans. Without the repowering option, PSO's Northeastern Station 1 would be retired in December, 1994. The unit lifetime, with repowering, will extend through 1999. The additional life impacts the future capacity difference schedule.

5.5.3.2 Annual Production Costs. Power production costs were estimated through the use of a computerized mathematical model, a specially developed version of PROCOS that simulates PSO system operation. The production costs include fuel costs, operating and maintenance (O&M) costs, and power purchase costs. The PROCOS computer program is the basic tool used by PSO 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

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

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 mathematicaly 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. The PROCOS 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.

(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.

(c) Specific 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 PSO system production costs with solar repowering 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 repowered unit requires special modelling 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, an equivalent hours at full solar power was calculated for each month of the year. This discrete representation of the solar unit was combined with the daily load variations by limiting the available hours of solar operation against the system peak load. This simplifying assumption was possible due to the flat natture of the PSO daily load pattern during the periods of peak solar insolation.

Following the loading refinement to the point that the amount of solar capacity available in each load period is accurately represented, the only remaining task in modeling the solar repowered facility was to modify the heat rate curve to reflect the solar input into the thermal unit. Actually, it is not the heat rate curve that is modified but the fuel burn or input-output curve. This curve is, of course, related to the heat rate curve. 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.

The heat rate adjustment was accomplished by modeling Northeast Station 1 as a hybrid unit. For periods of full equivalent solar hours, the heat rate of the hybrid unit was adjusted to 57.14 per cent of the fossil fired heat rate. For time periods when the solar systems were not available, the normal fossil fired heat rate was used.

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 PSO discounted revenue requirement code. The code works by calculating total annual revenue requirements--fixed costs of capital plus production costs. The cumulative present worth sum of these annual costs is levelized by use of the annual factor (capital recovery factor).

The equation form is shown below.

$$ALRR = \frac{\sum^{I} [(FC)_i + (AP)_i] [1+d]^{-i}}{CFR}$$

where

ALRR = annual levelized revenue requirements

$(FC)_i$ = fixed capital costs in year i

$(AP)_i$ = annual production costs in year i

d = discount rate

CRF = Capital recovery factor

and

$$CRF = \frac{1.0 - (1+d)^{-I}}{d}$$

5.6 GENERAL DATA

5.6.1 Plant Availability Data

(1) Solar Receiver Availability. The availability of the solar receiver and its associated components (tower, fluid circulation pumps, etc.) is expected to be higher than that of a conventional fossil-fired steam generator. This is a result of several factors. The exposed configuration of the receiver permits daily visual examination of the heat transfer surfaces and thus, potential failures may be detected before they cause a forced outage. The diurnal shutdown of the solar receiver also permits preventive maintenance and corrective repairs to be effected without diminishing availability. Babcock & Wilcox estimates a conservative availability for the receiver of 96 per cent. Calculations for previous solar receivers have yielded availabilities in excess of 99 per cent.

(2) Heliostat Availability. The average failure rate of 2,255 heliostats of the solar repowered plant has been calculated to be approximately one failure every 8 hours of operation. However, the failure of a single heliostat does not result in a forced outage of the entire field of heliostats, and thus does not affect plant availability. It is estimated that 20 per cent (451) of the heliostats must be inoperative at any given time for a forced outage to result. The probability that 451 heliostats would be inoperative at any one time due to electrical/mechanical failures of individual heliostats is essentially zero. Thus, the availability of the field of heliostats is essentially equivalent to the availability of the heliostat master controller: better than 99.5 per cent.

(3) Receiver Loop Availability. The Receiver Loop System transports the feedwater to the solar receiver and returns the steam to the plant exiting the receiver. The receiver loop is afforded high availability by the same factors influencing receiver availability: daily inspection is possible and diurnal shutdown permits

maintenance without affecting availability. The receiver loop is calculated to have an availability in excess of 99.9 per cent.

(4) Solar Repowered Plant Availability. The anticipated availability of the solar portion of the repowered plant is the product of the operational probabilities of its constituents: the solar receiver (>96 per cent), the heliostats (>99.5 per cent), and the fluid circulation loop (>99.9 per cent). The resulting anticipated availability of the solar repowered plant is in excess of 95 per cent. Thus, the solar repowered plant is expected to have an availability significantly above the threshold value of usefulness to the Public Service Company of Oklahoma.

5.6.2 Specialized Equipment Data

(1) Solar Receiver Equipment.

(a) Personnel Access. Access to the electrical equipment room near the top of the receiver support tower is provided by an elevator within the tower interior. Because of space limitations, the elevator is a small, light-duty elevator for personnel and light equipment transport. The elevator platform is approximately 1.0 m by 1.9 m (3'-4" by 6'-4"), with capacity for 1,000 kg (2,200 lb). A caged ladder, within the tower interior, also provides personnel access from grade to the electrical equipment room, providing a backup to the elevator. From this electrical equipment room to the solar receiver atop the tower, access is provided by a stairway.

(b) Chain Hoist. Small equipment and components are lifted from the electrical room to the receiver elevation above the tower interior by a chain hoist, supported from the receiver support structural steel. This hoist will be employed to lift repair equipment and replacement parts or components, weighing no more than 1,000 kg (2,200 lb) (elevator capacity) needed at the receiver elevation; replacement boiler tubes and superheater panels will not be handled by this hoist but by the polar crane. During construction, a temporary derrick will be used to lift major structural and equipment components of the receiver to the top of the tower.

(c) Polar Crane. A polar crane with a lifting capacity of 9,000 kg (10 tons) mounted atop the solar receiver will be used to lift replacement boiler tubes and superheater panels to the receiver. The polar crane telescopes radially so that it can be withdrawn to be within the outer diameter of the receiver, avoiding exposure to spillage or misdirected solar energy. The polar crane rotates on rails about the vertical axis of the receiver for a full 360 degrees, providing full access to all superheater panels and boiler tubes of the receiver. Equipped with a scaffold, the polar crane will permit close inspection of the solar receiver's surface and, when required, resurfacing of the receiver's high-aborptivity coating.

(2) Heliostat Equipment.

(a) Heliostat Washing Vehicle. The periodic cleansing of the heliostats will require the use of the heliostat washing vehicle. This vehicle consists of a truck-mounted, self-contained, high-pressure spray system. The vehicle carries tanks of detergent solution and rinse solution and washes the heliostats via vertical spray arms equipped with multiple spray nozzles. The washing vehicle may collect the wash and rinse water runoff via collection troughs along the side of the vehicle.

(b) Motorized Elevated Platform. The maintenance and inspection of the drive heliostat drive mechanism will require the use of a motorized elevated platform. This vehicle consists of an elevating work platform mounted on a motorized chassis. The speed and direction of the vehicle is controlled from the platform. This vehicle will facilitate personnel access to the heliostats' drive mechanisms which are some 15 feet above ground level.

(c) Heliostat Replacement Equipment. The replacement of damaged components or the replacement of an entire heliostat will require the use of component slings and cradles, alignment tools, and the services of a forklift or mobile crane (non-specialized equipment). The component slings and cradles facilitate the handling and lifting of the heliostat components by the forklift or crane without damage to the components. These will be supplied by the heliostat manufacturer for the initial installation. The alignment tools, specific to make of heliostat, will be employed to properly re-aim the repaired/replaced heliostat such that its image is properly directed onto the receiver. These alignment tools, too, will be supplied by the heliostat manufacturer for the initial installation.

APPENDIX B

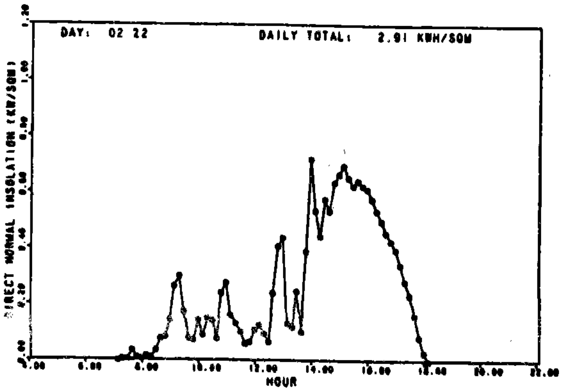
DAILY INSOLATION PROFILES

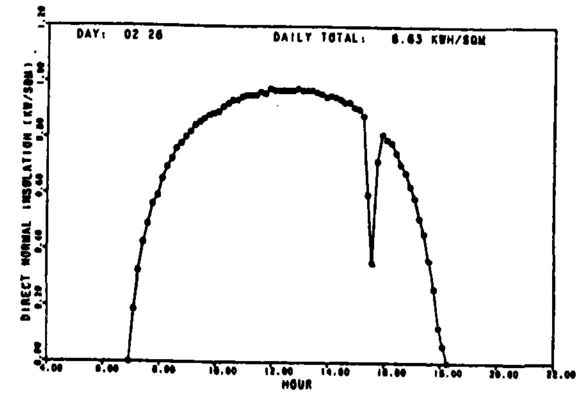
APPENDIX B
DAILY INSOLATION PROFILES

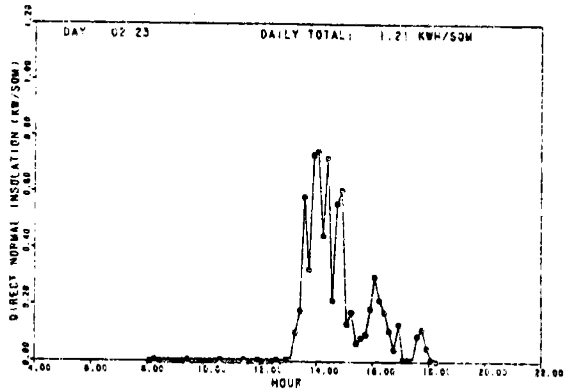
The following daily profiles of direct normal insolation were collected at Oologah, Oklahoma as part of the solar repowering project test program. The profiles are presented as plots of the average insolation occurring over 10-minute intervals; the data points are indicated in the profiles. The total direct normal insolation incident over the day is shown in the top right corner of each profile.

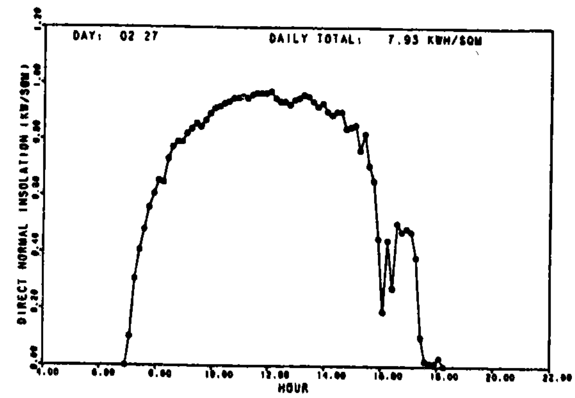
The profiles are shown in chronological order for the period beginning February 22 and ending April 27. Each page begins with the earliest profile at the top left corner of a page, proceeding down the left column first and then down the right column, and ending with the latest profile on the page at the bottom right corner. The data collection date for each profile is shown in the top left corner of the profile. Omitted are profiles for days where, because of equipment malfunctions or power failures, data were not collected.

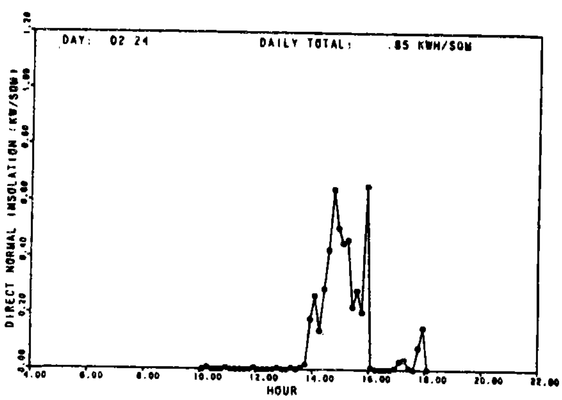
Two insolation profiles for June 7, 1980 are presented at the end of the listing; they show the difference in the pattern of direct insolation when it is averaged over 1-minute and 10-minute time intervals as recorded on the normal incidence pyrheliometer. The flux on the receiver would not have the extreme fluctuations that the insolation has; it would be smoothed by the spatial averaging associated with performance of the 510,000m^2 (120 acre) heliostat field.

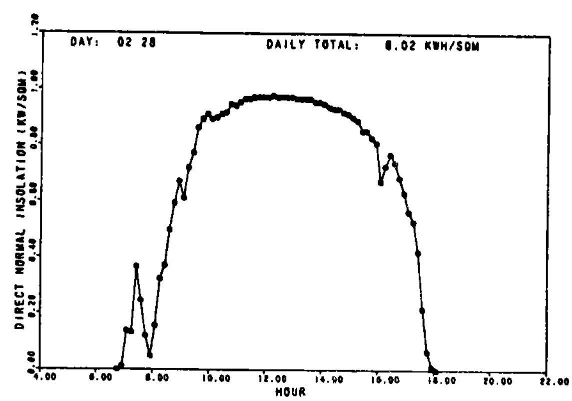

DAY: 02 22
DAILY TOTAL: 2.91 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

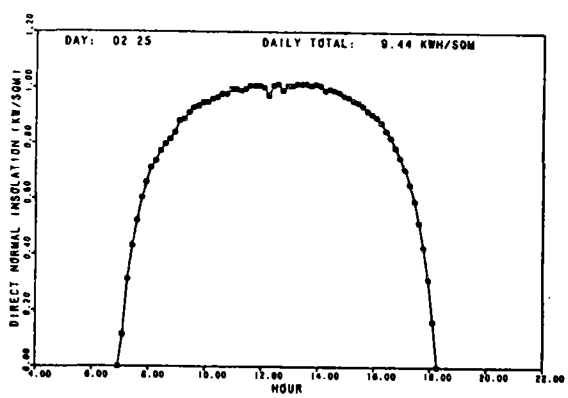

DAY: 02 26
DAILY TOTAL: 8.63 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

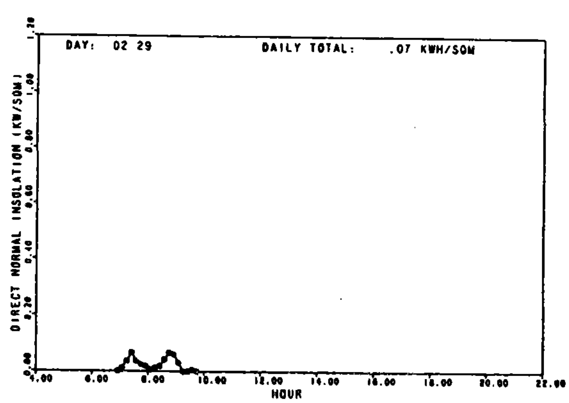

DAILY TOTAL: 1.21 KWH/SQM
HOUR

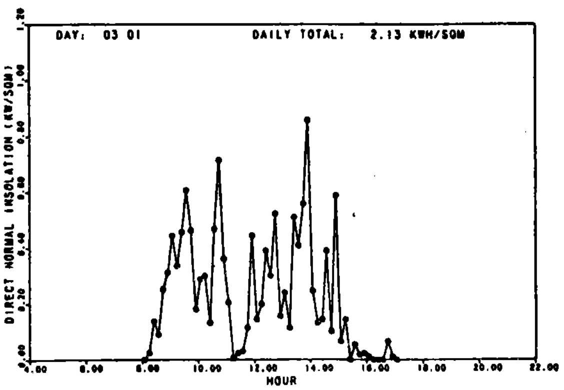

DAY: 02 27
DAILY TOTAL: 7.95 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

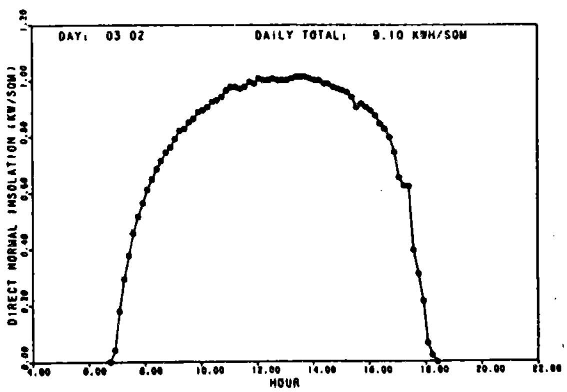

DAY: 02 24
DAILY TOTAL: .85 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

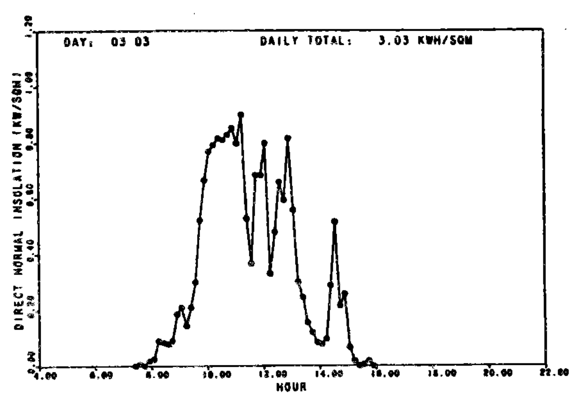

DAY: 02 28
DAILY TOTAL: 8.02 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

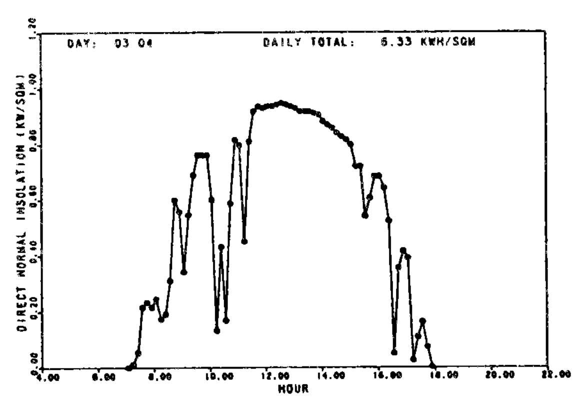

DAY: 02 25
DAILY TOTAL: 9.44 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

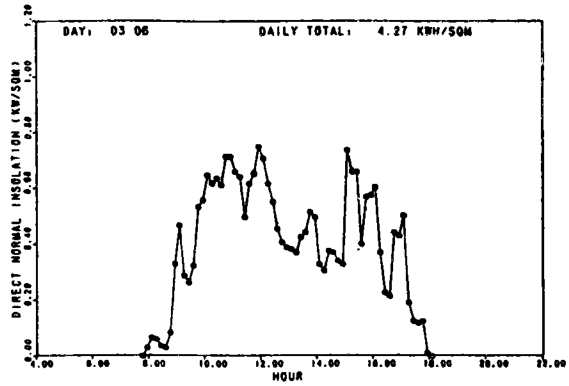

DAY: 02 29
DAILY TOTAL: .07 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

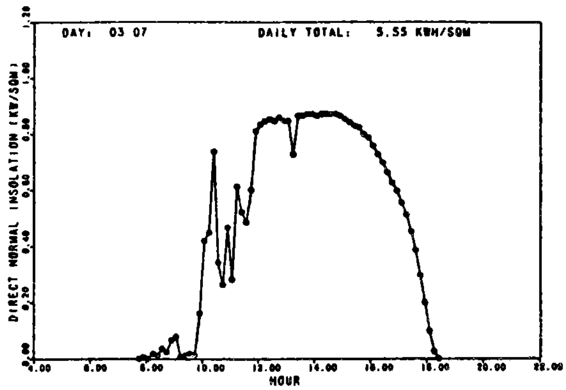

DAY: 03 01
DAILY TOTAL: 2.13 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

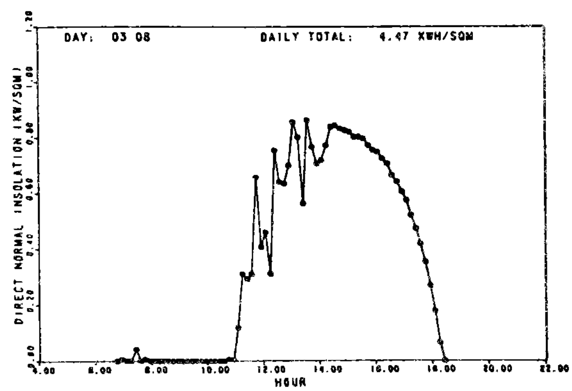

DAY: 03 02
DAILY TOTAL: 9.10 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

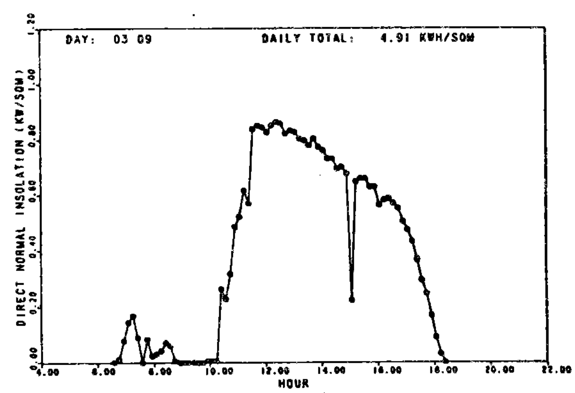

DAY: 03 03
DAILY TOTAL: 3.03 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

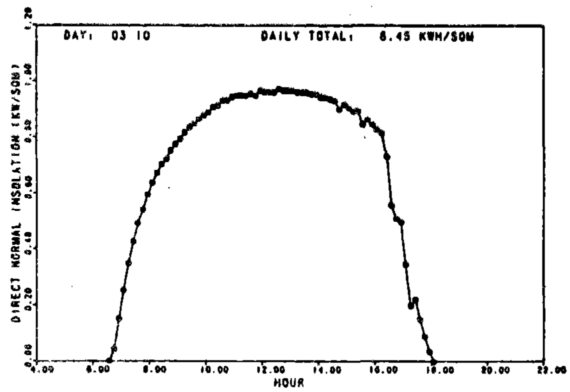

DAY: 03 04
DAILY TOTAL: 6.33 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

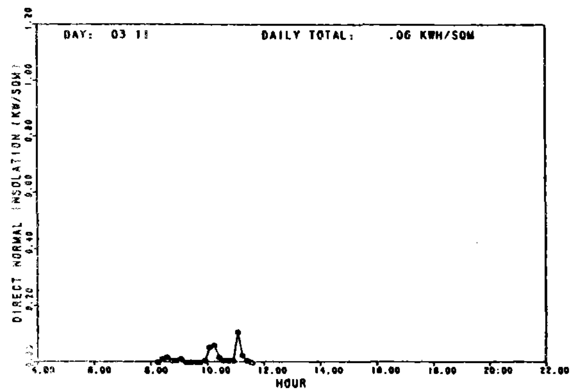

DAY: 03 06
DAILY TOTAL: 4.27 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

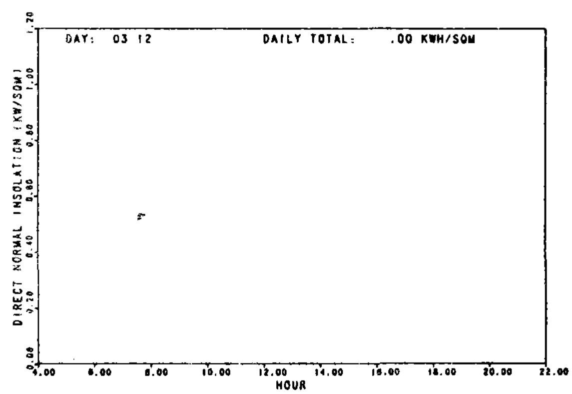

DAY: 03 07
DAILY TOTAL: 5.55 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

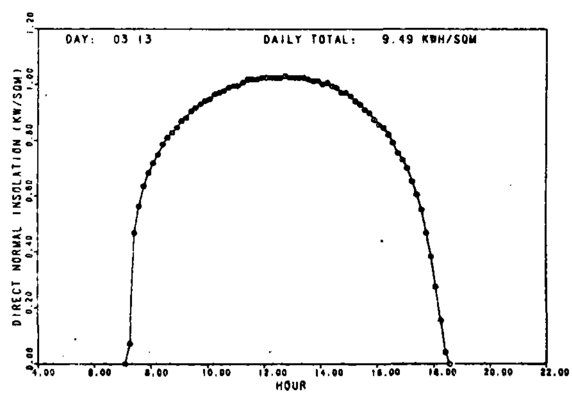

DAY: 03 08
DAILY TOTAL: 4.47 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

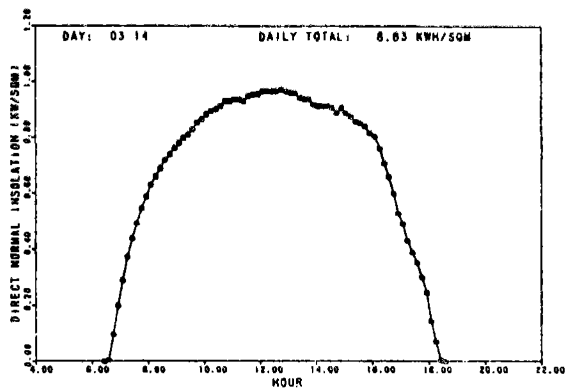

DAY: 03 09
DAILY TOTAL: 4.91 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

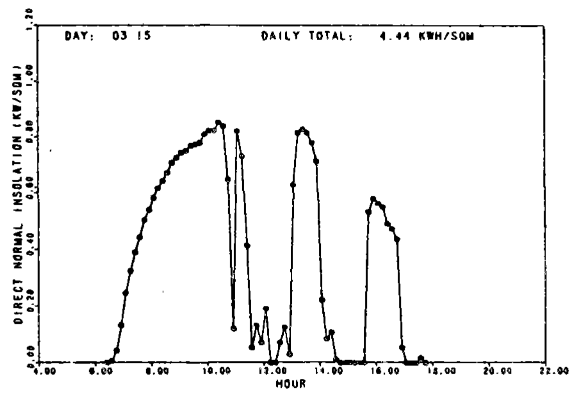

DAY: 03 10
DAILY TOTAL: 8.45 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

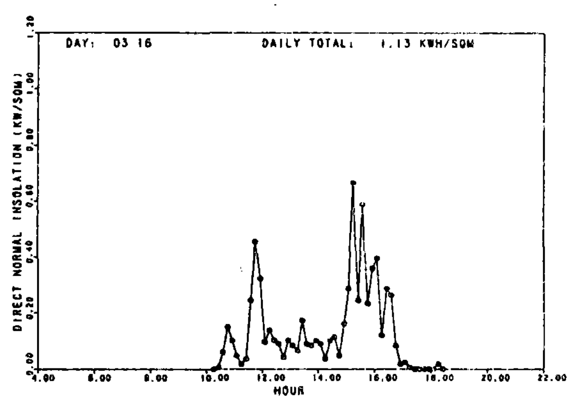

DAY: 03 11
DAILY TOTAL: .06 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

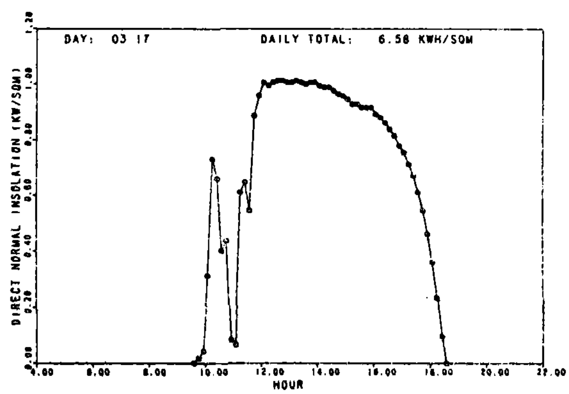

DAY: 03 12
DAILY TOTAL: .00 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

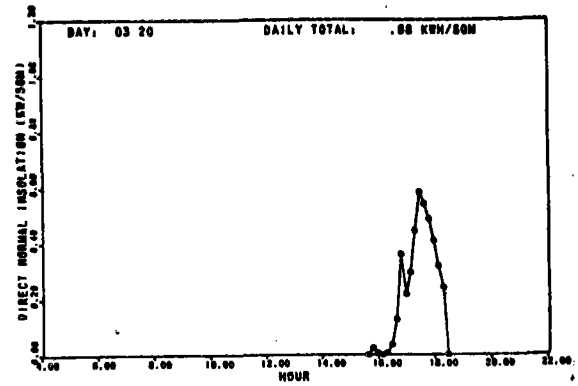

DAY: 03 13
DAILY TOTAL: 9.49 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

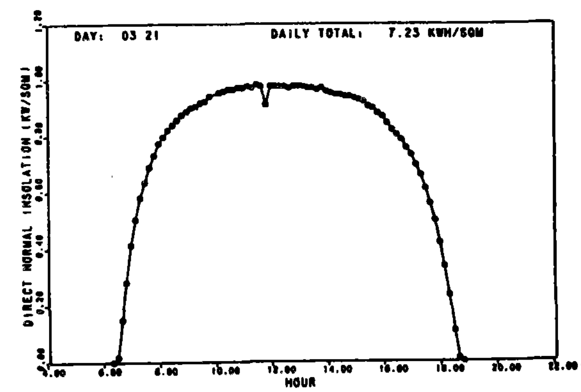

DAY: 03 14
DAILY TOTAL: 8.63 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

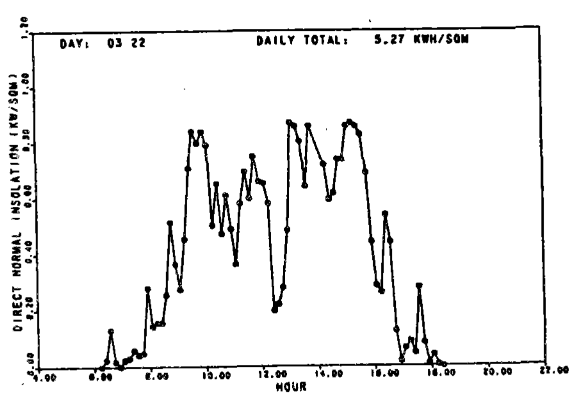

DAY: 03 15
DAILY TOTAL: 4.44 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

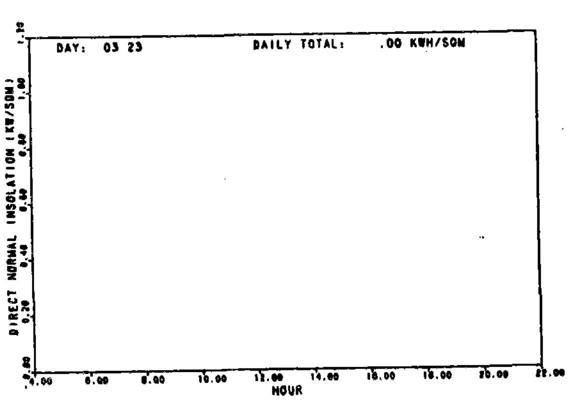

DAY: 03 16
DAILY TOTAL: 1.13 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

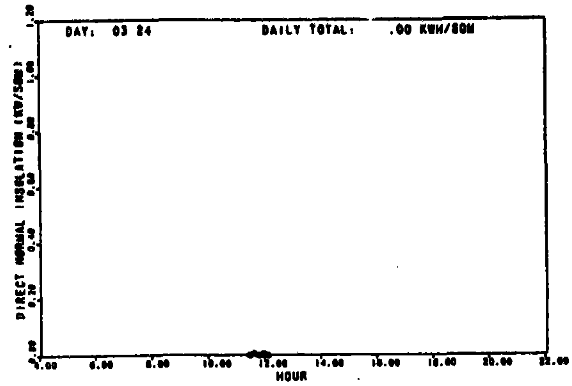

DAY: 03 17
DAILY TOTAL: 6.58 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

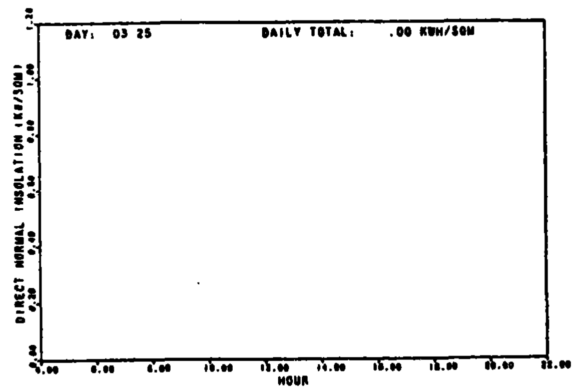

DAY: 03 20
DAILY TOTAL: .68 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

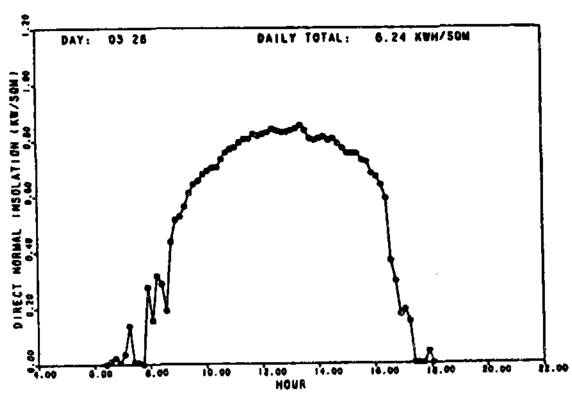

DAY: 03 21
DAILY TOTAL: 7.23 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

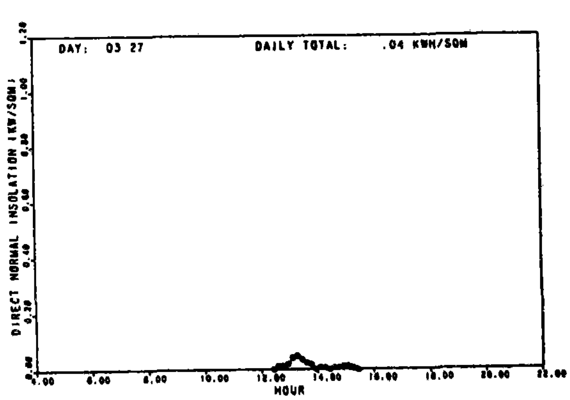

DAY: 03 22
DAILY TOTAL: 5.27 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

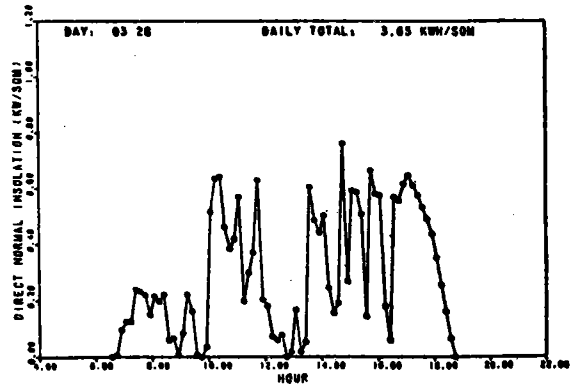

DAY: 03 23
DAILY TOTAL: .00 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

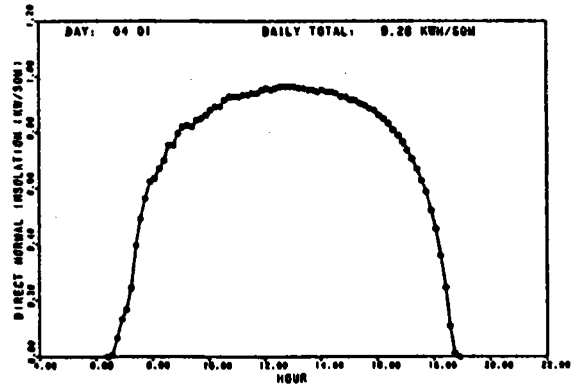

DAY: 03 24
DAILY TOTAL: .00 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

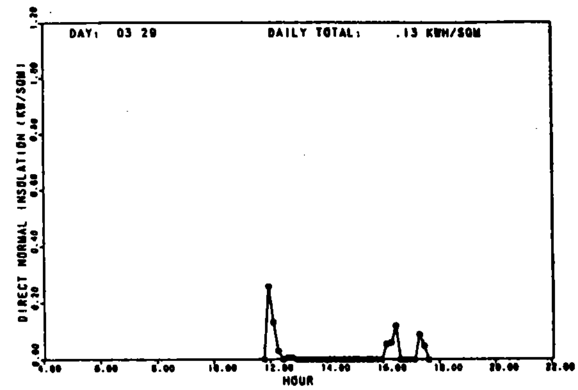

DAY: 03 25
DAILY TOTAL: .00 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

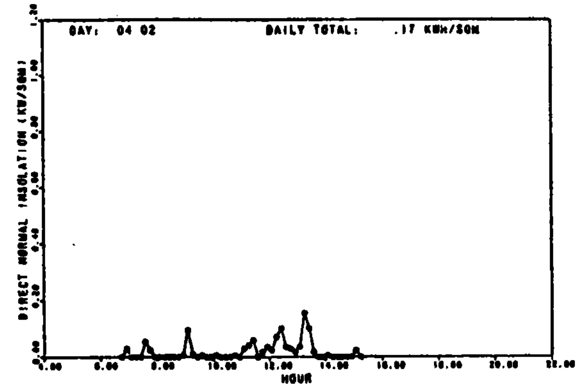

DAY: 03 26
DAILY TOTAL: 6.24 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

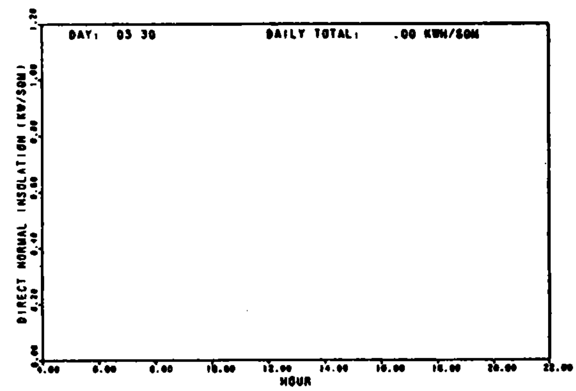

DAY: 03 27
DAILY TOTAL: .04 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

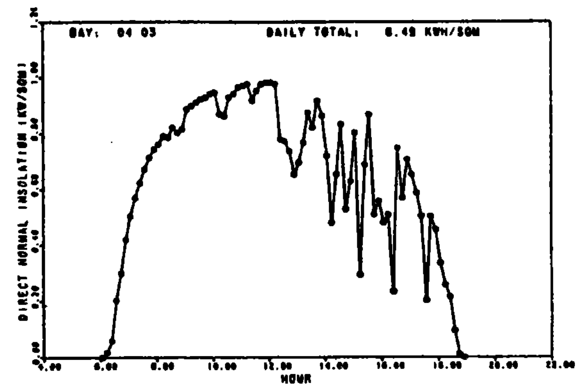

DAY: 03 28
DAILY TOTAL: 3.65 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

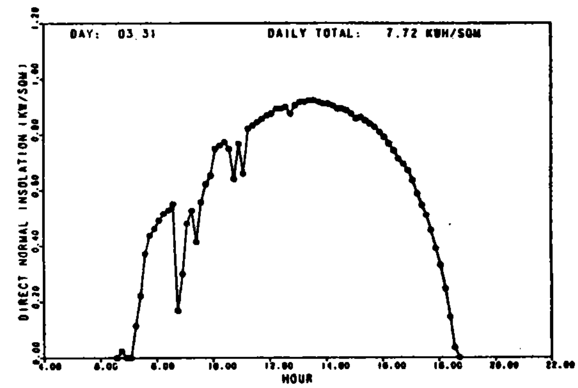

DAY: 04 01
DAILY TOTAL: 9.28 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

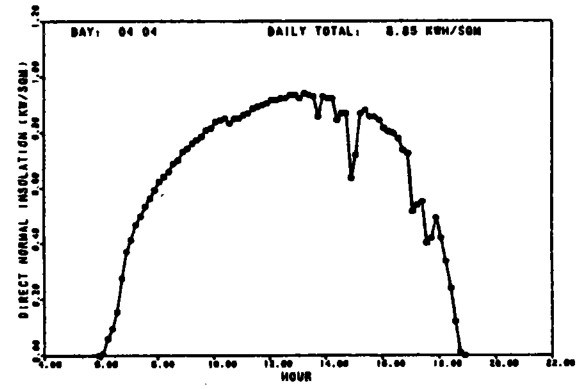

DAY: 03 29
DAILY TOTAL: .13 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

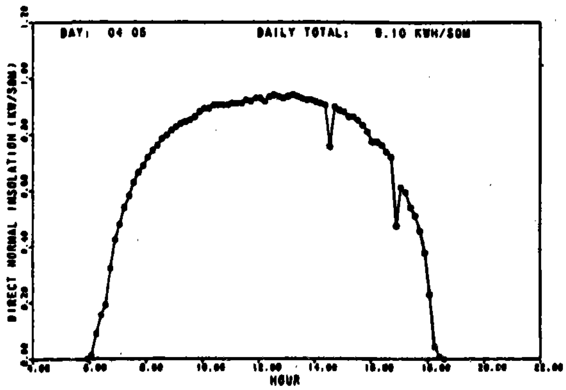

DAY: 04 02
DAILY TOTAL: .17 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

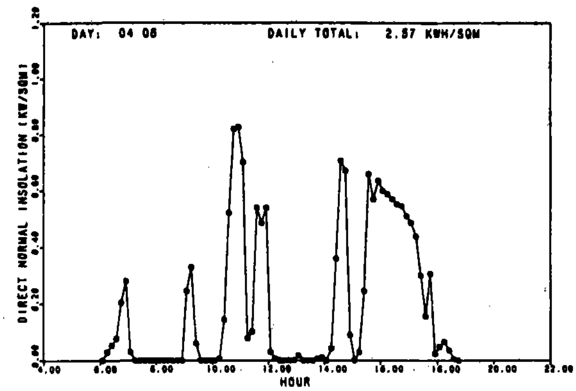

DAY: 03 30
DAILY TOTAL: .00 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

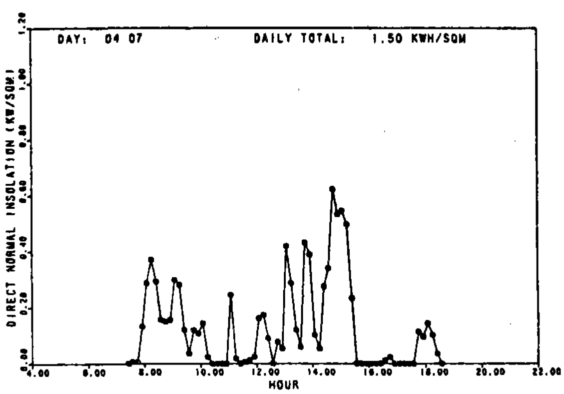

DAY: 04 03
DAILY TOTAL: 6.49 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

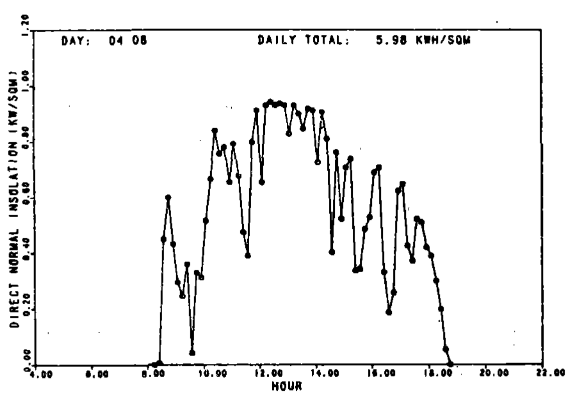

DAY: 03 31
DAILY TOTAL: 7.72 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

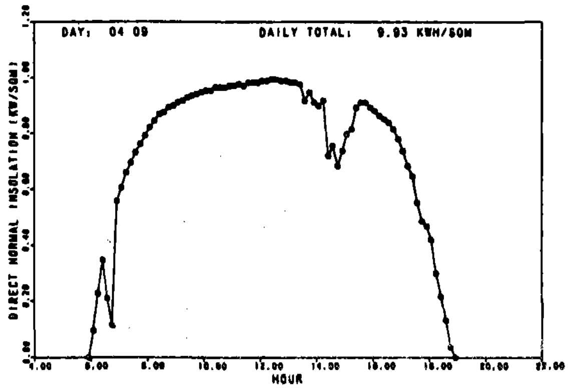

DAY: 04 04
DAILY TOTAL: 8.85 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

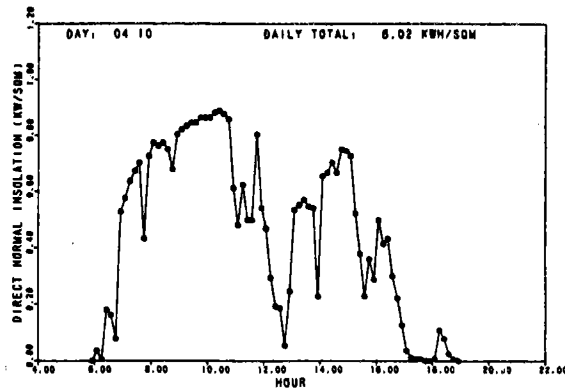

DAY: 04 05
DAILY TOTAL: 9.10 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

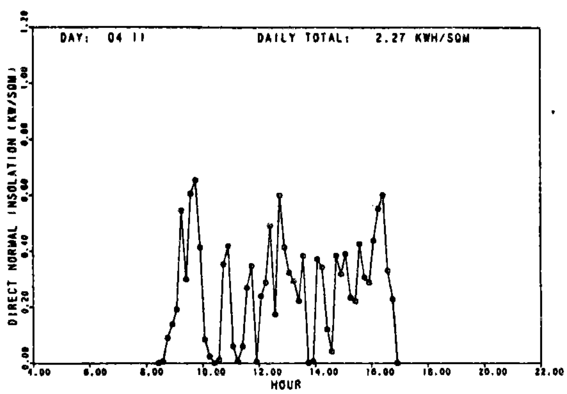

DAY: 04 06
DAILY TOTAL: 2.57 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

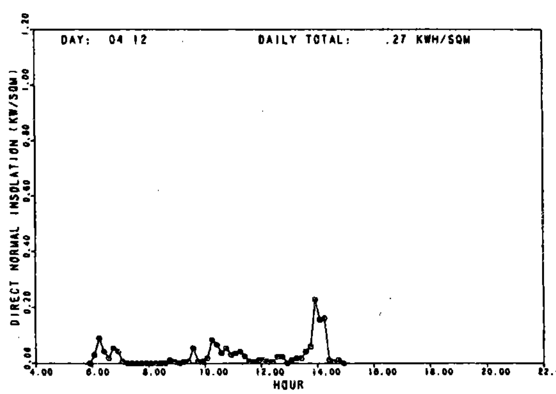

DAY: 04 07
DAILY TOTAL: 1.50 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR


DAY: 04 08
DAILY TOTAL: 5.98 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR


DAY: 04 09
DAILY TOTAL: 9.93 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR


DAY: 04 10
DAILY TOTAL: 6.02 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR


DAY: 04 11
DAILY TOTAL: 2.27 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR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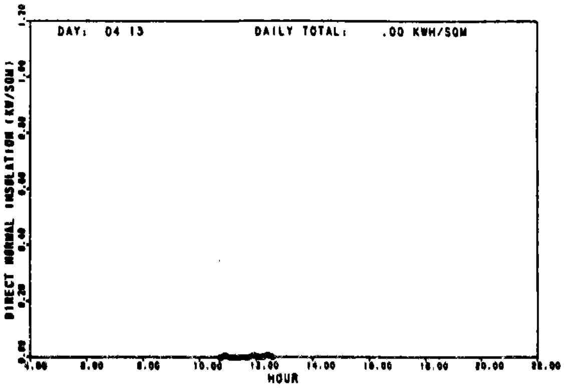
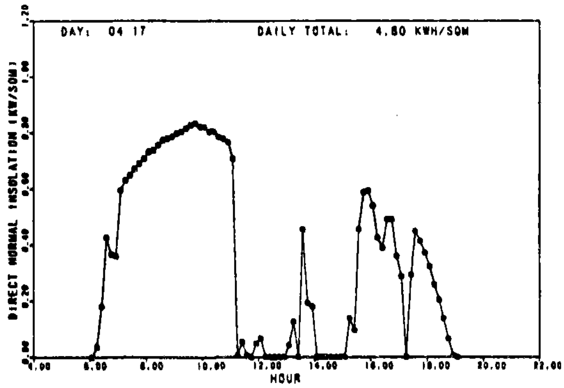
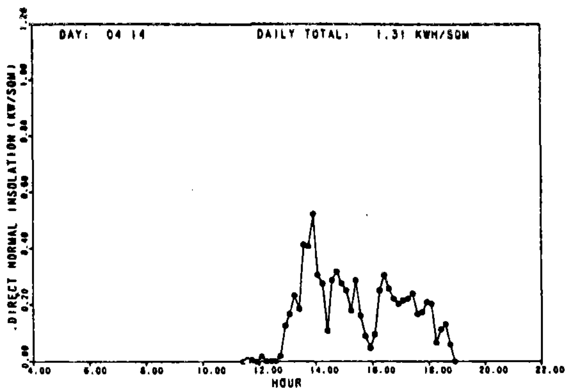
DAILY TOTAL: .27 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR


DAY: 04 13
DAILY TOTAL: .00 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR


DAY: 04 17
DAILY TOTAL: 4.80 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR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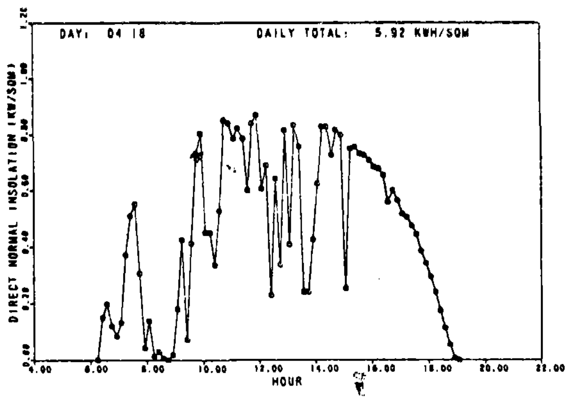
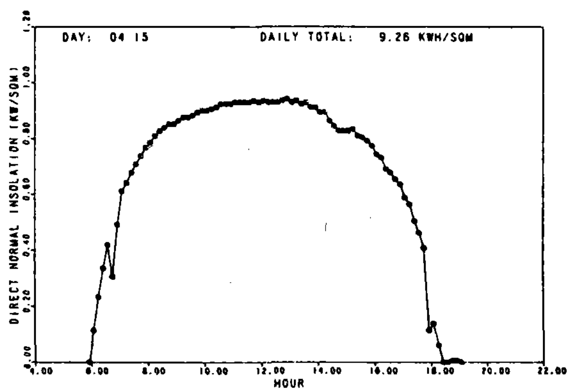
DAILY TOTAL: 1.31 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR


DAY: 04 18
DAILY TOTAL: 5.92 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR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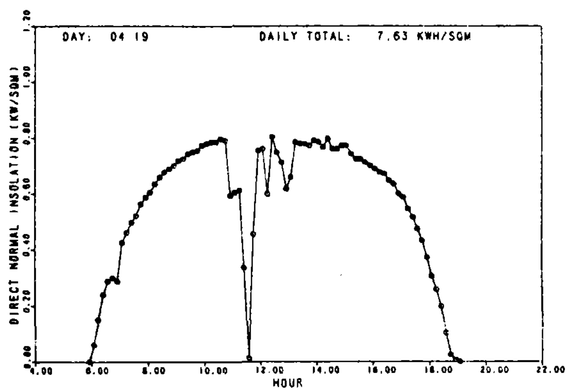
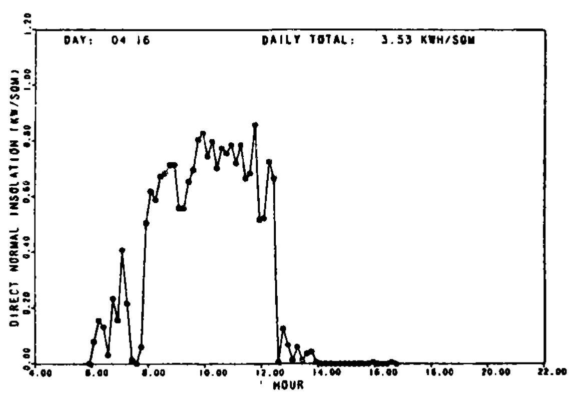
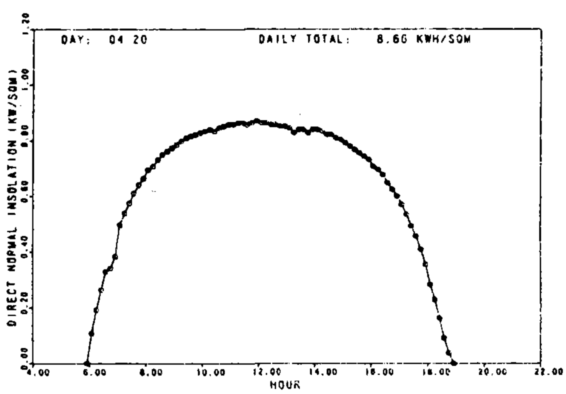
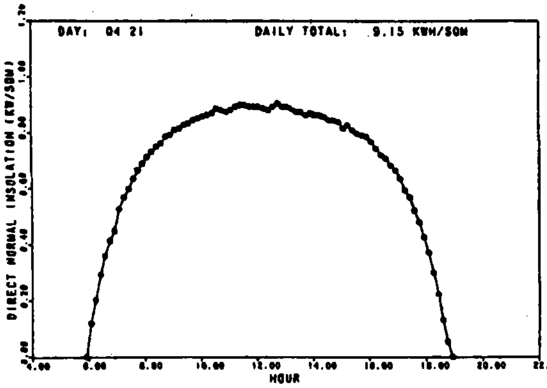
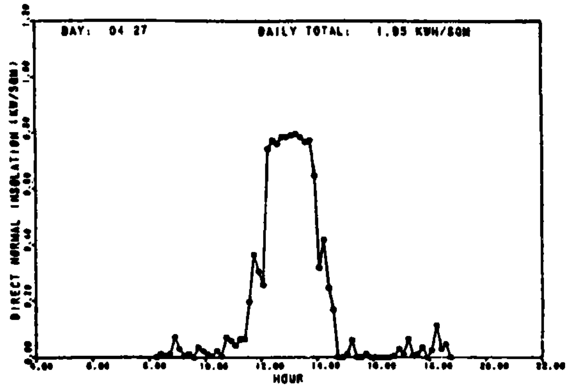
DAILY TOTAL: 9.26 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

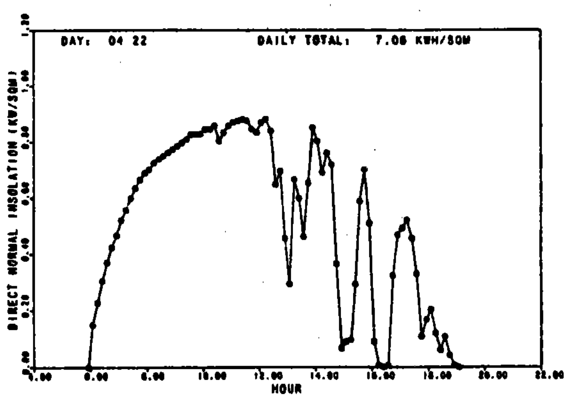

DAY: 04 19
DAILY TOTAL: 7.63 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR


DAY: 04 16
DAILY TOTAL: 3.53 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

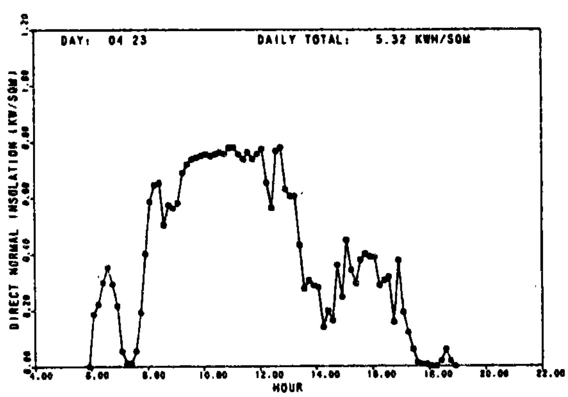

DAY: 04 20
DAILY TOTAL: 8.60 KWH/SQM
DIRECT NORMAL INSOLATION (KW/SQM)
HOUR

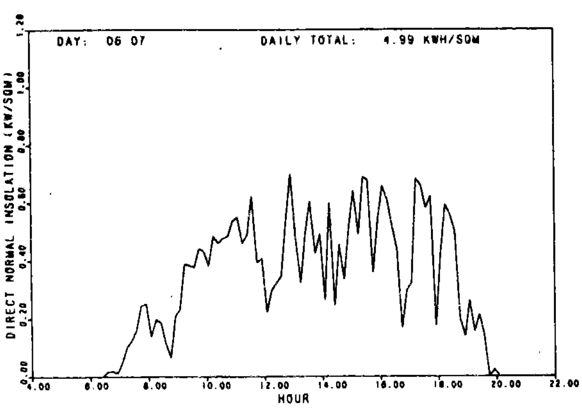


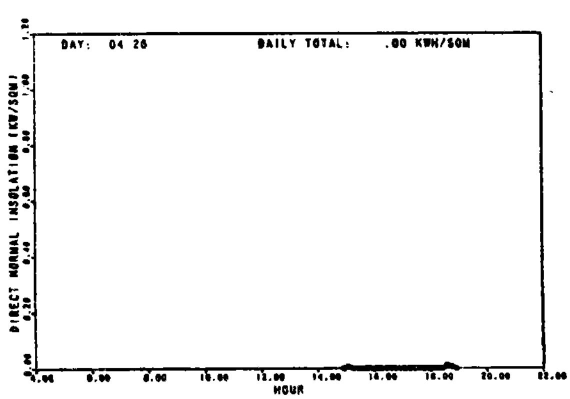


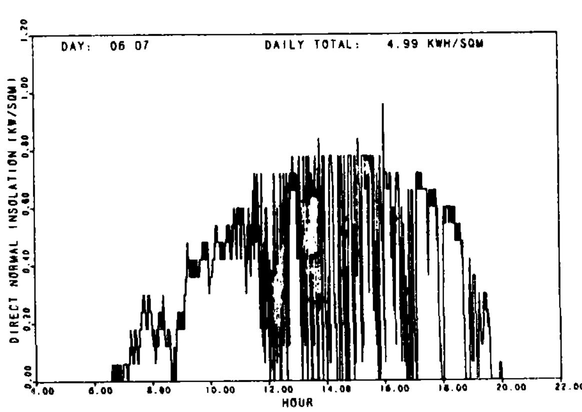


The following two insolation plots show the variation in insolation patterns when averaged over 10-minute and 1-minute time intervals. The 1 Wh/m^2 resolution of the digital meter output produces the 60 W/m^2 quantization. The flux on the receiver would be "smoothed" by the spatial average associated with the heliostat field.









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